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Measuring climate and environmental risks in the financial sector

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Introduction

"Climate risk is not only an environmental issue, but also a financial one. Institutions that fail to address it today will expose themselves to much greater consequences tomorrow".
Mark Carney[1]

In recent decades, the effects of climate change and environmental degradation have become a major concern for many economies around the world. This has led governments and businesses to reassess their impacts and consider their implications across all sectors.

The Intergovernmental Panel on Climate Change (IPCC)[2] has highlighted the tangible effects of rising global temperatures on climatic phenomena. According to the IPCC's 2023 Synthesis Report[3], human activities, especially greenhouse gas emissions, are one of the main drivers of climate change, with far-reaching impacts already being observed in all regions of the planet. Global surface temperatures have risen by about 1.2°C compared to pre-industrial levels, with significant impacts on weather phenomena and climate extremes. This warming is causing irreversible changes in ecosystems, sea levels and weather patterns, and these effects are expected to intensify if emissions continue to rise.

Economic development based on highly carbon-dependent production models in many economic sectors is increasing greenhouse gas emissions into the atmosphere (see Figure 1).

The result has been a steady rise in global temperature, which has exceeded 1°C above pre-industrial levels (see Figure 2)

This increase could reach 1.5°C above pre-industrial levels as early as 2030. In some scenarios, levels of 2.5°C could be reached by 2050 (see Figure 3).

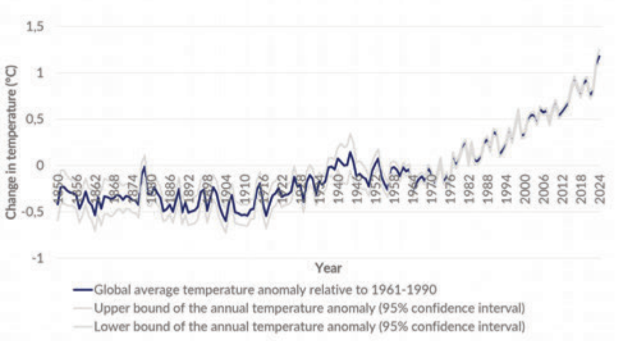
This temperature trend will lead to medium- and long-term changes in climate behavior, as well as an increase in the frequency and severity of extreme weather events, creating so-called "physical climate risks" for economic actors, which may vary by sector and region:

"Economic damages from climate change have been identified in climate-exposed sectors, with regional impacts on agriculture, forestry, fisheries, energy, and tourism, as well as through outdoor labor productivity. Some extreme weather events, such as tropical cyclones, have reduced short-term economic growth"[4].

With regard to environmental risks, according to the FSB's Task Force on Nature-Related Financial Disclosures (TNFD), "science has shown that nature is deteriorating on a global scale and that biodiversity is declining faster than at any time in human history"[5]. As a result, nature-related risks have risen to the top of the global political agenda.

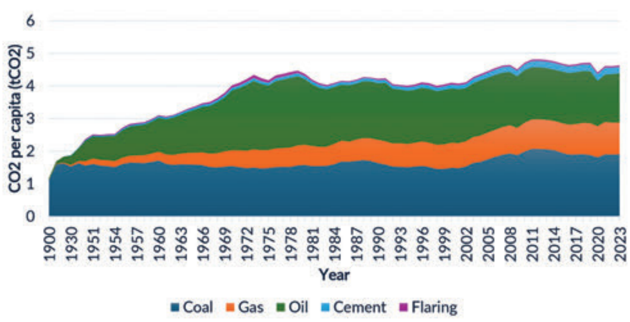
[1] Mark Joseph Carney (2015), former Governor of the Bank of England and Chairman of the Financial Stability Board.
[2] The IPCC (Intergovernmental Panel on Climate Change) is the United Nations body that provides scientific advice on climate change. Created in 1988, its goal is to provide governments with scientific information that they can use to develop climate policies.
[3] IPCC. AR6 Synthesis Report (2023).
[4] IPCC: AR6 Climate Change (2022).
[5] TNFD (2023).

Figure 2: Changes in surface temperature.



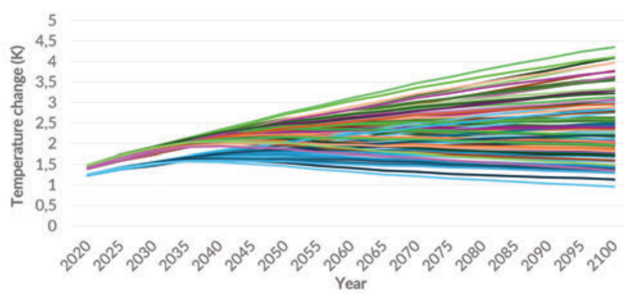
Source: Met Office Hadley Centre (2024). Further details can be found in chapter "Climate risks" of this publication.

Figure 1: historical anthropogenic CO2 emissions per capita.



Source: Global Carbon Budget (2024).

Figure 3: projection of surface temperature changes under different scenarios and percentiles (50th, 90th, 95th).



Source: NGFS (2024).

These include, but are not limited to, the following examples: i) critical supply chains, such as agriculture or semiconductors, face disruptions due to water shortages or water stress; ii) loss of pollinators negatively impacts agricultural production, while demand for pollinators is increasing in some countries; and iii) forest degradation threatens the long-term viability of the products on which some sectors depend.

In fact, central banks and financial institutions are increasingly recognizing that the degradation of nature is a source of systemic risk to the financial system and economies.

In this context, productive sectors and household economies can be transformed to mitigate or adapt to climate change and environmental degradation. However, the transition to a decarbonized productive system that also protects (or at least does not damage) the environment implies a drastic transformation of the global economy through major regulatory, market or technological changes, which also entails significant risks for economic agents, giving rise to the so-called "transition risks", which can affect economic stability[6].

Faced with this reality, governments are beginning to take political and fiscal measures to prevent and mitigate the negative impacts of human activities on climate and nature. Numerous international organizations have been created and are working to establish criteria and principles for measurement, performance and disclosure of information by economic actors[7]. In December 2015, the FSB established the Task Force on Climate-related Financial Disclosures (TCFD), which aimed to identify the information needed by investors, lenders and insurers to measure and assess the risks and opportunities associated with climate change[8].

Regarding the environment, the Task Force on Nature-Related Financial Disclosures (TNFD) was launched in June 2021 and received global endorsement from the G7 and G20. Its goal is to develop a disclosure framework for all organizations of different sizes, sectors and jurisdictions so that better quality environmental information can be made available to corporate and capital market decision-makers through reports in order to improve corporate and portfolio risk management[9].

In addition, the International Sustainability Standards Board (ISSB)[10] was established in November 2021 and published Sustainability Disclosure Standards (IFRS S1 and S2) in June 2023, endorsing the TCFD principles, which require companies to quantify and disclose their climate-related risks, as well as information on the strategy, governance and management of these risks, and to set metrics and targets.

Finally, the European Union's Corporate Sustainability Reporting Directive (CSRD) establishes a stricter regulatory framework for companies to disclose information on their environmental, social and governance (ESG) impacts. Starting in 2025, companies subject to this regulation will be required to provide detailed reports on their sustainability-related risks and opportunities based on the closing information for the fiscal year beginning in 2024, as well as their performance in terms of strategy, governance and sustainability metrics, in line with European and international standards to improve transparency and comparability of information.

With regard to the financial sector, and given its systemic importance in the global economy, eight central banks and supervisors established the Network for the Greening of the Financial Sector (NGFS) in December 2017. The NGFS now includes 134 central banks and supervisors, and aims to contribute to the development of environmental and climate risk management in the financial sector and to mobilize mainstream finance to support the transition to a sustainable economy[10]. In April 2019, the NGFS recommended the adoption of the TCFD principles[11]:

[6] For more information on the definition of physical and transition risks, see Management Solutions: "Managing the risks associated with climate change". 2020. Page 17.
[7] For more details see Management Solutions: "Managing the risks associated with climate change". 2020. Pages 24 and 25.
[8] Following the publication of the October 2023 "Status Report", the TCFD was disbanded. The FSB asked the IFRS Foundation to monitor the progress of climate-related disclosures by companies. (www.fsb-tcfd.org).
[9] https://tnfd.global/about/
[10] The ISSB aims to (i) develop sustainability disclosure standards, (ii) meet the information needs of investors, (iii) enable companies to provide comprehensive sustainability disclosures to global capital markets, and (iv) facilitate interoperability with disclosures that are jurisdiction-specific and/or aimed at broader stakeholder groups. Sourced from: https://www.ifrs.org/groups/international-sustainability-standards-board/
[11] NGFS (2023).

"NGFS members collectively commit to support the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD). The NGFS encourages all companies issuing debt or equity, as well as financial sector institutions, to disclose in line with the TCFD recommendations"[12].

The financial sector: in the spotlight

The financial sector is directly exposed to climate and environmental (C&E) risks through the positions it holds with its counterparties: these risks not only jeopardize the operational and financial performance of companies, but are also transmitted to the financial sector, as they can affect asset valuations and investment returns through the transmission channels[13] (see graph in Figure 4), thus amplifying systemic risks across global financial markets.

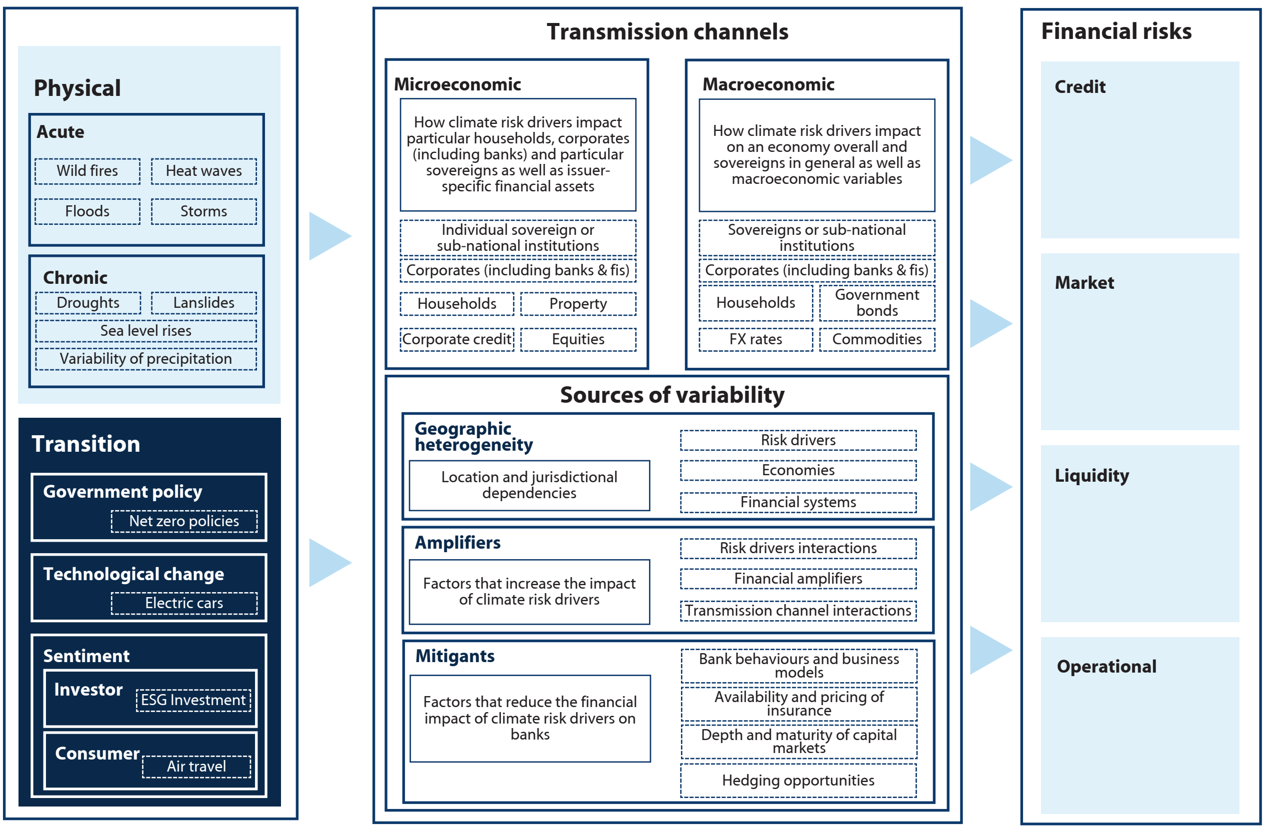
The effects of climate risks

Climate risks can affect all the traditional categories of risk to which financial institutions are exposed[14], including credit, market, operational, business, liquidity and reputational risks.

Physical risks, such as floods, wildfires or storms, directly affect companies' assets and operations, as they can disrupt production processes, damage assets and entail significant repair and recovery costs. This can lead to a change in the productive capacity of companies and deteriorate cash flows and profitability, increasing the probability of default for borrowers highly exposed to such risks. In addition, the value of assets that serve as collateral for credit loans may be reduced, further jeopardizing credit facilities.

[12] NGFS (2019).
[13] Transmission channels: refers to the causal chains that explain how climate risk factors affect banks both directly and indirectly through their counterparties, their assets and the economies in which they operate. BCBS: Climate-related risk factors and their transmission channels. April 2021. Climate-related risk factors and their transmission channels (bis.org).
[14] EBA (2024).

Figure 4: Financial risks derived from climate risk factors. BCBS (2024).



On the other hand, companies that do not adapt their production models to a decarbonized economy may experience a gradual erosion of their competitive position and market share, an increase in stranded assets or asset devaluation, especially in carbon-intensive sectors. This translates into reduced revenues and an increased risk of credit downgrade or default, creating significant credit risks for financial institutions.

In addition, not only the credit portfolio position, but also the valuation of financial instruments can be directly affected by climate risks. Equity and debt instruments of companies with high climate risk exposure may experience a change in their market value as investors recalibrate their expectations in light of emerging risks and opportunities.

This repricing process can lead to increased volatility in financial markets and result in significant losses for investors and entities holding these instruments. Fixed income instruments are susceptible to weather-related credit rating adjustments, which can affect their performance and market value. As market participants increasingly incorporate climate risk assessments into their investment decisions, the price of securities will reflect the increased perception of risk, which could lead to larger adjustments.

The impact of environmental risks

As with climate risks, the link between nature-related financial risks (biodiversity loss and ecosystem degradation) and financial institutions is through specific transmission channels (see Figure 5).

Both climate and environmental risks can also be amplified if insurance companies deem these risks in certain geographies or sectors too high to underwrite, thereby reducing their exposure or significantly increasing premiums, which could leave households and businesses uncovered, thus increasing systemic effects[15].

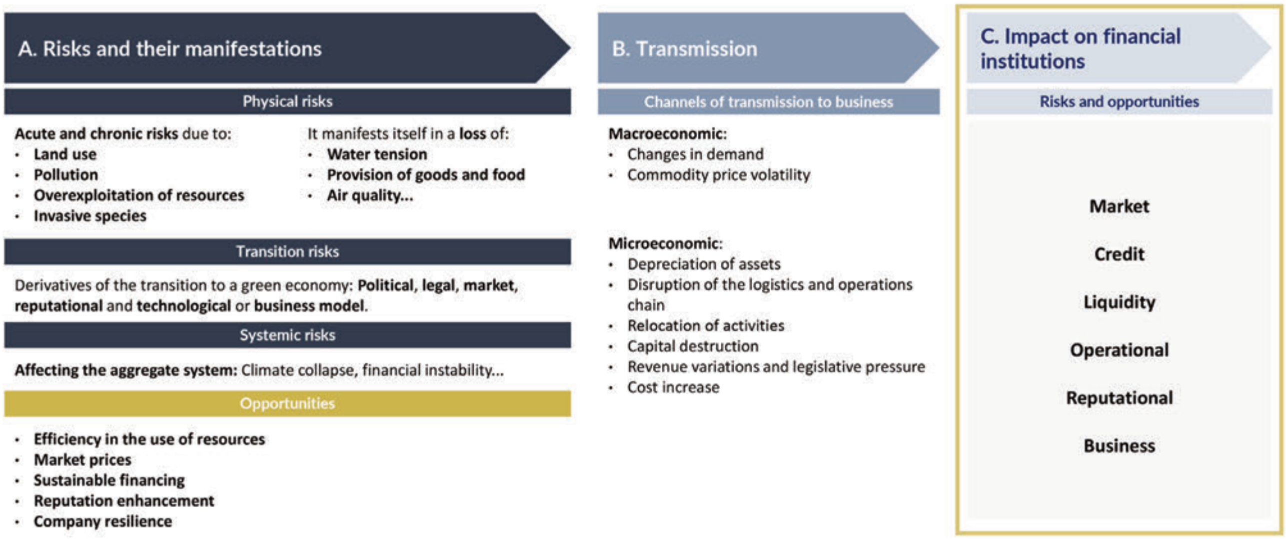
There is therefore an urgent need to develop methodologies for measuring these risks in financial institutions and insurance companies. Such measurement poses several challenges and complexities for the financial sector, stemming mainly from the uncertainty inherent in the impacts of climate change and environmental degradation, the lack of standardized metrics, the difficulty of integrating these risks into existing financial models, and the availability and quality of information:

- First, the uncertain and long-term nature of climate change and the slow pace of environmental degradation undermine the effectiveness of traditional risk assessment models, which rely heavily on historical data. C&E risks are characterized by the fact that they materialize over a long-term time horizon. Therefore, scenario analysis and stress testing, which can consider different future scenarios (rather than relying solely on historical data), become key analytical tools.

- Second, the lack of standardized metrics and definitions for C&E risks makes them difficult to measure and compare across industries and geographies. Although initiatives such as the TCFD or TNFD have made significant progress in encouraging the disclosure of C&E-related financial information, the variability in reporting practices and the

[15]FSB (2020).

Figure 5: Transmission channels of environmental risks.



Source: Management Solutions internal document based on the TNFD framework.

qualitative nature of much of this information limit its usefulness for risk assessment. This lack of standardization hampers the ability of financial institutions to conduct comprehensive analyses and systematically compare risks in their portfolios[16].

- Third, C&E risks require innovative modeling techniques that can incorporate future climate scenarios and their potential economic impacts. However, the development of such forward-looking models requires a sophisticated understanding of climate science and its interaction with economic variables, a skill that is still evolving within the financial sector.

- Finally, data availability and quality are additional hurdles. Accurate risk assessment depends on access to reliable, granular and relevant data on physical and transient risks associated with climate change and environmental degradation, which can be highly region-specific. However, the lack of granularity and accuracy of climate and environmental data (e.g., geolocated projections of climate impacts, information on emissions from specific industries, status and evolution of ecosystems, geolocation of companies' productive assets, etc.) hampers the ability of financial institutions to conduct accurate risk assessments. Initiatives to improve the quality and accessibility of individual and sectoral climate data are crucial to making progress in measuring such risks.

Moreover, integrating C&E risks into the financial decision-making process is crucial for two main reasons: (i) it allows institutions to make more informed lending, investment and insurance underwriting decisions, thereby increasing their own resilience to C&E-related risks; and (ii) by accurately measuring and pricing these risks, financial institutions can allocate capital more efficiently, directing funds toward projects and companies that are not only less susceptible to them, but also contribute to the transition to a low-carbon, environmentally friendly economy.

This integration is not without its challenges. Financial institutions face the complex task of integrating these risks into their current risk management frameworks, which were not originally designed to accommodate the multifaceted nature of C&E risks. This integration requires not only the development of new tools and metrics, but also a cultural shift within organizations to recognize the importance of C&E risks and prioritize their management[17].

In summary, the adoption of sound measurement methodologies by the financial sector is not only a regulatory requirement, but also a strategic imperative. It provides the basis for developing innovative financial products, such as green bonds and sustainability-linked loans, that can incentivize and support the transition to a sustainable economy. Furthermore, by accurately assessing and managing C&E risks, financial institutions can protect themselves against the reputational, operational and financial risks associated with climate change and environmental degradation, while playing a key role in mobilizing the investments needed to mitigate their effects.

In this context, this study aims to provide a perspective on the different methodologies for measuring climate and environmental risks, focusing on the financial and insurance sector. To this end, the paper is structured in four sections, which aim to: (i) summarize the supervisory requirements regarding the measurement of C&E risks; (ii) discuss different quantitative approaches that can be applied to the measurement of physical and transitional climate risks, depending on the nature of the portfolios; (iii) propose approaches to address the quantification of environmental risks; and (iv) show the application of the described methodology through a case study of the measurement of transitional climate risk impacts on a corporate bond portfolio[18].

[16]However, efforts towards this standardization are being made in some jurisdictions, such as the CSRD or the Pillar III requirements in Europe.
[17]For a discussion of climate risk management, see Management Solutions: "Managing the Risks Associated with Climate Change. 2020. Chapter "Managing risks associated with climate change".
[18]These approaches are implemented through Management Solutions' climate risk measurement tool, MS² (Management Sustainability Solutions). This is Management Solutions' proprietary tool, specifically designed to measure the risks associated with climate change, adapted to the particularities of the financial and insurance sector.

Executive summary

"Climate risk requires a scientific mindset: quantifying risk is the first step to managing it and turning it into opportunity".
Larry Fink[19]

Climate change, rising temperatures, the increasing severity of extreme weather events, and environmental degradation represent significant risks that can impact the development of economies worldwide. As economic models are based on highly carbon-dependent sectors, global temperatures continue to rise. These climate changes generate physical risks, such as an increase in the frequency and severity of phenomena like floods and heat waves, which impact the productivity and profitability of various economic sectors and represent an economic threat to companies and governments.

Given its central role in the economy, the financial sector faces direct and indirect risks related to climate change and environmental degradation. Financial institutions are exposed to climate risks through their credit, investment and insurance portfolios. Physical risks, such as forest fires and storms, affect the productive capacity of companies and can erode the value of assets securing loans, increasing the risk of default and the deterioration of financial balance sheets. This context requires the banking and insurance sectors to re-evaluate their risk management practices in order to anticipate, manage and mitigate climate and environmental impacts.

It is therefore necessary to develop quantitative mechanisms to measure the impact that climate and environmental risks can have on the economic value of the balance sheets of institutions, with the aim of managing risks and strengthening the resilience of the financial system, thus promoting a structural change towards a sustainable economy.

Supranational requirements for measuring climate and environmental risks

The growing concern about climate change and environmental degradation has led regulators and financial authorities to establish a regulatory framework for the measurement of climate and environmental risks and to promote the integration of these risks into the management models of financial institutions.

The Basel Committee on Banking Supervision (BCBS) has developed 18 principles that form an essential pillar for the management and supervision of climate risks, covering aspects such as governance, capital adequacy and the integration of climate risks into risk analysis frameworks.

In Europe, the European Banking Authority (EBA) and the European Central Bank (ECB) have developed specific frameworks that complement these international principles. The EBA has issued guidelines on the integration of ESG (environmental, social and governance) risks into the strategy, governance and risk management systems of financial institutions. Similarly, the ECB has included in its supervisory expectations that institutions integrate climate-related risks into their strategy, risk management and disclosure, as well as conduct climate stress tests, with the aim of strengthening transparency and accountability in decision making.

Other global regulators have also adopted important frameworks. In the United Kingdom, the Bank of England has issued guidelines emphasizing the identification and measurement of climate risks in large financial institutions, while in the United States, the SEC has developed rules for the disclosure of climate risks.

These global efforts to consolidate specific regulations reflect the critical importance of climate and environmental risks in the financial system. While there are differences in approaches across jurisdictions, the convergence towards international standards points to greater integration of sustainability in the financial sector.

Climate risks

There are two main types of climate risks that affect the financial sector: physical risks and transition risks.

Physical risks refer to damage from extreme (acute) weather events, such as floods, forest fires and storms, and gradual (chronic) changes in climate, such as sea level rise and global warming. These risks directly affect the physical assets of companies and thus increase the risk of default by financial counterparties. In the case of loans secured by real estate or industrial assets, these phenomena can reduce the value of the collateral, affecting financial ratios and increasing the probability of losses for financial institutions.

[19] Laurence Douglas Fink (2020), managing director and chairman of Blackrock.

To properly assess physical risk, climate scenarios are used to forecast possible changes in climate variables, such as temperature and rainfall, on a regional and global scale. These scenarios, developed by the Intergovernmental Panel on Climate Change (IPCC), combine socioeconomic trajectories and greenhouse gas emission levels to predict different degrees of global warming and its impact on the climate.

The physical risk measurement methodology uses these projections to simulate the probability of extreme weather events and calculate the expected impact on assets in financial portfolios based on the geolocation of physical assets and their exposure to weather events. This is done using "damage curves" (also called impact functions) that quantify the likely economic loss depending on the intensity of the weather event.

On the other hand, transition risks are associated with the process of change towards a low-carbon economy. These risks arise from regulatory, technological and market changes aimed at reducing greenhouse gas emissions. Carbon-intensive sectors, such as energy and transportation, are particularly exposed to these risks, as they face potential asset devaluations or additional costs to comply with sustainability regulations. For financial institutions, transition risks represent the possibility that certain assets may lose value or that counterparties may face higher costs to adapt to new environmental regulations or technology.

Transition risk analysis uses transition scenarios that project different pathways towards decarbonization of the economy. These scenarios consider variables such as the speed with which climate policies are implemented and the level of innovation in clean technologies. The transition scenarios make it possible to forecast how the shift towards a sustainable economy could impact economic sectors, assessing the exposure of financial assets to regulatory and technological risks.

The methodology for measuring transition risks in financial portfolios uses these scenarios to estimate the impact on the credit quality and asset value of counterparties. In the case of corporate loan portfolios, the methodology applies a sectoral sensitivity analysis to assess the vulnerability of each company according to its exposure to transition risks. This analysis identifies the counterparties with the least adaptive capacity, calculating the impact on the probability of default and the loss in the event of default. Similarly, for financial asset portfolios, valuation models are used to estimate the impact of transition risk on corporate and government bonds and equities, allowing investment portfolios to be adjusted to reflect these risks.

Environmental risks

Environmental risks include ecosystem degradation, biodiversity loss and natural resource depletion. These risks are driven by factors such as deforestation, pollution and changing land-use patterns, and affect both supply chains and the security of essential resources. As such, they all pose significant threats to the economy. For financial institutions, exposure to environmental risks implies potential economic losses due to the vulnerability of counterparties in natural resource-dependent sectors.

As with climate risks, environmental risk scenarios can be used to simulate the impact of different levels of environmental degradation on financial assets. These scenarios project, for example, how the loss of pollinators or water stress may affect agricultural productivity and, consequently, the economic stability of companies in this sector.

To measure environmental risk, a methodology is proposed that focuses on assessing companies' resilience to the loss of natural resources and the vulnerability of their supply chains, analyzing the impact of resource degradation on revenues and on the sustainability of companies' assets and, therefore, on their solvency.

Methodologies and models available today are important and accessible tools for addressing complex climate and environmental challenges, enabling effective integration of these risks into financial analysis and supporting strategic decision making in a context of increasing environmental uncertainty.

The management of climate and environmental risks has become a very important issue, especially in the financial sector. Managing these risks requires quantifying the impact on the value of investments through the use of advanced methodologies and tools to strengthen decision making.

It is therefore necessary to strengthen internal governance and invest in technology to facilitate the integration of these risks into the business strategy. This process should be carried out in cooperation with regulators and by promoting sectoral initiatives to overcome data limitations, among other things.

Regulatory context

"International regulation must recognize that environmental risk has no borders. Only a global regulatory vision can prepare the financial sector for a sustainable future".
Kristalina Georgieva[20]

The regulatory framework for managing climate and environmental (C&E) risks emphasizes the need to integrate them into financial institutions' risk frameworks. This section provides an overview of the key regulations and regulatory expectations, highlighting how authorities in different jurisdictions are setting the essential requirements for incorporating C&E risks into institutions' risk models, data strategies and governance structures. By aligning their strategies and models with these regulatory expectations, institutions will not only meet evolving regulatory standards, but also strengthen their resilience to the growing challenges posed by C&E risks.

Global: BCBS Principles for Effective Management and Monitoring of Climate Financial Risks[21]

The Basel Committee on Banking Supervision (BCBS) published 18 principles to improve the management of climate-related financial risks, with the aim of strengthening risk management and supervisory practices. These principles are addressed to both banks and prudential supervisors, with a particular focus on improving corporate governance, internal controls and assessment processes, and the management and reporting of climate-related risks. The BCBS promotes a principles-based approach, encouraging banks to integrate climate risks into their governance frameworks (Principles 1 to 4) and risk management processes (Principle 5). Principles 6 to 12 extend these guidelines to incorporate climate risks into capital adequacy, liquidity and scenario analysis, thereby strengthening banks' resilience in the face of changes driven by climate policy. Principles 13 to 18, addressed to prudential supervisors, underscore the importance of proactively supervising these risks and encourage international cooperation and the adoption of common practices for assessing and managing climate-related financial risks.

The principles provide guidance on integrating climate risks into risk models and stress testing frameworks, offering banks a roadmap for aligning their practices with supervisory expectations. The recommendations on governance and internal controls are particularly important in the context of developing and validating new risk models that incorporate both physical and transition climate risks.

While these principles are not legally binding, they are consistent with some other regulations and expectations, such as the European Central Bank's (ECB) supervisory expectations on climate and environmental risk management[22].

Global: BCBS bulletin on the implementation of principles for managing climate-related financial risks[23]

This bulletin builds on the BCBS principles outlined above by providing practical guidance on the challenges associated with implementing climate risk management practices. One of the key issues addressed is the availability and quality of data, which is often a challenge in integrating climate risks into financial models. Banks are encouraged to use specific questionnaires and conduct due diligence on clients at the intake stage, supplemented by public disclosures and third-party data providers. However, the Bulletin cautions against over-reliance on external sources and emphasizes the need for internal climate data collection processes.

In addition, the BCBS suggests the use of scenario analysis to test different climate risk scenarios, which should complement internal models. These implementation suggestions provide firms with practical strategies to improve climate risk assessments, even in the face of data challenges.

Europe: European Commission's 2021 Banking Package (CRR III/CRD VI)[24]

The European Commission's 2021 Banking Package (which includes CRR III and CRD VI) is a key regulatory framework for integrating ESG risks, which include both climate and environmental (C&E) risks and other sustainability factors, into financial institutions' risk management systems. CRR III requires the development of internal ratings-based (IRB) models and risk quantification processes. Key requirements include definitions of default, data used for modeling and standards for rating systems, estimation of risk parameters, and internal governance. The regulation emphasizes the need to harmonize definitions of ESG risks, including environmental, physical and transition risks, and requires firms to integrate these risks into their business and risk strategies.

CRD VI further strengthens the sustainability approach by integrating climate and environmental risks into the prudential framework. Institutions must adopt strategies and processes that enable them to assess and manage ESG risks over different time horizons. Article 87a specifically requires institutions to develop strategies to cover short, medium and long-term exposures to climate-related risks and to integrate these risks into all dimensions of their business, from strategy to internal controls.

[20] Kristalina Ivanova Georgieva-Kinova (2021), directora del Fondo Monetario Internacional.
[21] BCBS (2022).
[22] BCE (2020).
[23] BCBS (2023).
[24] Comisión Europea (2021).

Europe: EBA guidelines on ESG risk management[25]

The European Banking Authority's (EBA) guidelines provides a structured approach to integrating ESG risks, in particular climate risks, into risk management frameworks. The guidelines emphasize the need for institutions to integrate ESG risks into their risk management systems, ensuring that climate risks are taken into account in strategy formulation, governance frameworks and internal controls.

Institutions should incorporate climate-related risks into their policies, limits and internal control frameworks. In addition, the guidelines suggest establishing appropriate risk appetites and key risk indicators (KRIs) to monitor and manage exposure to climate risks. By aligning ESG risks with the institution's overall risk strategy, the guidelines ensure that climate risks are not treated as separate from other financial risks, but are fully integrated into the organization's risk profile.

The EBA guidelines are divided into three main blocks: (i) a reference methodology for ESG risk identification and measurement; (ii) minimum standards and a methodology for ESG risk management and monitoring; and (iii) CRD VI compliance plans.

The first block, on the methodology for identifying and measuring ESG risks, requires materiality assessments on an annual basis, or at least every two years for small and non-significant credit institutions (SNCI). These assessments must be integrated into internal policies and procedures, taking into account all types of material financial risks in sectors with a high contribution to climate change. In addition, qualitative and quantitative ESG impact data should be collected on the most relevant activities and a risk-based approach should be adopted that assesses the likelihood of such risks materializing and their impact. It is essential to implement data collection systems on ESG risks and to assess the risk profile of companies, especially large companies, using three assessment methods: exposure-based, industry-based, portfolio-based – including portfolio alignment methods, and climate scenario-based.

The second block focuses on minimum standards and methodologies for managing and monitoring ESG risks, emphasizing the integration of these risks into the institution's risk management framework. Institutions are required to manage and mitigate these risks in the short, medium and long term, using tools such as financial term adjustment and portfolio diversification. It is critical to understand how ESG risks impact the business model and to clearly define the material risks faced. It is also important to train employees on these risks, establish an appropriate risk appetite and communicate strategic objectives. The material impact of ESG risks should be incorporated into the ICAAP and ILAAP, assessing their impact on credit, market, liquidity, operational, reputational and concentration risks, and establishing early warning indicators for continuous monitoring.

The third block states that transition plans should address and mitigate ESG risk exposures, especially in sectors critical to climate change. Short-, medium- and long-term goals should be aligned with business strategies and reflected in the institution's risk appetite. It is essential to establish clear roles and responsibilities for ESG management, maintain fluid communication at all levels of the organization, and ensure that the necessary capabilities and resources are in place. Institutions should use specific metrics, such as financed greenhouse gas emissions, to assess their resilience to physical risks and manage biodiversity risks. They should also establish processes to collect and verify data, promote client transition, and assess the impact of their financing activities in the context of their risk management policies.

Europe: EBA report on the role of environmental and social risks in the prudential framework[26]

The EBA report assesses the ability of the prudential framework to capture environmental and social risks and proposes specific improvements to accelerate the integration of these risks into financial management. It also suggests that environmental and climate factors should be incorporated into customer due diligence processes, credit risk differentiation and risk quantification methodologies.

The report recommends that environmental factors be considered in the valuation of financial collateral, and that stress testing programs incorporate climate scenarios to assess potential long-term impacts. The report also highlights the importance of recalibrating rating systems to reflect environmental and social risks and to ensure that these factors are incorporated into the estimation of risk parameters such as probability of default (PD) and loss given default (LGD).

[25] EBA (2025).
[26] EBA (2023).

Europe: ECB supervisory priorities for 2024-2026[29]

The ECB has outlined supervisory priorities for the period 2024-2026, with a particular focus on climate-related risks. The ECB plans to follow up on the weaknesses identified in the 2022 climate risk stress tests and to assess the adequacy of institutions' climate risk expectations by the end of 2024.

The main focus will therefore be on reviewing lenders' alignment with these expectations, with non-compliance potentially leading to the application of sanctions or specific add-ons. The ECB will also review disclosure requirements related to climate risks and their integration into reputational and legal risk analysis. While these priorities are not binding rules, they reflect the ECB's commitment to ensuring that financial institutions fully integrate climate risks into their operational and strategic frameworks.

Europe: ECB Guidance on internal models[27]

The ECB Guidance on Internal Models sets out supervisory expectations for the use of internal models, particularly in the context of credit risk modeling. It interprets the EBA Guidelines with additional emphasis on governance, model validation and audit processes. The Guidance requires institutions to ensure the integration of climate-related risks into internal models, in particular when calculating credit risk parameters.

The ECB also encourages institutions to adopt conservative approaches when data on climate risks are limited, ensuring that climate risks are adequately reflected even in the absence of complete data sets. This Guidance is essential for institutions wishing to modify existing credit risk models or develop new models that take into account climate-related risks.

Europe: ECB final guidance on climate and environmental risks[28]

The ECB's final guidelines on climate and environmental risks provide a comprehensive framework for integrating climate risks into the governance, strategy, risk management and disclosure processes of financial institutions. The guidelines require that climate risks be integrated into business models and strategies, and that boards and senior management take these risks fully into account in their decision-making.

Institutions are expected to integrate climate risks into their Internal Capital Adequacy Assessment Process (ICAAP), risk appetite frameworks and credit risk monitoring. In addition, the guidelines require institutions to disclose climate-related risk metrics and other key information to ensure transparency for stakeholders and compliance with Pillar 3 requirements.

Europe: Opinion on the supervision of the management of environmental, social and governance (ESG) risks faced by Institutions for Occupational Retirement Provision (IORPs) (EIOPA-BoS-19-248)[30]

In December 2019, the European Insurance and Occupational Pensions Authority (EIOPA) published the Opinion on the supervision of the management of environmental, social and governance (ESG) risks faced by Institutions for Occupational Retirement Provision (IORPs) (EIOPA-BoS-19-248). This document provides specific guidance to IORPs on how to integrate ESG factors into their risk management processes and decision-making. The Opinion highlights the need for a comprehensive assessment of long-term risks related to climate change and other sustainability issues, driving further alignment with sustainable practices in the pension industry.

[27] BCE (2024).
[28] BCE (2020).
[29] BCE (2023).
[30] EIOPA (2019).

Europe: Opinion on the supervision of the use of climate risk scenarios in the Solvency and Financial Condition Assessment Process (ORSA) (EIOPA-BoS-21-127)[31]

In April 2021, the European Insurance and Occupational Pensions Authority (EIOPA) published its Opinion on the supervision of the use of climate risk scenarios in the Solvency and Financial Condition Assessment Process (ORSA) (EIOPA-BoS-21-127). This opinion provides recommendations for insurers to incorporate climate risk scenarios in their solvency analyses, underlining the importance of assessing the potential impact of climate change on long-term financial stability and encouraging proactive management of these risks within the insurance sector.

UK: Bank of England (BoE) report on climate-related risks and the regulatory framework for capital[32]

The Bank of England published a report in March 2023 outlining some thoughts on climate-related risks and regulatory capital frameworks, including the development of internal risk identification, measurement, and monitoring capabilities; the need to improve the use of forward-looking tools such as scenario analysis and stress testing; capturing long- and short-term risks; and ensuring a robust framework for assessing the impact of climate risks on capital (e.g., including climate risks in the expected credit loss allowance).

UK: Bank of England (BoE) Supervisory Statement 3/19 and "Dear CEO" Letter (PRA)[33,34]

In both publications, the Bank of England set out detailed expectations and guidance on how companies should integrate their approaches to managing climate-related financial risks, including developing a strategic approach, identifying current and plausible future risks, and taking appropriate steps to mitigate those risks. These expectations were to be met by the end of 2021.

US: OCC, Board and FDIC principles for managing climate-related financial risks at large financial institutions[35]

In October 2023, the U.S. federal banking regulatory agencies published a set of principles intended to help financial institutions focus on key aspects of climate-related financial risk management, such as governance, policies, procedures, limit setting, strategic planning, risk management and measurement, data and reporting.

[31] EIOPA (2021).
[32] BoE (2023).
[33] BoE (2019).
[34] Sam Woods (2020).
[35] The Comptroller of the Currency, the Federal Reserve System, and the Federal Deposit Insurance Corporation (2023).

US: U.S. Securities and Exchange Commission (SEC) final rules for investor climate-related disclosures[36]

In March, the US Securities and Exchange Commission (SEC) published its final rules to improve and standardise climate-related disclosures for investors. These rules, based on the framework developed by the Task Force on Climate-related Financial Disclosures (TCFD), are tailored to the needs of investors and the situation of SEC registered companies. The goal is to ensure consistency, comparability, and reliability of climate-related disclosures, particularly with respect to material risks affecting a company's business strategy, operating results, or financial condition, as well as its transition plans.

Registrants must include information on physical (acute and chronic) and transitional (regulatory, technological, market, etc.) climate risks and their impact on business and corporate strategy. Disclosure is required on climate change targets, transition plans and methodologies used to measure and monitor progress, including the use of carbon offsets or renewable energy certificates (RECs).

The framework also requires the submission of greenhouse gas (GHG) emissions metrics for Scopes 1 and 2, if relevant to the company's business, with the option to obtain an assurance report from an independent third party. Companies must also detail the financial impacts of severe weather events and transition activities, as well as costs related to carbon offsets and RECs. The regulation allows for a gradual adaptation phase, with full implementation starting in fiscal year 2025 (FYB 2025).

The regulatory and supervisory requirements outlined above show how regulators, supervisors, and international institutions are making progress in developing frameworks, regulations, and standards aimed at channeling investment toward economic transition, increasing transparency around sustainability and climate risk, and ensuring the resilience of the financial system. However, this growing regulatory pressure poses significant challenges for both the financial sector and the regulators themselves. In the area of ESG risks, there are still many areas that require further clarity and regulatory development. One of the key challenges is the lack of a uniform framework for assessing the impact of ESG risks on different categories of financial risk (credit, market, operational, etc.) in a consistent manner. Currently, no standard methodology has been defined with a consistent approach, which leads to a high degree of uncertainty in applying coherent and consistent methodologies and in comparing the impact of risks and opportunities across different entities and geographies.

The development of these regulations in the coming years will be essential to establish clear guidelines that allow for an effective and aligned assessment of the impact of ESG risks and a holistic and complete integration of sustainability into the processes, strategies and reports of financial sector players.

Increasing regulatory pressure, exemplified by frameworks such as the BCBS Principles and the ISSB standards, makes it clear that quantitative measurement of climate and environmental risks is critical to meeting regulatory expectations and ensuring the resilience of the financial system. These regulations require not only the identification of risks, but also their quantification through specific metrics and stress tests necessary to accurately assess their impact on portfolios and balance sheets.

For example, in its supervisory guidelines, the ECB requires financial institutions to integrate climate risks into their management strategies and processes, using methodologies that make it possible to calculate the impact of extreme events, such as flooding, on the value of mortgage collateral or loan portfolio assets. Without this quantification, it would be impossible to anticipate the financial impact of physical or transition risks, or to comply with requirements such as the CSRD Directive, which requires transparency in disclosure and alignment with sustainable strategies.

In conclusion, as mentioned above, regulations and supervisory expectations require that climate and environmental risks be incorporated into the management systems of financial institutions. It is therefore imperative to identify and measure the impact of these risks on financial institutions. For this reason, financial institutions continue to develop and improve measurement methodologies that will allow them to better understand and incorporate these risks into their management processes.

The following chapter presents a methodological approach that translates these expectations into concrete tools for measuring climate risks. This approach allows institutions not only to comply with regulations, but also to proactively manage risks and strengthen their ability to adapt in a constantly changing economic and climatic environment.

[36] SEC (2024).

Climate risks

"Physical risk reminds us how vulnerable we are, while transitional risk shows us how powerful we are to change our destiny. Embracing both is crucial to the finances of the future".
Antonio Guterres[37]

Definition of physical and transition risks

Risks associated with climate change can be analyzed both in terms of their nature, in order to understand their characteristics and evolution, and in terms of their impact on organizations, individuals and society in general. As part of the preparation of the Sixth Assessment Report (AR6), the IPCC itself addressed the concept of risks associated with climate change and their specific application to the financial and investment sectors. In this analysis, the IPCC defines the concept of risk as follows:

"Potential adverse consequences to human or ecological systems, recognizing the diversity of values and objectives associated with those systems. In the context of climate change, risks may arise from the potential impacts of climate change, as well as from human responses to climate change. Relevant adverse consequences include those affecting lives, livelihoods, health and well-being, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species"[38].

In the financial sector, these risks have been interpreted in terms of the potential financial and non-financial risks that may result from such adverse outcomes. Thus, the Network for Greening the Financial System (NGFS), based on the original TCFD definitions[39], classifies climate risks into two broad areas[40,41]:

- Physical risks: risks arising from the occurrence of weather and climate phenomena, such as heat waves, floods, storms, etc. (acute risks), or from the progressive change in and climate patterns such as rising temperatures, rising sea levels, desertification, or the gradual loss of ecosystems and biodiversity or scarcity of resources (chronic risks).

- Transition risks: risks arising from the adjustment processes towards a low-carbon and circular economy, through elements such as changes in policy and regulation, technology or changes in market sentiment.

For the financial and insurance sectors, managing the risks associated with climate change therefore requires a prior quantification of the impact of these two risks on their activities and, in particular, on their capacity to amplify traditional risks.

For example, credit risk may be amplified by, among other things[42]: (i) the economic loss of investments in credit portfolios or financial investments (both banking book and trading book), resulting from the negative impact on the value of such portfolios determined by the deterioration of credit parameters; (ii) the loss in value of the physical assets of counterparties; (iii) the potential increase in operating losses; (iv) the deterioration of the firm's liquidity position; (v) the increase in business risk (eceiving lower than expected returns on an investment); (vi) losses associated with underwritten insurance policies; or (vii) potential losses resulting from a deterioration in reputation.

Given the relevance of the impact on credit and investment portfolios, measurement methodologies in to this area have been developed and applied with greater intensity in the financial and insurance sectors. The following section presents different methodological alternatives to show how the impacts of physical and transition risks can be quantified.

Measurement of physical risks

This section discusses various methodological aspects of measuring physical risks associated with climate change: First, the physical scenarios that serve as a starting point for developing projections of the impact of risks derived from meteorological events and their future effects are described; next, the methodology for assessing the impact of physical risks on the value of collateral is presented; then, the analysis of the impact of these risks on credit portfolios and financial investment assets is developed, examining the methods for quantifying the risk and its possible impact on the value of assets; finally, the methodology for measuring physical risks in property-casualty and life insurance portfolios is examined.

Physical scenarios

The analysis of physical risks requires the consideration of different scenarios that include projections of the possible future evolution of climatic conditions and their impact on land, oceans and atmosphere in different geographical areas. In this context, IPCC AR6 uses a combination of climate models and socio-economic trajectories to understand the impacts of climate change under different scenarios.

[37] Antonio Manuel de Oliveira Guterres (2021), Secretary General of the United Nations.
[38] IPCC (2020).
[39] Task Force on Climate-Related Financial Disclosures.
[40] NGFS (2020).
[41] In addition, other losses associated with legal claims, known as "liability risk", may arise.
[42] For a more detailed analysis, see BCE Chapter 3.

The main scenarios considered in AR6 are Shared Socioeconomic Pathways (SSP), which describe possible global socioeconomic futures, and Representative Concentration Pathways (RCP), which represent different levels of greenhouse gas concentrations in the atmosphere. These two sets of pathways are combined to form global scenarios that reflect both the impact of greenhouse gas emissions and future socioeconomic pathways, providing a more complete picture of how climate and society might evolve in different contexts.

Shared Socioeconomic Pathways (SSP): the SSPs consider 5 different ways in which socio-economic actors could shape the future society:

a) **SSP1 ("Sustainability"):** a world moving toward sustainability, characterized by increased international cooperation and joint efforts to achieve sustainable development goals in an equitable manner among countries.

b) **SSP2 ("Middle of the Road"):** a scenario in which trends follow their historical trajectory, with slow but steady progress towards environmental targets.

c) **SSP3 ("Regional Rivalry"):** a scenario of growing nationalism and regional challenges, leading to fragmented environmental policies and less global cooperation.

d) **SSP4 ("Inequality"):** an increasingly unequal world.

e) **SSP5 ("Fossil Fuel-Based Development"):** a scenario based on fossil fuel-intensive economic growth.

Representative Concentration Pathways (RCP)[43]:

a) **RCP1.9:** Low emissions scenario with the aim of limiting global warming to 1.5°C by the end of the century.

b) **RCP2.6:** Low emissions scenario with significant greenhouse gas (GHG) reductions, aiming to limit global warming to 1.7°C by the end of the century.

c) **RCP4.5 and RCP6.0:** Medium to high emissions scenarios that assume relatively ambitious policies to reduce emissions in the second half of the century. In these scenarios, global warming could reach up to 2.6 °C and 3.1 °C respectively by the end of the century.

d) **RCP8.5:** High emissions scenario, which represents the absence of climate policies and a continued increase in emissions throughout the 21st century. In this scenario, global warming could reach a maximum of 4.8°C by the end of the century.

In its Sixth Assessment Report (AR6), the IPCC has proposed four combinations of SSP and RCP scenarios as standard scenarios, called SSPX-Y combinations, which are associated with different levels of global warming by the end of the century, relative to pre-industrial levels. These combinations allow different trajectories of development and response to climate change to be represented.

SSPX-Y scenarios combine the Shared Socioeconomic Pathways (SSP) with the Representative Concentration Pathways (RCP) based on radiative forcing levels. Radiative forcing measures the change in the Earth's energy balance due to greenhouse gas emissions and allows scenarios to be classified into different levels, such as SSP1-1.9 or SSP1-2.6, depending on the magnitude of the projected impact.

By combining socioeconomic projections with greenhouse gas concentration levels, these scenarios provide a more coherent view of the future under different combinations of socio-economic development and climate policies, allowing us to assess the likely level of global warming and its impacts on climate over the course of the century.

These scenarios allow the projection of values associated with different climate variables (precipitation in millimeters of rainfall, near-surface wind speed, evaporation including sublimation and transpiration, maximum daily near-surface air temperature, etc.) at each time point until at least 2100 (with daily or monthly granularity, depending on the model underlying the generation of the variable), and for different

[43] The number associated with each RCP represents the level of radiative forcing in the year 2100, expressed in watts per square meter (W/m^2), resulting from cumulative greenhouse gas emissions.

latitudes and longitudes of the globe (generally with a 1° latitude grid, although there are geographically disaggregated projects to extend this granularity, such as the Coordinated Regional Climate Downscaling Experiment or CORDEX[44]).

However, while projecting the evolution of these variables is the starting point for quantification, it is necessary to characterize the occurrence of so-called "hazards". These refer to the possibility of climatic events, such as floods, storms, heat waves or droughts, which may cause loss of life, injuries or other health impacts, as well as material damage to property, infrastructure, livelihoods, services, ecosystems and natural resources.

For example, the risk of flooding can be estimated by considering physical variables such as the amount of precipitation in a given period. If these variables exceed certain thresholds, there is an increased probability of a flood with severe consequences.

These events can be characterized using simple methods or by applying complex climate models. In addition, it is essential to define a threshold that indicates when a given hazard could

The main SSPX-Y scenarios are as follows (summarized in Figure 6):

i. **SSP1-1.9:** represents one of the most ambitious trajectories in terms of climate change mitigation. This scenario combines SSP1, which describes a more sustainable and cooperative future, with a very low radiative forcing of 1.9 watts per square meter (W/m^2) by 2100. It is one of the scenarios designed to limit global warming to 1.5 °C above pre-industrial levels, in line with the target set in the Paris Agreement on climate change.

ii. **SSP1-2.6:** combines the SSP1 scenario with a radiative forcing of 2.6 W/m^2. This scenario assumes rapid and effective action to mitigate climate change.

iii. **SSP2-4.5:** combines SSP2, which assumes progress in which neither environmental concerns nor economic policies play a dominant role, with a radiative forcing of 4.5 W/m^2 by 2100. This scenario reflects a world in which development follows an intermediate path, without a strong push towards global sustainability, but neither towards a fossil fuel-intensive model.

iv. **SSP3-7.0:** uses the SSP3 scenario, which reflects a fragmented world with regional conflicts and combines it with a forcing of 7.0 W/m^2. This scenario shows less international cooperation and greater challenges in climate change mitigation.

v. **SSP5-8.5:** integrates the SSP5 scenario, a world centered on fossil fuel-based economic growth, with a high forcing of 8.5 W/m^2. It represents a high emissions scenario without significant actions to reduce carbon emissions.

[44]https://cordex.org/.
[45]With respect to the pre-industrial level.

Table 6: Summary of the main IPCC SSPX-Y physical scenarios.

Scenario	Global warming in 2100[45]	Physical risks
SSP1-RCP1.9 (SSP1-1.9)	1.0 °C - 1.5 °C	Low
SSP1-RCP2.6 (SSP1-2.6)	1.0 °C - 1.8 °C	Low
SSP2-RCP4.5 (SSP2-4.5)	2.1 °C - 3.5 °C	Moderate
SSP3-RCP7.0 (SSP3-7.0)	2.8 °C – 4.6 °C	High
SSP5-RCP8.5 (SSP5-8.5)	3.3 °C - 5.7 °C	Very high

Figure 7: Examples of thresholds for defining hazards.

Hazards	Variable	Composite index	Thresholds (illustrative example[46])	Unit of measurement of intensity
Pluvial flooding	Rainfall intensity	n/a	20	Millimeters
Convective storm	Wind speed near the surface	n/a	80th percentile	Meters per second
Drought	Precipitation	Proportion of water	80th percentile	No dimensions
	Evaporation including sublimation and transpiration			
Fire	Precipitation	Fire index	80th percentile	No dimensions
	Maximum daily near-surface air temperature			

materialize, taking into account one or more physical variables. This allows the physical risk event (hazard) to be managed as a dichotomous variable (see some illustrative examples of thresholds in Figure 6).

Based on this characterization, and taking into account the values of the underlying climatic variables obtained from the SSPX-Y scenarios, it is possible to simulate the occurrence and intensity of the hazards, and thus to estimate a frequency of occurrence for a given time horizon and geographical area.

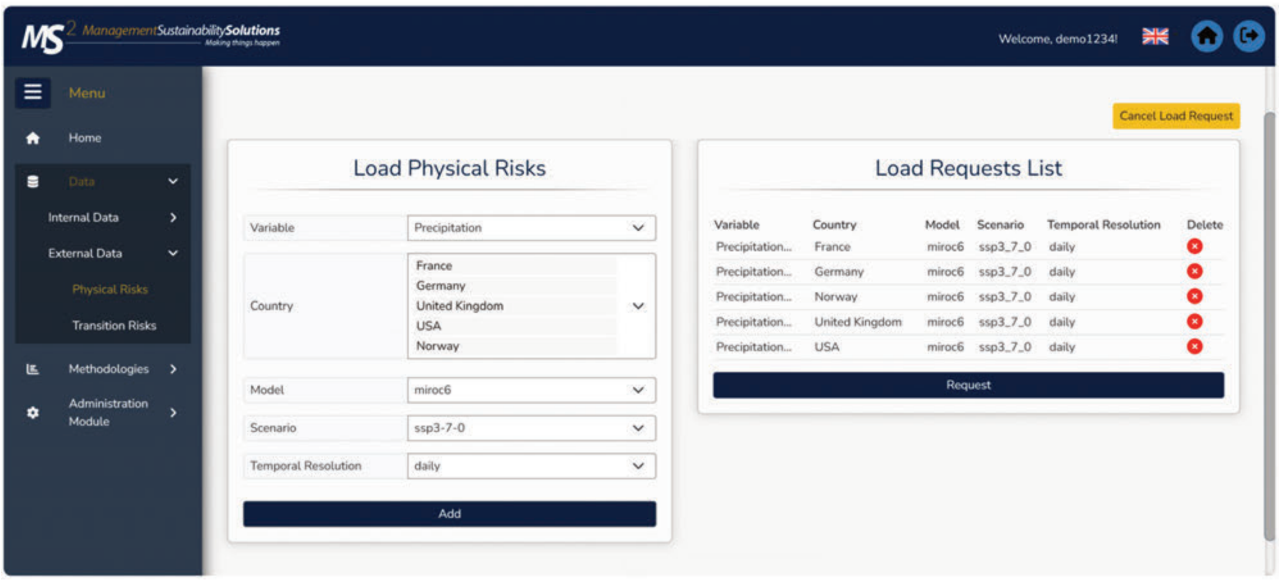
From an operational perspective, the integration and preparation of the data needed for these scenarios requires the handling of large volumes of information in specific formats. This process presents considerable technical challenges, especially in the ingestion, processing and continuous updating of data for each scenario. To address these complexities effectively, it is essential that the processes for measuring climate risk are designed to efficiently manage the data involved, ensuring their adequate and timely treatment.

To address these challenges, Management Solutions has developed a specialized tool for measuring climate risk, called Management Sustainability Solutions (MS^2). This solution integrates the management of these aspects, being able to import, process and store physical scenarios obtained from sources such as Copernicus[47], which are used to perform quantitative calculations. MS^2 offers an intuitive and easy-to-use interface, which also integrates the technical infrastructure necessary for the efficient processing of data for each scenario (see Figure 8).

[46] Based on historical data, the specific conditions of the geography under study and the experience of experts, a threshold is established that indicates when a given physical hazard may materialize, considering one or more physical variables. The values presented in the table are merely illustrative and represent general starting values that are aligned with the current state of relevant scientific research. These values can be adjusted according to the specific context of the case under analysis.

[47] Climate scenario projections produced by the Copernicus Climate Change Service (C3S), https://climate.copernicus.eu/climate-projections.

Figure 8: Example of loading physical scenarios in the MS^2 tool.



Measuring the impact on a mortgage portfolio

The analysis of physical risks in a mortgage portfolio follows a methodology aligned with the UNEP-FI framework[48], designed to comply with the Working Group on Climate-related Financial Disclosures (TCFD) recommendations. Its main objective is to assess how extreme weather events affect the valuation of physical assets used as collateral in real estate portfolios, focusing on the loan-to-value (LTV) ratio.

This methodology is based on the analysis of scenarios and projections of climate risk variables (more details in section 'Physical Scenarios'). By determining the geographic location of the portfolio's collaterals it is possible to estimate the frequency and intensity of physical risks in those regions.

For the development of this methodology, it is necessary to integrate climate models that provide information on the severity and frequency of hazards over time, based on different climate scenarios. Damage curves, or impact functions, convert these climate variables into economic impacts, estimating the percentage of asset value that could be lost due to specific events. These curves are key to assessing the vulnerability of assets to physical hazards and serve as the basis for calculating potential economic losses.

For each risk, scenario and year, the economic impact is determined by combining the frequency of the physical risk (the frequency with which it occurs), the economic value of the collateral and the impact function, which provides the percentage loss of asset value as a function of the intensity of the risk.

This economic loss is then applied to the value of the guarantee to calculate a simulated loss. The effect on the collateral can be assessed in two complementary ways: first, by calculating the annual impact and using it to estimate changes in the Loan To Value (LTV) over time; and second, by assessing the cumulative impact on the LTV as the value of the collateral decreases year by year. In this way, there is a clear understanding of how risks can affect LTV, which helps to measure risk over the medium and long term.

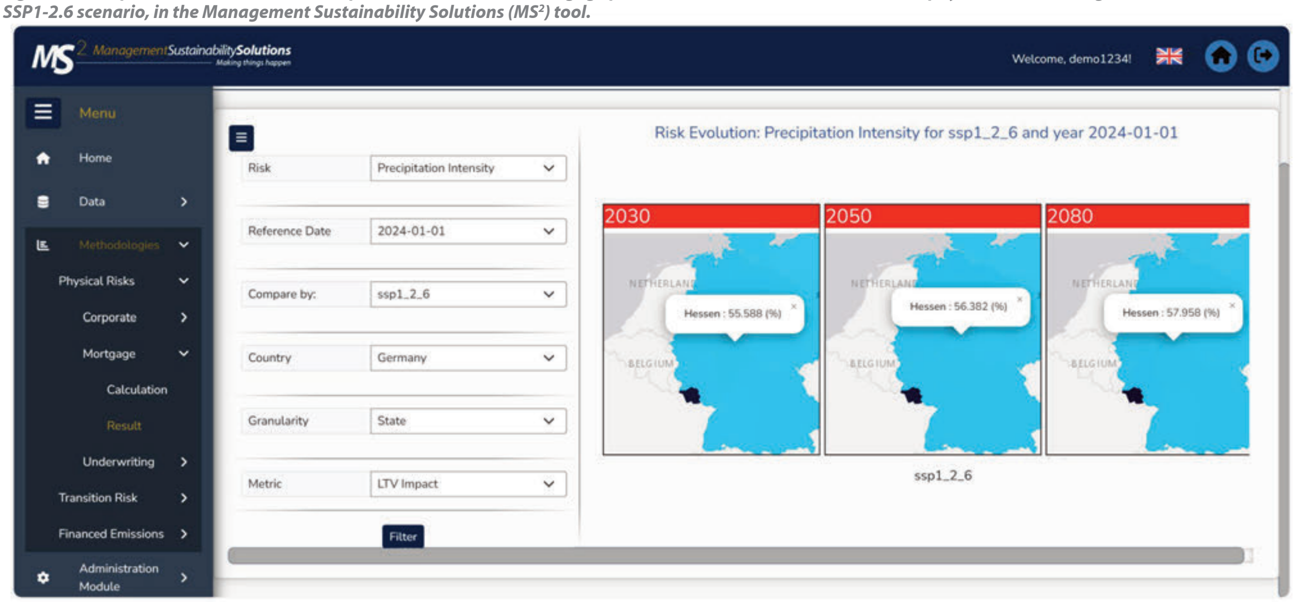
This LTV is a factor commonly used by financial institutions to derive loss given default (LGD). Therefore, the new adjusted LTV, which reflects the economic impacts of physical risks, can be used to estimate changes in LGD. Or another option is to apply a haircut to the collateral values within the LGD estimation process and recalculate the LGD model. Thus, the effects of climate risks on LTV directly influence changes in LGD, highlighting the financial risks posed by climate-related phenomena.

In order to carry out a measurement exercise using the methodology described above, it is necessary to have specific data on the mortgage portfolio under analysis. In particular, to allow a granular measurement of risk, information on the geolocation of mortgage collateral, as well as information related to their economic value, is particularly relevant. Having both a granular and consolidated view on the main exposures of the portfolio is also significant for analyzing the most relevant exposures to climate risk.

The methodology described in this section allows for a comprehensive analysis of the impacts of physical weather risk at the level of each mortgage exposure. This facilitates the simulation of the effect of collateral value loss due to damage caused by physical risk events, as well as its impact on significant parameters such as LTV and LGD (see Figure 9).

[48]UNEP-FI, U. N. (2024).

Figure 9: Example of the evolution of the impact on the LTV of the mortgage portfolio in 2030, 2050 and 2080 due to physical risk (flooding) in the SSP1-2.6 scenario, in the Management Sustainability Solutions (MS^2) tool.



Measuring the impact on loan portfolios and financial investment assets

Physical risk assessment for a corporate loan portfolio can also be approached through a quantitative technique, using damage curves to assess the impact of physical hazards on the counterparty's assets (mainly property, plant and equipment). By integrating the frequency and intensity of hazards with these damage curves, one can estimate the depreciation in the value of the assets and, consequently, the decrease in the value of the counterparty's assets, which ultimately influences creditworthiness.

The process begins with identifying the range of physical hazards linked to climate change that may affect portfolio companies. These hazards may include wildfires, floods, tropical cyclones, droughts and other extreme events. The frequency, severity and definitions of these hazards are based on physical scenario projection data, as discussed above.

In the established scenarios, these physical events affect companies' physical assets, such as factories, infrastructure, extraction facilities, fields and crops. These assets, whose value is typically represented in the property, plant and equipment (PP&E) account on the balance sheet, represent long-term physical assets that companies use to generate revenues and profits. The methodology requires access to data on the total value of assets, the value of PP&E, and their geographic distribution for counterparties within the portfolio. In addition, it is advisable to take into account the differentiated impact of the different types of assets according to their relevance in each sector.

With these data, combined with physical scenario projections, it is possible to estimate the frequency and intensity with which a specific hazard will affect the company's productive assets over time.

To do this, it is essential to integrate relevant counterparty data, such as the value of their assets and their geographic distribution. However, detailed and location-specific information on the operating sites of a broad set of portfolio companies is often not part of the data infrastructure and collection processes of financial institutions and must be collected additionally. It can be obtained on a large scale using existing data solutions and the use of proxies to manage potential information gaps. This is especially relevant when handling large customer portfolios, where the methodology needs to be made compatible with top-down estimates for a more complete and accurate risk assessment.

As in the case of the mortgage portfolio, the translation of physical risks into economic losses can be addressed by means of damage curves or impact functions. For each hazard associated with the identified climate risk (see section 'Physical Scenarios' for details) affecting a given asset type, there are specific damage curves that provide the percentage of expected damage from the occurrence of that risk. These curves are the basis for quantifying potential economic losses by assessing the vulnerability of assets to various physical hazards.

By aggregating the total losses in value of all of a company's PP&E due to a specific peril in a given scenario and year, the Yearly Damage Loss (YDL) can be calculated. YDL represents the percentage loss experienced by the counterparty's assets as a result of physical risk, impacting those productive assets critical to the company's revenue generation. It is assumed that this impact will lead to both a decrease in revenues and an increase in costs, as the assets will need to be repaired and restored to working order to ensure operational continuity.

Figure 10: examples of impact on PD and LGD of the portfolio due to physical risk (flood) under the SSP5-8.5 scenario in the Management Sustainability Solutions (MS^2) tool.

This physical shock is reflected in the depreciation of assets and serves as an indicator of physical weather risk for the corporate entity, either as a counterparty to a loan or as an issuer of a financial asset. The last step, for a corporate loan portfolio, is to translate the YDL into an impact on the Probability of Default (PD) of the counterparties, which can be done by applying a structural valuation model (e.g. Merton). The methodological framework assumes that the impact on the firm's PP&E shifts the distribution of asset values, resulting in changes in PD at a given point in time. This methodology adapts PD over the business cycle, with YDL acting as a "climate risk credit quality indicator" for physical risk in the corporate loan portfolio.

If some of these assets are also collateral for a specific loan, this will also directly affect the LGD estimate. In any case, even when physical assets are not collateral, there may also be an impact on LGD. This impact could be calculated by exploiting the PD-LGD correlation, for example, by defining the relationship between changes in PD and corresponding changes in LGD. By analyzing both PD and LGD, the overall effect of physical risk on expected credit losses for each counterparty and across the entire loan portfolio can be estimated.

For financial assets - such as stocks and bonds - it is essential, after estimating the YDL, to assess how this affects their Net Asset Value (NAV). This analysis will be carried out by applying different valuation models, both for equities and for fixed income instruments such as corporate and government bonds. In the case of equities, a valuation model based on dividends or earnings per share can be used to calculate the financial impact. This model evaluates changes in stock value based on how the physical climate shock affects the company's dividend payout.

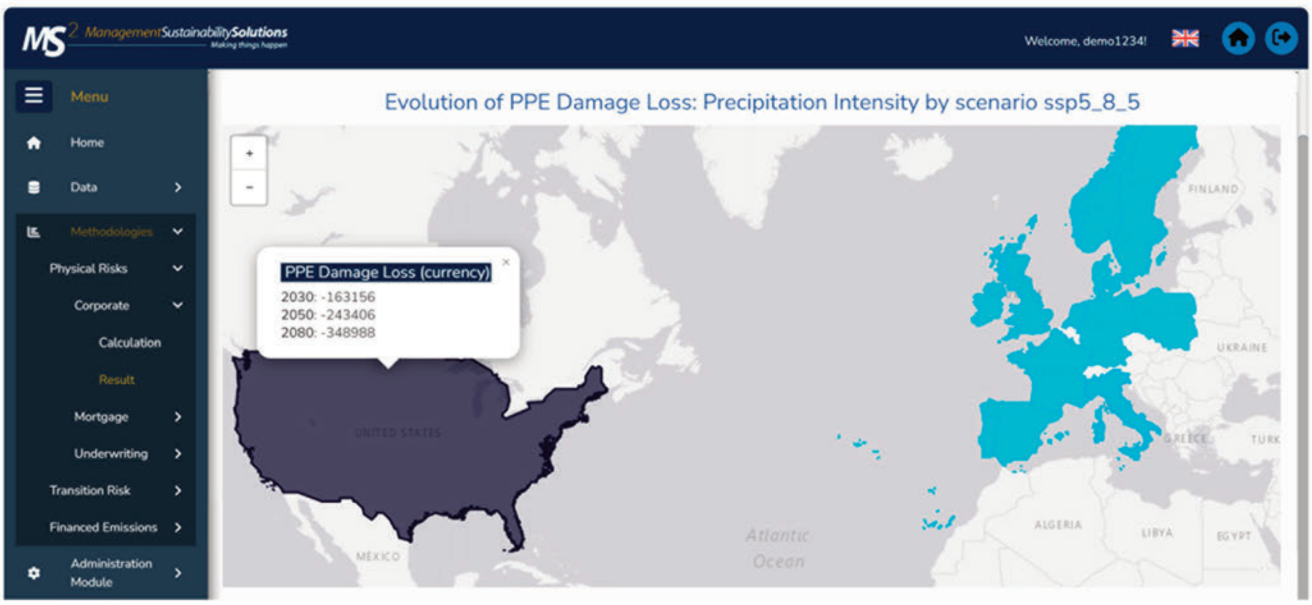
In the case of corporate bonds, an approach based on a structural valuation model can also be used to assess how the physical weather shock affects the creditworthiness of the issuer. The model calculates the probability of default as a function of the issuer's financial condition. Once the impact on creditworthiness is determined, a weather-related spread is calculated to estimate changes in bond prices, providing an estimate of how the value of the corporate bond will fluctuate due to physical weather risks.

For government bonds, the YDL is calculated on the basis of the issuing country's productive assets. This requires a geographical distribution of these assets. Although there could be different options to achieve this distribution, one of the methodologies used by Management Solutions and incorporated in MS^2 has been estimated using data from the Litpop base[49]. The financial impact of the physical shock is then applied proportionally to the coupon rate of the bond, reflecting the expected costs and opportunities faced by the issuing government under the climate scenario. This adjustment allows us to estimate how the value of the government bond might change in response to the physical risk.

The methodology described in this section allows for a comprehensive analysis of the impacts of physical climate risk at the level of each credit exposure and financial asset. This facilitates the simulation of the impact on risk parameters PD and LGD (see Figure 10) and on the value of

[49]A database containing high-resolution maps of national asset value estimates, distributed proportionally to a combination of nighttime light intensity and population data. https://doi.org/10.3929/ethz-b-000331316.

Figure 11: Examples of portfolio counterparties' PP&E value losses due to physical risk (flooding) under the SSP5-8.5 scenario in the Management Sustainability Solutions (MS^2) tool.



financial assets (NAV) due to damage caused by physical risk events (see Figure 11).

Measuring impact on underwriting portfolios in the insurance industry

In the same way as for the credit investment portfolio and financial assets, a quantitative methodology can also be applied to assess the impact of physical weather risks on property and casualty insurance underwriting portfolios, as well as on life insurance portfolios.

Property and Casualty (P&C) insurance portfolio

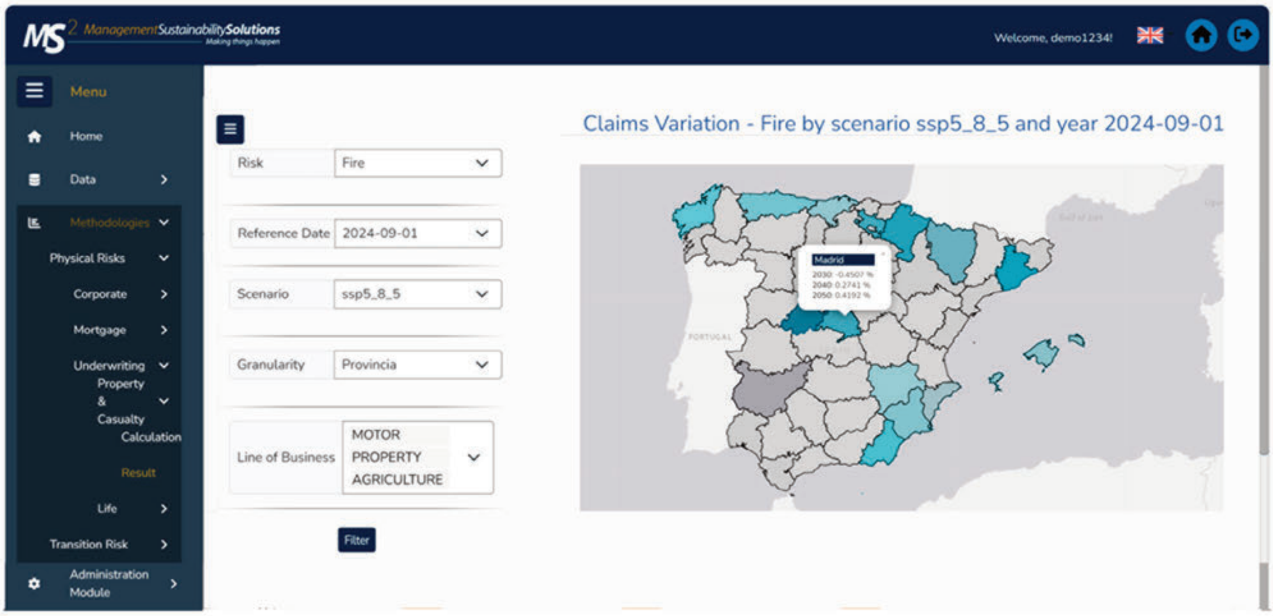
The physical risk analysis for the property and casualty (P&C) underwriting portfolios is based on an estimate of the expected increase in claims experience. The main assumption of this methodology is that the pricing and reinsurance ratios remain unchanged compared to the current scenario. Depending on the granularity of the available data, the methodology can be applied both at the individual policy level and at a more aggregated level, such as region, province or country, as well as across different lines of business or products.

Having both a granular and consolidated view of the portfolio's main exposures is essential for analyzing the most relevant exposures to climate risk.

The methodology is developed in several key steps:

- First, modeling climate phenomena involves representing each phenomenon with projected climate variables, which are derived from physical scenarios (as described earlier in this document). These projections reflect the expected frequency of the various climate hazards.
- Secondly, current weather-related losses are estimated. This initial calculation aims to establish an annual estimate of the costs associated with each physical event, taking into account both the frequency with which these events occur and their intensity. At this stage, damage curves or impact functions are used to estimate the percentage of asset value that could be lost due to each specific event. These curves are essential for understanding the degree of vulnerability of different types of assets to various physical hazards and provide a basis for calculating potential financial losses.
- Once the initial loss estimates have been obtained, these values must be adjusted to take into account the specific characteristics of the insurance policies covering the related assets. This involves aggregating the loss estimates for each product and then applying a correction factor that adjusts the calculated loss based on historical loss data. This adjustment ensures that the estimated losses more accurately reflect the actual loss experience of the portfolio.
- After this adjustment, the next step is to project future losses under various climate scenarios. The process is similar to the initial estimation, but using data projected for future years such as 2030 or 2050. In each case, the frequency and intensity of physical events are

Figure 12: Projection of the change in P&C portfolio loss experience due to climate risk-related wildfires under the SSP5-8.5 scenario for 2030, 2040 and 2050 in the Management Sustainability Solutions (MS²) tool. Note: simulated data, for illustrative purposes only.

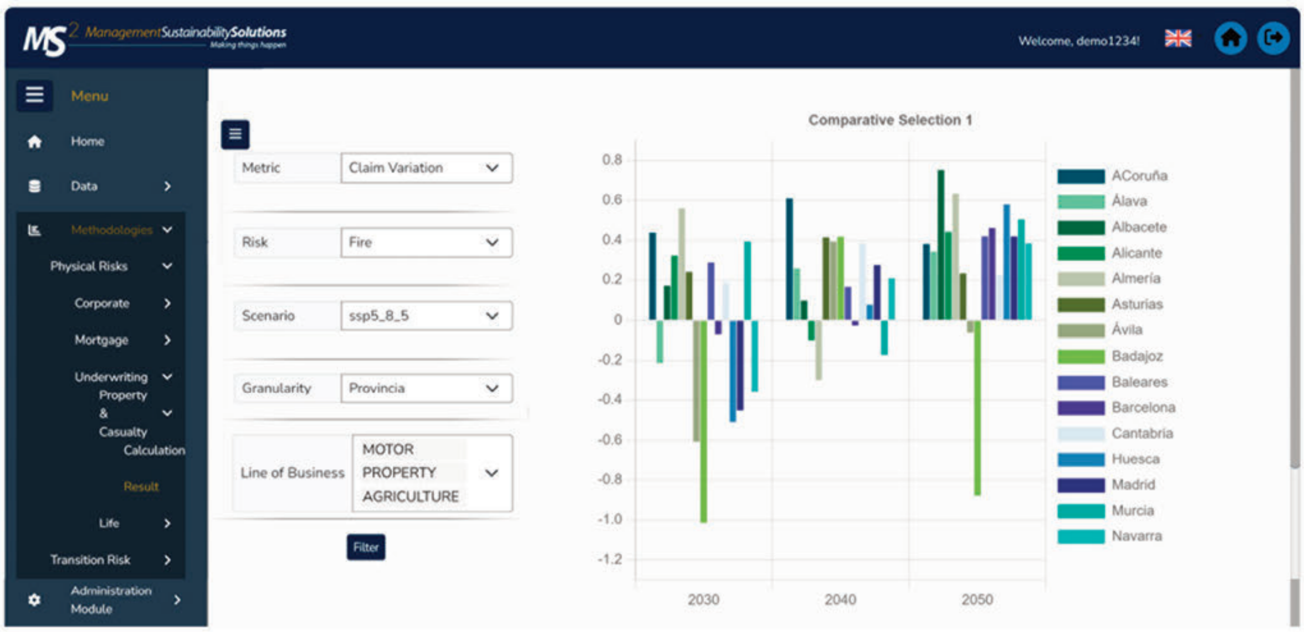


recalculated, and the adjusted losses are projected over time. Future losses are then compared with current losses to assess how losses are expected to evolve as the climate changes.

- Finally, the calculation of net claims takes into account the applicable reinsurance agreements and risk compensation funds. In the case of reinsurance, the ratio of net claims to gross claims is calculated, and this ratio is used to adjust the estimated costs. Similarly, if a risk compensation pool exists, a percentage of the total loss is offset against the pool, reducing net claims accordingly.

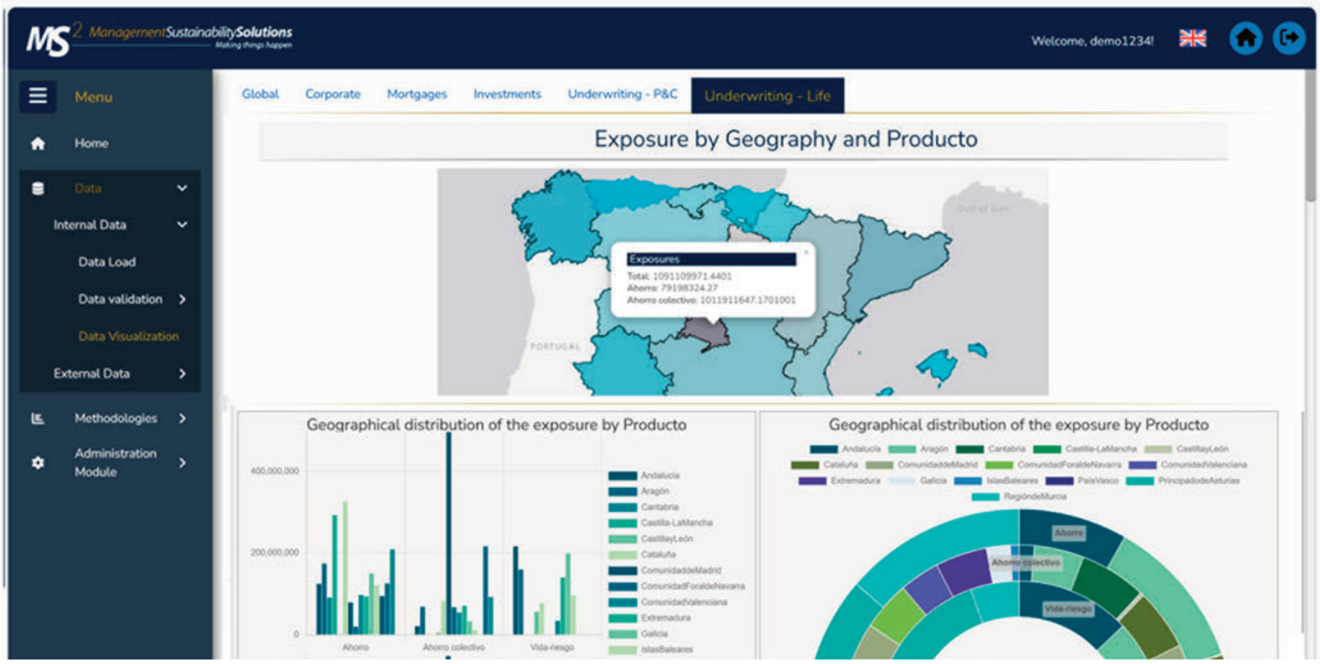
Using this structured approach, it is possible to provide a quantitative view of how physical climate risks are expected to affect the loss experience of an underwriting portfolio in the short, medium and long term, due to damage caused by physical risk events (see Figure 12), as well as to make comparisons across different axes (see Figure 13).

Figure 13: Regional comparison of the projected increase in expected costs (loss ratio) of the P&C portfolio due to climate risk-related wildfires under the SSP5-8.5 scenario for 2030, 2040 and 2050 in the Management Sustainability Solutions (MS²) tool.



Note: simulated data, for illustrative purposes only.

Figure 14: Illustrative example of the life insurance portfolio in the Management Sustainability Solutions (MS²) tool.



Life insurance portfolio

To assess the impact of climate change on a life insurance portfolio, the following approach focuses on the effect of climate-related changes on mortality rates[50]. It consists of modeling how climate change, in particular the increased frequency of heat waves and the shortening of winter seasons, affects mortality rates. This assessment is carried out through a mathematical model that incorporates several critical factors, such as average annual temperature, GDP per capita, and statistical data related to temperature and precipitation. The model also takes into account variations based on parameters by age and administrative divisions (ADM2 level[51]), and also considers differences by country, age, year and sex. In addition, the model takes advantage of historical mortality statistics broken down by age, country and year to improve the accuracy of the projections.

[50] The approach is based on the methodology described in the document "Valuing the Global Mortality Consequences of Climate Change Accounting for Adaptation Costs and Benefits" by Carleton, and is in line with the conclusions of the study "Projections of Temperature-Related Excess Mortality under Climate Change Scenarios" by Gasparrini. The methodology is also supported by the United Nations Development Programme (UNDP).

[51] The geographical classification ADM2 refers to the second level of administrative division of a country, which may include provinces, districts, counties or municipalities, depending on the territorial organization of each State.

Figure 15: Diagram of the mortality shock calculation methodology for underwriting the life insurance portfolio.

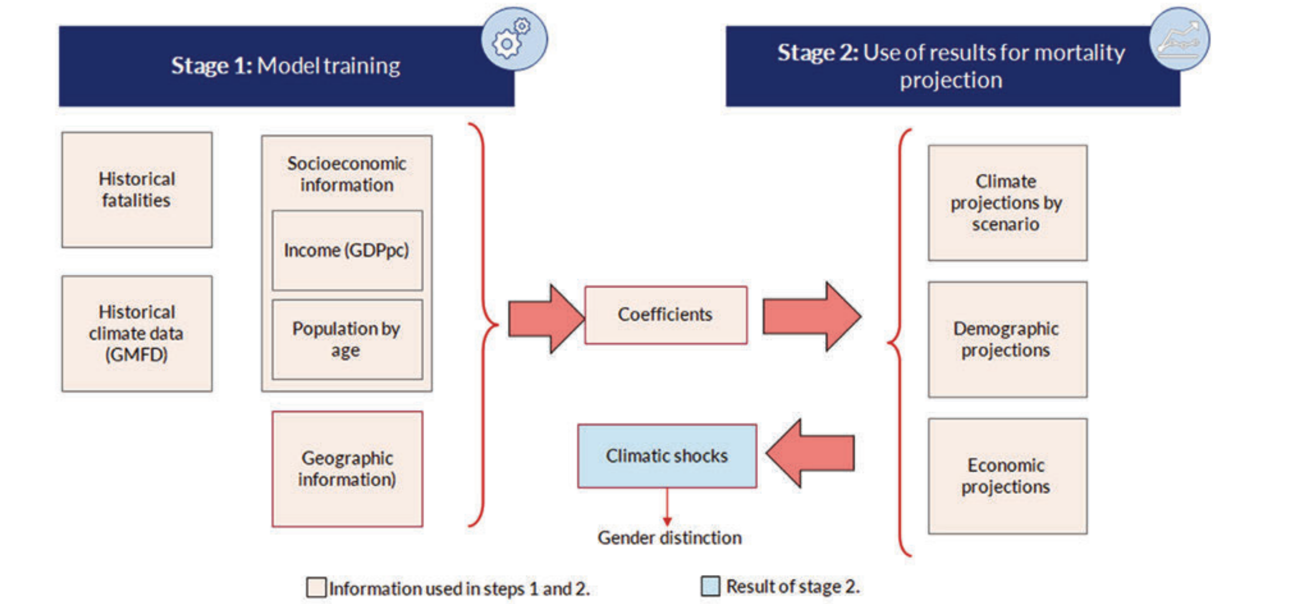
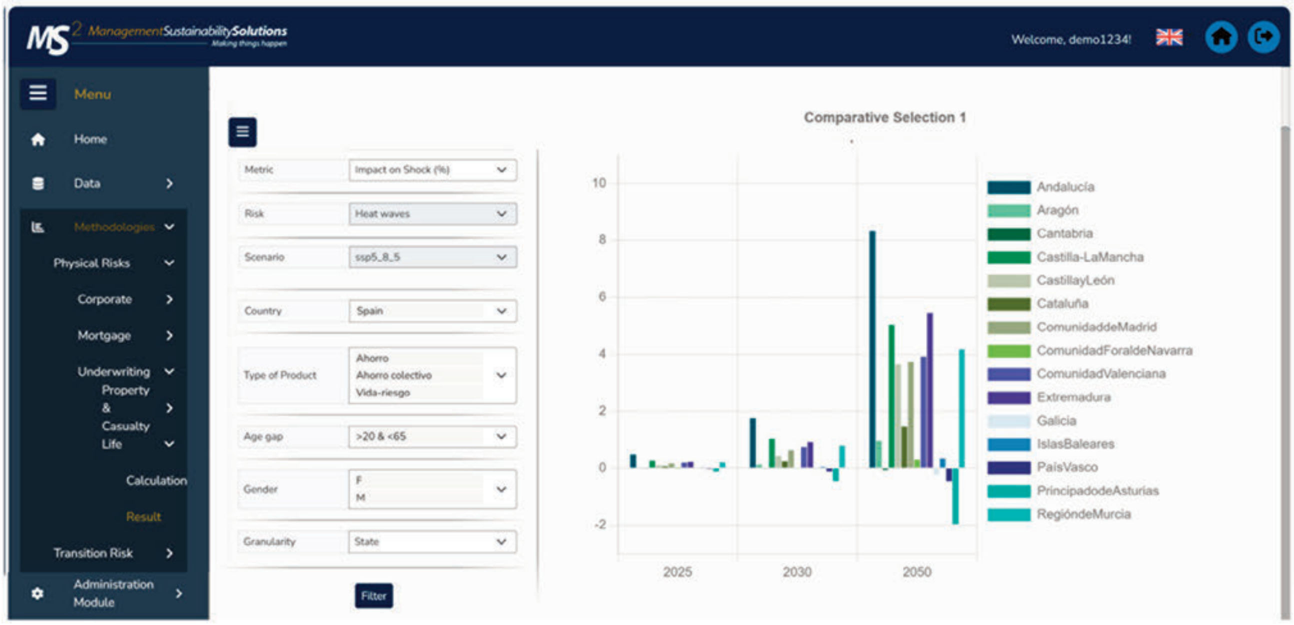


Figure 16: Examples of shocks and regional scale comparison of life portfolio mortality rates due to physical risk (heat waves) under the ssp5-8.5 scenario in 2025, 2030 and 2050 in the Management Sustainability Solutions (MS[2]) tool.



Note: simulated data, for illustrative purposes only.

Having both a granular and consolidated view of the main exposures and characteristics of the portfolio is essential for analyzing the most relevant exposures to climate risk (see Figure 14).

Applying climate scenario projections, particularly those related to rising temperatures and increased incidence of heat waves, the model estimates mortality impacts for different future time horizons, such as 2025, 2030, 2050 and 2100. These mortality shocks are generated for specific geographic regions and are differentiated by age group and sex (see Figure 15).

Once the mortality shock has been calculated for a given year, climate scenario and geographic region, its impact can be used to assess the effect on the mathematical provisions of life insurance policies at the time of valuation. For policies with annual coverage, this information is essential to determine the necessary premium adjustments. However, the precise application of these mortality shocks, whether on provisions or on premiums, will vary depending on the insurer and the specific conditions of the policies in question.

This methodological approach makes it possible to quantitatively assess the projected impact of physical weather risks on the mortality rate of a life underwriting portfolio over the short, medium and long term, considering rising temperatures and the increasing incidence of heat waves (see Figure 16).

Measurement of Transition Risks

This chapter explores methodologies for measuring the impact of transition risks on investment and credit portfolios, using climate scenarios that project the impact of decarbonization policies and other structural changes on markets. First, the "Transition Scenarios" section analyzes possible pathways to a low-carbon economy, showing how the timing and intensity of these policies affect specific sectors. Next, the subchapter "Measuring the impact on the corporate loan portfolio" describes how transition risk in corporate credits is assessed by combining transition risk factors and sectoral sensitivities in heat maps to estimate the climate credit quality index of each counterparty under different scenarios. Finally, the subchapter "Measuring the impact on the investment portfolio of financial assets" presents a methodology for assessing the transition risk in various financial asset classes - such as corporate bonds, sovereign bonds and equities - highlighting how the shift towards a sustainable economy may influence the value of these assets. This comprehensive analysis allows simulating and consolidating the projected effects on the value of portfolios, providing a holistic view of transition risk exposure.

Transition scenarios

Under a scenario of no meaningful policies, physical climate risks will increase substantially, especially over longer time horizons. However, climate policies aimed at mitigating these physical risks may have significant economic effects on specific sectors, resulting in higher transition risks. The degree of economic disruption depends on the timing, stringency and anticipation of climate policies.

From a risk management standpoint, these policies represent a trade-off between long-term physical risks and short- and medium-term transition risks.

One of the most relevant actions to meet climate targets is the implementation of decarbonization policies together with a shift in market preferences towards more sustainable options. On the one hand, changes in market sentiment, driven by awareness of future climate risks, could significantly affect the profitability of high-emission sectors. On the other hand, the timing and nature of policymakers' actions will determine whether emissions reduction targets are met.

In this regard, the speed and timing of the transition are crucial. Clear and timely policy guidance will increase the ability of economic agents to plan for the replacement of existing infrastructure and allow technological progress to keep energy costs manageable. In contrast, a sudden, uncoordinated or disruptive transition would be more costly, especially for sectors and regions that are more vulnerable to structural change.

To take into account the different possible transition scenarios, the NGFS has developed a framework that identifies four possible pathways to a low-carbon economy[52]:

- The orderly scenarios assume that climate policies are introduced early and gradually become more stringent. To the extent that these policies contribute to emissions reductions in a measured way to meet climate targets, the transition risks are relatively moderate.
- Disordered scenarios explore higher transition risks due to delayed or divergent policy change across countries and sectors. Due to a sudden and unforeseen response, emissions reduction targets for some sectors of the economy may even need to be deepened to stay on track to meet climate goals, leaving businesses little time to adapt.
- The "hot world" scenarios assume that some climate policies are implemented in some jurisdictions, but that globally emissions continue to rise, in a context where governments do very little to prevent climate-related structural changes.
- The "too little, too late" scenarios assume that, generally speaking, governments and economic agents do not do enough to meet climate targets, leading to irreversible structural climate changes.

Within this framework, the NGFS has developed seven transition scenarios (NGFS Phase 5[53], Nov. 2023), as shown in Figure 17.

[52]52NGFS (2020).
[53]https://www.ngfs.net/en/ngfs-climate-scenarios-phase-v-2024.

Figure 17. Transition scenarios developed by the NGFS.

Scenario	Transition	Decarbonization policies	Low carbon technology	GHG emission reduction targets	Transition risks
Net zero 2050	Ordered	Immediate and smooth	High penetration	Zero net CO_2 emissions by around 2050	High
Below 2 °C	Ordered	Immediate and smooth	Moderate penetration	Zero net CO_2 emissions by around 2070	Moderate
Low demand	Ordered	Immediate and requiring less energy demand and stronger behavioral changes	High penetration	Zero net CO_2 emissions by around 2050	High
Delayed transition	Disorder	No change until 2030, very strict after 2030	High penetration from 2030	Zero net CO_2 emissions by around 2060	High
Fragmented world	Too little too late	Not immediate and too weak	Moderate penetration	Limited reduction of CO_2 emissions	High
Nationally Determined Contribution (NDC)	The world of the hot house	All decarbonization policies announced for 2030, with no changes after that year	Limited penetration	Limited reduction of CO_2 emissions	Low
Current policies	The world of the hot house	No more climate policies regarding today	No penetration	Emissions grow to 2080	No risk

Note: There is also a "Zero Divergent Network" scenario but only in the NGFS Phase 3 version; it was discarded in NGFS Phase 4 (obsolete scenario).

The processes supporting climate risk measurement exercises must ensure adequate and efficient treatment for the ingestion, processing and continuous updating of data for each transition scenario. To address these challenges, as mentioned in the previous paragraphs, Management Solutions has developed a specialized climate risk measurement tool called **Management Sustainability Solutions (MS2)**.

This solution fully integrates the management of these aspects, allowing the import, processing and storage of data obtained from sources such as NGFS, which are used to perform quantitative calculations. In addition, MS² facilitates the visualization of these projections (see Figure 18), which contributes to the analysis of scenarios and the interpretation of quantitative results generated by the calculation methodologies.

Measuring the impact on the corporate loan portfolio

To assess the impact of transition risks on a credit portfolio, the methodology is aligned with the framework developed by UNEP-FI[54]. This approach leverages qualitative heat maps to quantify risks, which are specifically tailored to different economic sectors and geographic regions[55].

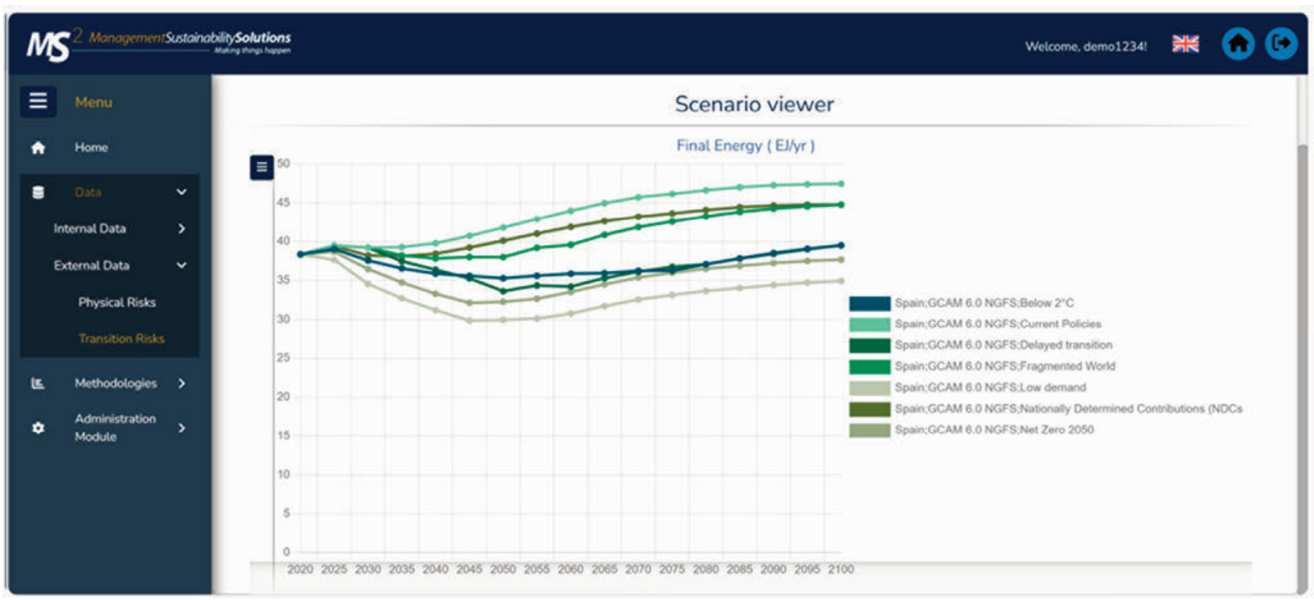
A heat map serves as a visual tool that highlights the potential impact of transitional risks - such as political changes or technological advances - on an organization. A key aspect of this process is the segmentation of industries by sector. By focusing on specific sectors, this approach ensures that companies in each segment experience a consistent level of exposure to transition policies. This segmentation is critical to identifying both the risks and opportunities associated with the shift to a low-carbon economy. Since different sectors present different degrees of vulnerability during this transition, accurate segmentation is essential for precise risk identification.

In the context of increasing global attention to sustainability and climate change mitigation and adaptation, understanding how the climate transition affects different sectors within a bank's corporate credit portfolio is key to informed decision making and risk management. Heat maps provide a qualitative assessment of transition risks affecting risk factor trajectories (RFPs) across various countries, sectors, time horizons and climate scenarios.

RFPs represent the mechanisms through which transitional risks - such as political changes, carbon pricing or technological advances - affect a company's cash flows and thus its ability to meet debt obligations.

[54]UNEP Financial Initiative: Extending our horizons.
[55]For more information on heat mapping, see UNEP Financial Initiative: Beyond the Horizon.

Figure 18: Transition scenarios, example of display of the "Final Energy" variable in the MS² tool.



The "Final Energy (E/yr)" variable refers to the final energy consumed annually, expressed in units of energy per year (E/yr). This measure represents the energy actually used by the final sectors of the economy (such as transportation, industry, housing and services), after losses associated with energy generation, transmission and distribution. This variable is just one example of the many available in the model and is particularly relevant in the analysis of decarbonization scenarios, given the key role of energy consumption in the transition to low-carbon economies.

Four key RFPs are considered:

1. Direct emissions costs: calculated by multiplying the carbon price by the sector's direct emissions (Scope 1), reflecting the impact of carbon pricing on the sector's emissions costs.

2. Indirect emissions costs: captures how the increased emissions costs of the above sectors are passed through the supply chain, impacting input prices. It is calculated by multiplying the input price by the volume of inputs used in production.

3. Capital expenditures: represents the investments required for the transition to more efficient and lower-emission operations, including new technologies. This cost is determined by the price of capital and the net increase in the capital stock.

4. Income: reflects the potential impacts on the sector's income due to factors such as changes in product prices, changes in consumer preferences and the application of taxes or subsidies. It is calculated by multiplying the sector's total production by the price of its goods or services.

These trajectories collectively take into account the effects of direct and indirect costs of emissions, changes in income, and required investments in low-carbon technologies. The results of the climate scenario model provide detailed trajectories for each economic sector that can be refined through customized sensitivity analyses. These trajectories are critical for extrapolating borrower-level impacts to the entire portfolio.[56]

It is important to note that the RFPs are evaluated against a baseline scenario, which assumes that borrowers' current credit ratings reflect a "business-as-usual" world in which no significant additional actions are taken to address climate change beyond current policies. This scenario corresponds to the NGFS "Current Policies" scenario and acts as the baseline scenario. It should be noted that the term "reference" in this context refers to projections of the macro-financial environment in the absence of additional climate transition shocks in order to provide a reasonable point of comparison for evaluating other scenarios.

The RFPs calculated from the NGFS scenarios provide a quantitative estimate of the impact of transition risk according to certain economic and climatic parameters. However, these calculations are adjusted by a qualitative analysis provided by heat maps introducing sectoral sensitivity coefficients. These coefficients make it possible to adapt the quantitative calculation of RFPs by considering the expected exposure to transition risk in each sector. Thus, the heat maps help refine the RFP results by integrating the specific vulnerability of each sector, which can amplify or mitigate the estimated impact in the different transition scenarios.

[56] Other methodologies could also take into account additional elements, such as leverage or the capital position of counterparties.

Figure 19: PD and LGD impact examples of a corporate loan portfolio, comparison between two portfolio sectors (oil and gas vs. power generation); in the Net Zero 2050 scenario in 2020,2030,2050 in the Management Sustainability Solutions (MS²) tool.

This example shows that, in a scenario of orderly transition and full decarbonization of the economy by 2050 (Net Zero 2050), the example portfolio faces higher risk (and thus increased PD and LGD) in the oil and gas related sectors compared to power generation. However, both sectors would be negatively impacted in this transition scenario. Note: simulated data, for illustrative purposes only.

The combination of the adjusted RFPs with the sectoral sensitivities derived from the heat maps makes it possible to calculate, for each counterparty, a "climate credit quality index". For each climate scenario developed by the NGFS, a set of RFPs and heat maps can be generated, as each reflects a specific policy context, economic evolution and energy transition. This implies that, for each scenario, a unique binomial RFP and heat map is defined that incorporates sectoral sensitivities and expected exposure in that particular context. Thus, the "climate credit quality index" is calculated on a scenario-specific basis, allowing an assessment of how transition risk and its impact on credit quality varies under different projections. This modeling provides a detailed view of how the various transition scenarios affect the vulnerability of counterparties at the sectoral and regional level.

In other words, this index incorporates different risk factors and sector-specific vulnerabilities in a weighted manner, thus reflecting the impact of the transition to a low-carbon economy on the value of counterparties' assets. Transition risk is considered a systemic risk distinct from idiosyncratic and other systemic factors (considered constant). This change in the distribution of asset values causes variations in the probability of default (PD) at a given point in time, using a structural valuation model (e.g., Framework Merton) that correlates a company's PD with the potential decline in the value of its assets.

Once the PD in a climate transition scenario is estimated, the impact on LGD could be calculated by taking advantage of the PD-LGD correlation.

By analyzing both PD and LGD, it is possible to estimate the overall impact of transition risk on expected credit losses for each counterparty and for the entire loan portfolio.

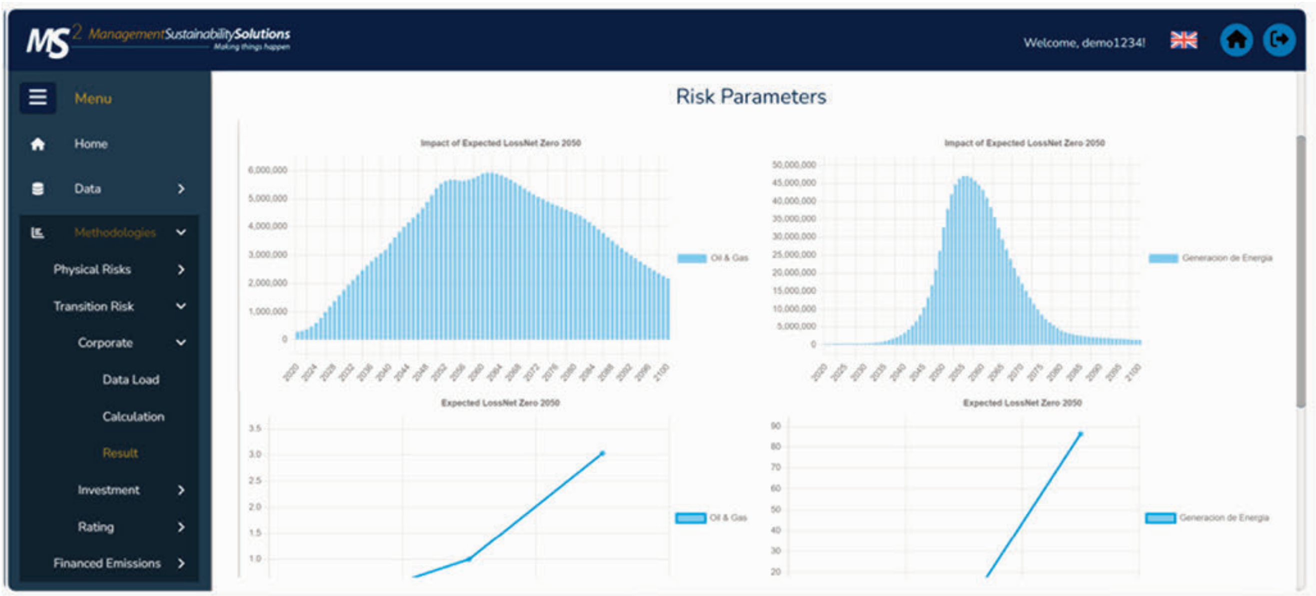
The methodology described in this section allows for a detailed analysis of the impacts of transitional climate risk at the individual exposure and counterparty level, facilitating the simulation of the effect of different trajectories of potential climate transitions on the credit risk parameters of the portfolio (see Figure 19) and, therefore, on the expected loss (see Figure 20).

Measuring the impact on the investment portfolio of financial assets

The methodology for assessing climate transition risk in the investment portfolios of banks, asset managers and insurance companies covers various types of financial assets, including corporate bonds, sovereign bonds and equities. In this context, transition risk refers to fluctuations in asset values caused by the global shift to a more sustainable economic model. These fluctuations are largely influenced by market participants' expectations of future costs and opportunities for asset issuers.

These expectations are modeled using climate policy projections and possible pathways to a more sustainable economy, according to the different climate scenarios developed by the NGFS. These scenarios help anticipate

Figure 20: Examples of expected loss impact of a corporate loan portfolio, comparison between two portfolio sectors (oil and gas vs. power generation); in the Net Zero 2050 scenario in 2020,2030,2050 in the Management Sustainability Solutions (MS²) tool.



Note: simulated data, for illustrative purposes only.

how climate change-related policies and regulations could evolve, as well as the economic and market impacts such policies could have on financial asset issuers.

In the case of corporate bonds and equities, the approach involves analyzing how the issuer's revenues are distributed across economic sectors and geographic regions. In the case of sovereign bonds, the analysis focuses on the sectoral composition of the country's Gross Value Added (GVA). This provides a clear understanding of where the issuer's revenues are generated and how they might be affected by climate-related factors.

Once the breakdown of revenues has been established, the next step is to assess how these revenues might change under different climate scenarios. This is done by examining trends in specific climate-related variables that are relevant to each sector and region. For example, if an emitter operates in a sector that is highly exposed to regulatory changes aimed at reducing carbon emissions, its revenue forecasts would reflect the potential impact of such policies. The financial impact is then calculated on the basis of these expected changes in revenue.

This methodology is based on a bottom-up approach, which analyzes each financial asset individually, identified by its International Securities Identification Number (ISIN), and performs an exhaustive analysis of the sources of income linked to the issuer. The revenues are then allocated to economic sectors and regions. The sector classification can be based on the Climate Policy Relevant Sectors (CPRS) framework. This classification is a key assumption of the model, as it links economic sectors to specific climate variables that could influence future revenue streams.

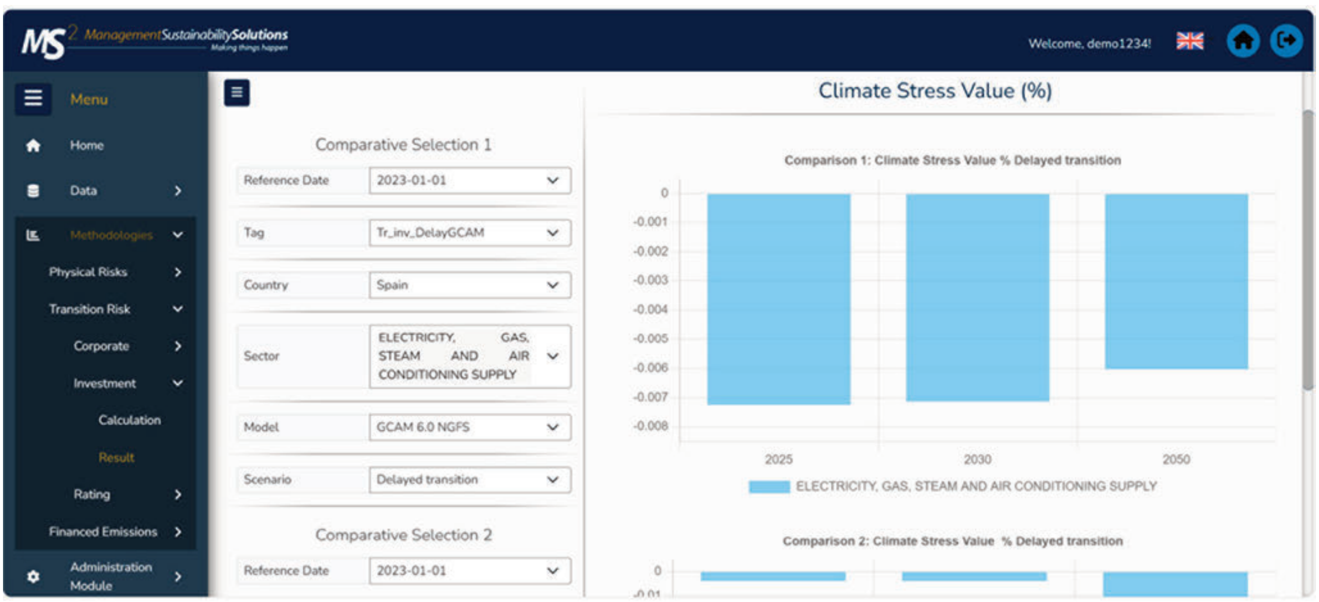
The trends observed in these climate variables - such as carbon prices, energy costs or regulatory changes - help determine how revenues could evolve under different scenarios.

To assess the potential impact of climate policy changes, each CPRS sector is associated with a relevant NGFS variable. This association implies that a correlation is assumed between the behavior of the CPRS sector and the evolution of the NGFS variable under different climate scenarios. Therefore, the positive or negative impacts of climate policies on the NGFS variable serve as an indicator of the expected effects on the corresponding sector.

For example, in the case of the fossil fuel sector (which encompasses the extraction, production, refining and distribution of fossil fuels), its performance can be assumed to be linked to the demand for primary energy produced from fossil sources. This demand is a variable that is included in the NGFS scenario projections. In general terms, precisely defining the sectors and associating them with one or more significant scenario variables is an essential step in the development of the methodology, as it allows for a more accurate assessment of the potential impacts of climate policies on the different economic sectors.

Using the evolution of the NGFS variable in the selected scenario compared to a baseline scenario (usually the "Current Policies" scenario is used as the reference baseline scenario), it is possible to derive a climate policy shock, which indicates the magnitude of the economic shock. This

Figure 21: Example of impact on net asset value in 2050 for the delayed transition scenario of a sample investment portfolio (stocks, corporate bonds, government bonds). Illustrative examples in the Management Sustainability Solutions (MS²) tool.



makes it possible to assess how the revenues of each economic sector and geographic region linked to a specific issuer could be affected and, consequently, its impact on financial results.

In order to carry out an accurate measurement exercise, it is essential to have specific data on the counterparties issuing the financial assets in the portfolio under analysis. In particular, information on counterparties' revenues, broken down by economic sector and geographic region, is particularly relevant for a granular risk assessment. Having both a detailed and consolidated view of the portfolio's main geographic and sectoral exposures is crucial for analyzing and understanding the most significant impacts on the measurement of climate risk.

Once the climate policy shock has been determined, the next step is to calculate its financial impact and understand how it affects Net Asset Value. This calculation varies depending on whether the asset is a stock or a fixed income instrument, such as corporate or government bonds.

For equities, the financial impact of climate stress can be calculated using the dividend or earnings per share based valuation model (e.g. Gordon-Shapiro). For corporate bonds, the impact is assessed by estimating how the climate policy shock affects the creditworthiness of the issuer, for the estimation of the probability of default. Once the effect on creditworthiness is determined, a climate-related spread is calculated to estimate the change in bond prices due specifically to the transition shock.

In the case of government bonds, the financial impact is applied proportionally to the coupon rate of the bond. This adjustment takes into account the expected costs and opportunities for the issuing government under the assessed climate scenario. Applying this proportional adjustment provides an estimate of how the value of the bond might be impacted in response to the climate transition.

The methodology described in this section allows for a comprehensive analysis of the impacts of climate transition risk at the level of each financial asset in an investment portfolio. This facilitates the simulation of the effect of different trajectories of possible climate transitions on the net asset value of financial instruments (see Figure 21).

Environmental risks

"To effectively manage environmental risk, financial institutions must quantify it. Financial sustainability cannot be separated from environmental sustainability, and only numbers can prove it".
Janet Yellen[57]

As environmental risks increasingly attract the attention of supervisors and economic and financial institutions, there is a pressing need for effective measurement frameworks. Management Solutions is therefore making progress in developing a methodology to measure the impact of environmental risks on financial institutions' portfolios. This section provides an overview of the current regulatory environment for risks arising from natural environmental degradation and presents the methodological basis for quantifying them in a robust manner.

Definition of risks

Risks related to nature (often referred to as natural or environmental risks), encompass the potential negative impacts resulting from the degradation of ecosystems, the loss of biodiversity and the inability of ecosystems to continue to provide natural resources at the rate required by economic agents. These risks manifest themselves in various forms, such as physical disruptions caused by water scarcity, soil degradation, deforestation, or the collapse of ecosystems essential to industries such as agriculture or manufacturing. As experts increasingly recognize the link between natural ecosystems and economic activity, the importance of managing these risks has risen significantly on the global policy agenda.

The urgency stems from the rapid loss of biodiversity, which is occurring at a rate unprecedented in human history, as evidenced by the fact that, according to the Stockholm Resilience Center[58], six of the nine planetary boundaries of the Earth's living systems have already been breached (see Figure 22).

In addition to these physical impacts, companies also face transition risks. These include social pressures, regulatory changes and market transformations as stakeholders from governments to consumers demand greater transparency and accountability in the management of natural resources. The growing recognition of systemic risks, affecting entire economies through interconnected supply chains, puts biodiversity loss and nature degradation at the forefront of global policy agendas.

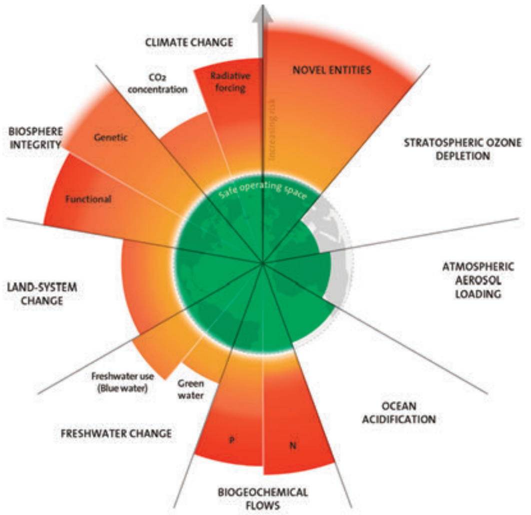
Governments are also stepping in, developing and implementing policies to prevent and mitigate these risks, while companies face the challenge of adapting to growing social awareness and regulatory obligations around natural resource management.

One of the main frameworks for addressing nature-related risks is the Taskforce on Nature-related Financial Disclosures Framework[59]. This initiative is led by experts from the financial, business and scientific sectors, as well as non-governmental organizations, with the support of international partners such as the United Nations and the World Economic Forum. Its mission is to create a framework to help organizations manage and disclose the financial risks related to nature, such as biodiversity loss and ecosystem degradation. The framework is based on four key pillars: governance, strategy, risk and impact management, and metrics and targets. This closely aligns with the structure established by the TCFD and reflects the growing intersection of climate and natural risk information.

The TNFD also distinguishes between acute and chronic natural hazards. Acute risks arise from immediate natural disasters - such as water shortages, biodiversity loss or ecosystem degradation - which can disrupt supply chains, damage infrastructure and cause significant economic losses. Chronic risks, on the other hand, stem from long-term environmental degradation - such as soil erosion or declining water quality - which can reduce agricultural productivity and undermine the long-term sustainability of natural resource-dependent industries.

[57] Janet Louise Yellen (2021), U.S. Secretary of the Treasury.
[58] Stockholm Resilience Center (2023).
[59] https://tnfd.global/.

Figure 22: Six of the nine planetary boundaries have been crossed.



Source: Richardson et al., 2023

The regulatory landscape for nature-related risks is evolving rapidly, driven largely by EU regulations such as the Corporate Sustainability Reporting Directive (CSRD)[60] and the European Sustainability Reporting Standards (ESRS)[61]. These frameworks impose extensive reporting requirements on companies, requiring transparency on environmental, social and governance (ESG) factors.

In particular, the Directive requires companies to publish detailed information on their nature-related risks and impacts. This includes the concept of dual materiality, which assesses not only the financial impact of natural risks on the company, but also the company's own impact on nature. Reporting under the CSRD covers a wide range of topics, including greenhouse gas reduction targets, biodiversity conservation, pollution mitigation and water resource management. The CSRD and ESRS establish a transition period for companies to fully comply with these disclosure standards, with adoption deadlines varying depending on the size and type of company.

These regulations aim to standardize and improve corporate transparency on nature-related risks and ensure that stakeholders, including investors and consumers, are well informed about how companies manage their environmental impacts. This change is crucial as financial institutions, such as banks and asset managers, increasingly scrutinize the nature-related risks included in their portfolios.

European banks, in particular, have been proactive in adapting their operations to these regulatory changes. Many have adopted tools such as the Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE)[62] framework and the Aqueduct Water Risk Atlas[64] to assess nature-related risks in their business models. These tools help financial institutions map their dependence on natural resources and assess risks associated with biodiversity loss and water stress. At present, this framework does not fully integrate a forward-looking vision, which is one of the drawbacks of this approach. However, the lack of nature-related scenarios is a limitation that, once addressed, will make it possible to incorporate such a prospective approach.

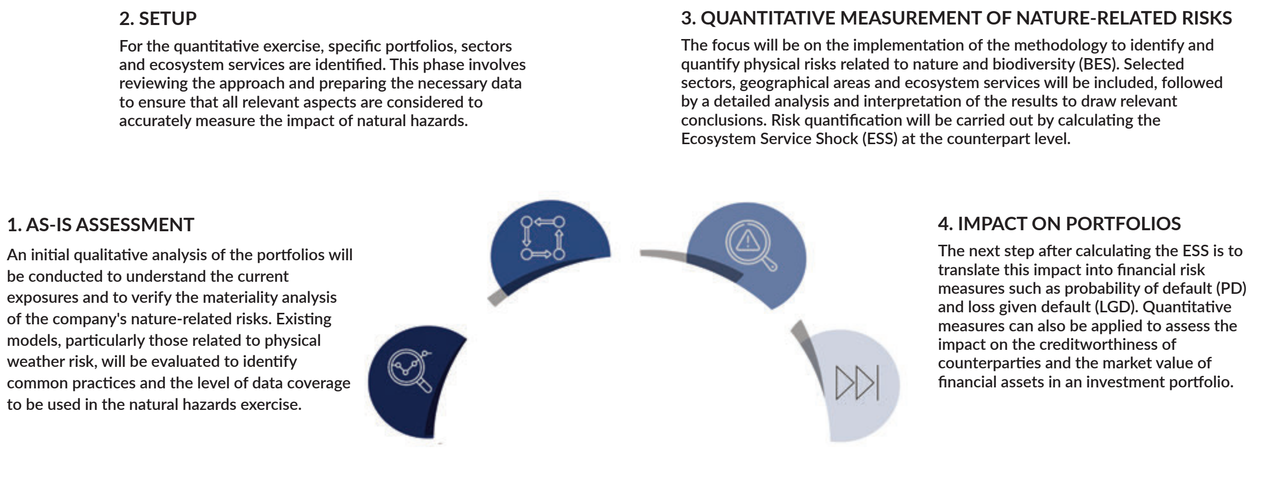
TNFD also recommends sector- and nature-specific guidance to help companies navigate the complex landscape of nature-related risks. As biodiversity becomes an integral part of financial risk assessment, TNFD's LEAP (Locate, Assess, Assess, Assess, Prepare) methodology provides companies with a systematic approach to assess how nature-related risks affect their operations. Financial institutions, particularly in the EU, are now required to integrate these assessments into their governance and risk management structures.

Looking ahead, the integration of nature-related risks into corporate governance is set to become even more stringent as regulators increasingly emphasize the need for nature-friendly business practices. Financial institutions that fail to take these risks into account may face significant legal, solvency and reputational consequences as global regulations tighten and stakeholders demand greater accountability.

In conclusion, natural risks represent a growing challenge for both companies and the financial sector, as biodiversity loss and environmental degradation intensify. With the emergence of frameworks such as the TNFD and regulatory developments in certain regions, especially the European Union, the regulatory landscape is becoming clearer, laying

[60] Directive on corporate sustainability reporting.
[61] ESRS: European Sustainability Reporting Standards.
[62] ENCORE (2023).

Figure 23: Proposed multi-phase approach to measuring nature-related risks.



the groundwork for more comprehensive and standardized disclosure of nature-related information. In this context, companies must not only recognize their dependence on natural ecosystems, but also proactively manage the risks associated with their degradation to ensure long-term sustainability.

Measuring the impact on the asset portfolio: investment and loan portfolio

The approach proposed in this section for measuring the impact of nature-related risks on asset portfolios - in particular investment and credit portfolios - is based on integrating biodiversity and ecosystem services (BES) into financial risk assessment, and overcoming challenges such as data availability and the current development of scenario analysis for these risks.

This approach, structured in several phases (see Figure 23), focuses on assessing the material impacts of biodiversity and ecosystem services on economic and financial activities. Natural risks, especially physical risks such as water scarcity, deforestation and land degradation, are considered to be immediate threats and highly relevant to portfolio stability.

The objective is to establish a quantitative framework for measuring the impact of these physical risks on the credit risk of a corporate loan portfolio or on the market risk in an investment portfolio, with a focus on short-term risk exposure. This is because forward-looking scenario analysis on nature-related risks is still in its infancy. A 2023 Network for Greening the Financial System (NGFS) report[64] highlights the importance of assessing economic and financial risks linked to nature. While comprehensive, forward-looking scenarios for these risks do not yet exist, the NGFS emphasizes that qualitative and static assessments can provide valuable insight into the current exposure of portfolios to natural risks.

The steps in the proposed approach to quantitatively measure a financial institution's exposure to physical natural risk are described below.

1. The first step is to assess the current state of the portfolio and its exposure to natural risks. To this end, a preliminary qualitative analysis is carried out to identify the sectors and assets with the greatest exposure, taking into account the critical ecosystem services for each sector. In addition, the materiality of these risks is assessed by analyzing the extent to which biodiversity loss and ecosystem degradation affect key sectors of the portfolio, such as agriculture, forestry and water-intensive industries. This phase also includes an assessment of any physical climate risk models already in use at the company, to identify possible methodological synergies and explore the availability of relevant data.

2. The second phase, called "set-up", consists of refining the approach and collecting the necessary data to measure the exposure to natural hazards as accurately as possible, based on the findings of the first phase. This phase involves a detailed identification of counterparty and sector information, including specific data on the activities and geographic locations of clients and their production sites, so that location-specific natural risks are captured. During this stage, a preliminary data model is also established to identify gaps and possible strategies to ensure adequate coverage of relevant information.

[64]NGFS (2023).

3. The core of the approach is the third step: quantifying the physical risks related to nature and their impact on the portfolio. It should be noted that these risks are defined as the threat of loss of natural capital, which includes the decline of renewable and non-renewable natural resources, the extinction of animal and plant species, and the deterioration of the interactions between these elements. These risks are generally associated with the loss of biodiversity and ecosystem services (BES).

   In this process, a comprehensive analysis of the sectoral exposure to BES is performed, taking advantage of the analysis performed in the first step and focusing on those BES that represent a greater risk materiality for the entity. This allows quantification of the ecosystem services most vulnerable to natural hazards. The assessment can be based on tools such as the ENCORE methodology or WWF's "Scape Risks" map[65], which help prioritize the ecosystem services and sectors most relevant to the portfolio. Risk quantification is done by calculating the Ecosystem Service Shock (ESS), which combines hazard probability, sector exposure and geographic area vulnerability to estimate the financial impact of these risks in specific sectors and geographic areas. For example, risks such as water scarcity or deforestation are assigned a score based on their potential impact on specific sectors. The ESS is calculated for each sector and geographic region of each counterparty, assessing how ecosystem services, such as water availability or pollination services, affect the counterparties in the portfolio. The ESS quantification methodology is based on several key components. First, hazard probability is calculated, using historical data such as the World Bank's Development Indicators database[66] and other sources[67] that provide estimates of the likelihood of certain natural hazards affecting specific sectors. The next step is to analyze sectoral exposure, or the degree to which a sector depends on particular ecosystem services; for example, sectors that rely heavily on water or fertile soils are more vulnerable to events such as drought or soil erosion. Finally, the vulnerability of each country is considered, taking into account specific factors such as economic resilience and environmental policies. Countries with weaker environmental protection or a high dependence on natural capital are considered more vulnerable. At the end of this process, the ESS provides a quantitative estimate of potential losses from ecosystem degradation or biodiversity loss, giving a detailed picture of the impact of natural hazards on portfolio stability.

4. Once the ESS has been calculated, the next step is to translate this impact into traditional financial risk parameters such as probability of default (PD) and loss given default (LGD). For this purpose, structural valuation

[65]Biodiversity RiskFilter_Methodology, WWF Risk Filter, WWF.
[66]World Bank - World Development Indicators.
[67]NGFS (2023).

models are used to estimate PD and LGD. Similarly, it is possible to extend the analysis using quantitative methods to assess the impact on the creditworthiness of counterparties and, in addition, to estimate the impact on the market value of financial assets in an investment portfolio.

The approach described allows a first estimate of the exposure to natural risk to be obtained through a quantitative and granular analysis. From these results, aggregate visualizations and heat maps can be generated to facilitate more precise materiality exercises and, on the other, provide economic assessments of the impact on the entity. By way of illustration, we present the results obtained for a fictitious portfolio of corporate loans (see Figure 24).

The values shown are obtained by consolidating the ESS of the counterparties, determined by individually assessing each counterparty's natural risk exposure, in the main country/sector groups.

These models provide general estimates of how nature-related risks affect solvency and potential losses. However, they do not take into account counterparty-specific mitigation strategies and resilience factors, which would require more detailed data and complex analysis.

The methodology described has limitations, such as the lack of forward-looking scenarios comparable to those for climate risks, and in 2024 there are still no widely accepted models for these risks. It therefore focuses on short-term assessments using historical data and static analysis. However, it is possible to integrate this methodology for certain specific natural hazards (some BES) using IPCC scenario projections. This approach represents a key area for the future development of quantitative measurement methodologies.

In addition, the limited availability of data on ecosystem services, sectoral dependencies and geographic exposure implies resorting to approximations that may affect accuracy. The lack of detailed geolocation of assets also makes it difficult to adequately capture local risks.

Despite these limitations, the methodology provides a structured approach to measuring the impact of biodiversity loss and ecosystem degradation on investment and credit portfolios. By integrating ecosystem services data into traditional risk models, financial institutions can take a first step toward quantifying their exposure to these emerging risks. This leads to a more robust future assessment that not only helps meet regulatory requirements, but also strengthens internal risk management and facilitates better-informed decisions to mitigate these impacts.

Figure 24: Example of aggregation of results for an illustrative portfolio, showing the portfolio's ESS broken down by country and sector.

Sector/Country	United States	France	Germany	China	United Kingdom	Italy	Spain	Switzerland	Netherlands	India	Rest of the World
CONSUMER DISCRETIONARY	-0.022%	-0.014%	-0.014%	-0.008%	-0.003%	-0.001%	-0.003%	-0.001%	-0.001%	0.000%	-0.022%
CONSUMER STAPLES	-0.049%	-0.017%	-0.023%	-0.012%	-0.003%	-0.004%	-0.002%	-0.002%	-0.001%	-0.002%	-0.030%
ENERGY	-0.013%	-0.006%	-0.001%	-0.006%	-0.004%	-0.006%	-0.002%	-0.001%	-0.004%	-0.005%	-0.025%
FINANCIALS	-0.019%	-0.012%	-0.005%	-0.005%	-0.008%	-0.008%	-0.008%	-0.004%	-0.005%	-0.009%	-0.033%
HEALTH CARE	-0.119%	-0.064%	-0.038%	-0.053%	-0.022%	-0.027%	-0.004%	-0.016%	-0.005%	-0.009%	-0.097%
INDUSTRIALS	-0.028%	-0.008%	-0.011%	-0.007%	-0.004%	-0.001%		-0.006%	-0.003%	-0.003%	-0.043%
INFORMATION TECHNOLOGY	-0.049%	-0.012%	-0.002%	-0.004%	-0.020%	-0.003%		-0.004%	-0.008%		-0.028%
MATERIALS	-0.063%	-0.003%	-0.011%	-0.004%	-0.003%	-0.001%	-0.002%	-0.006%	-0.001%	0.000%	-0.014%
REAL ESTATE	-0.065%	-0.027%	-0.013%	-0.009%	-0.024%	-0.007%	-0.014%	-0.004%	-0.008%	-0.002%	-0.049%
TELECOMMUNICATION SERVICES	-0.023%	-0.025%	-0.007%	-0.009%	-0.009%	-0.024%	-0.009%	-0.004%	-0.006%	-0.005%	-0.052%
UTILITIES	-0.085%	-0.016%	-0.008%	-0.014%	-0.005%	-0.005%		-0.002%	-0.003%	-0.001%	-0.027%

Illustrative example

The purpose of this exercise is to demonstrate the application of the methodology presented in chapter "Measuring the impact of financial assets on the investment portfolio" of this white paper. A specific case is used to analyze the impact of transition risk on a corporate bond portfolio, illustrating how this methodology can be applied in a realistic context to assess the impact of climate change on the risk of an investment portfolio.

The analysis is developed based on a fictitious portfolio of 8,414 corporate bonds issued by companies from various economic sectors, including energy, financial activities, manufacturing, and utilities (e.g., electricity, water, gas). These issuers operate in multiple countries, with a diversified geographic distribution across regions with varying levels of regulatory pressure and commitment to climate change.

Sectoral and geographic diversity is detailed in Figures 25 and 26, which show:

- Economic sectors: issuers are classified according to NACE codes[68], with a higher concentration in financial activities, energy, industrial and supply services.
- Geographical distribution: The main regions are Europe, with a significant concentration in France, as well as the United States and China.

In addition, the impact measurement methodology takes into account the sectoral and geographic composition of the issuing counterparties' revenues. Where detailed information is not available, it is assumed that revenues are fully concentrated in the country and primary sector reported by the issuer.

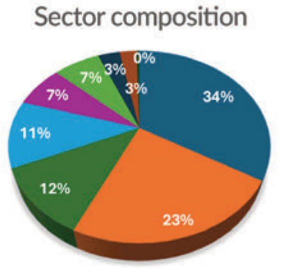
This diversity allows us to capture the complexity inherent in transition risk analysis, highlighting how changes in policies, regulations, technology and markets can significantly impact companies that rely heavily on fossil fuels.

The exercise simulates a short, medium and long term analysis defined for the years 2025, 2030 and 2050 respectively under a Delayed Transition scenario; see chapter 'Climate risks' for more details on scenarios. This scenario assumes a continuation of fossil fuel use without significant changes until 2030, followed by a strict implementation of climate policies after that year. These policies include an initial regional fragmentation of carbon prices, converging to a global price by 2070, with the goal of limiting global temperature increase to less than 2°C by 2100. This context creates a disorderly transition and poses greater long-term economic impacts and risks, especially for energy-intensive and carbon-dependent sectors.

The fictitious portfolio has a total value of approximately 22 billion euros and is intended to replicate a real investment portfolio of a financial institution at the end of 2023. The data

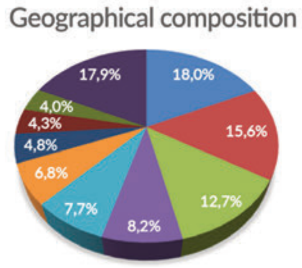
[68] Statistical classification of economic activities: https://eur-lex.europa.eu/ES/legal-content/summary/statistical-classification-of-economic-activities-nace-revision-2-1.html

Figure 25: Classification of the sample portfolio by macroeconomic sector.



Sector	Weight in the portfolio
FINANCIALS	33.6%
ENERGY	23.3%
INDUSTRIALS	11.5%
UTILITIES	11.3%
CONSUMER STAPLES	7.2%
COMMUNICATION SERVICES	6.9%
OTHER	3.6%
HEALTH CARE	2.5%

Figure 26: Sample portfolio ranking by main issuer country.



Country	Weight in the portfolio
France	18.0%
USA	15.6%
China	12.7%
Italy	8.2%
Germany	7.7%
United Kingdom	6.8%
Switzerland	4.8%
Spain	4.3%
Netherlands	4.0%
Rest of World	17.9%

includes market prices and interest rates as of December 31, 2023, providing a realistic framework to contextualize the analysis in the economic conditions of that period.

In terms of financial instruments, the portfolio includes:

- Coupon bonds and zero-coupon bonds.
- variety of coupon payment frequencies, including annual, semi-annual and quarterly.
- A smaller, insignificant portion of the portfolio consists of callable and perpetual bonds, which are modeled as plain vanilla bonds.

The calculation follows the methodology described in section 'Measuring the impact on the investment portfolio of financial assets', starting with the assignment of each economic sector in the portfolio to a CPRS (Climate Policy Relevant Sector). These sectors are assigned a key variable based on the NGFS scenarios. These variables allow the estimation of a shock for each sector and geography at the time horizons of the analysis, comparing the climate transition scenario (delayed transition) with the baseline scenario (current policies).

For example, Figure 27 shows the projected evolution and impact of the shock for the variable representing projections of primary energy production from fossil fuels (EJ/year). This variable is linked to the CPRS sector "Energy - Fossil" and is used to estimate the impact on the activities of the fossil fuel energy production sectors. This approach is extended to all sectors and geographies in the portfolio and applied to each issuing counterparty.

Once the sectoral and geographical analysis is complete, the specific impact of the climate shock on each issuer counterparty is calculated. A structural valuation model is used to assess the impact of this shock on the issuer's creditworthiness. Based on this analysis, the bond is repriced to calculate a weather spread that reflects the change in the bond price due solely to the transition shock.

This process is repeated for all the bonds in the portfolio and for the three time horizons chosen (2025, 2030 and 2050), making it possible to quantify the financial impact

[69] According to the scenario narrative, there are no differences between the two scenarios until 2030, which means that the impact on the sector is zero during this period. From 2030, the impact starts to increase, reaching an estimated shock of 62% in 2050. The data were obtained using the Management Sustainability Solutions (MS^2) tool, using scenarios provided by the NGFS.

Figure 27: Climate policy impact (%) on the CPRS Energy - Fossil sector in 2050, comparing the delayed transition scenario (green) with the current policy scenario (blue) [69].

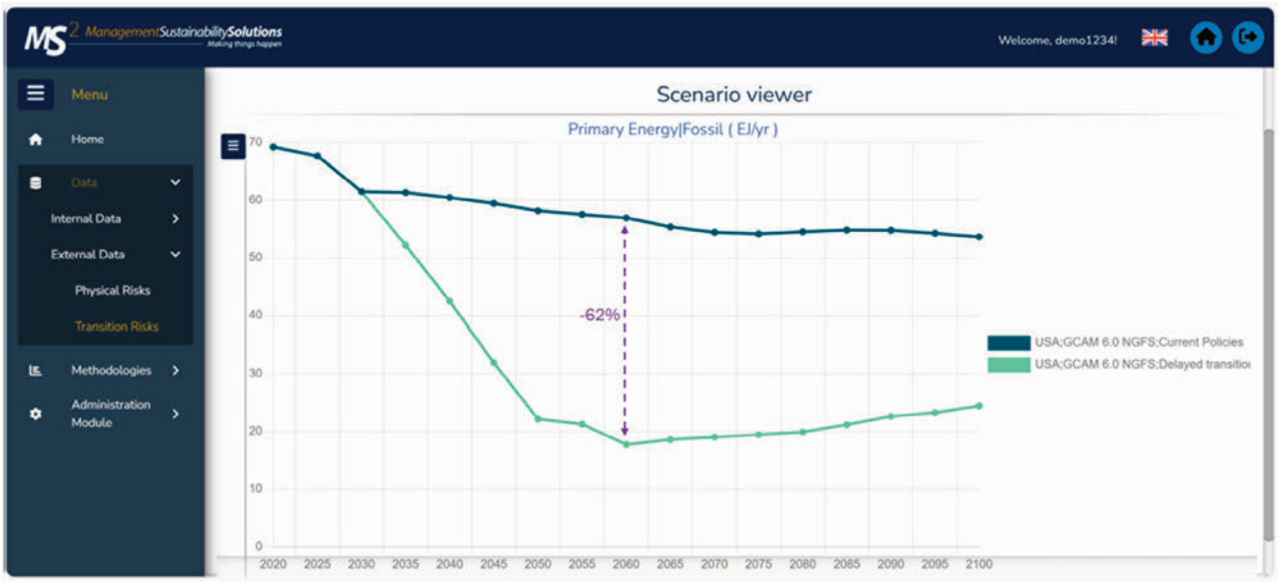
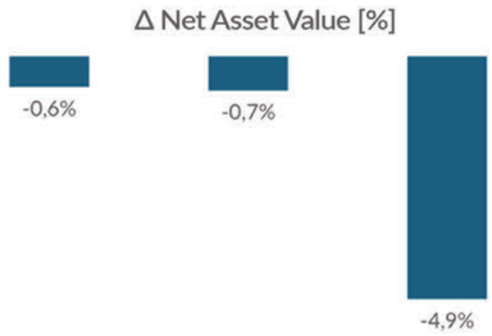


Figure 28: Projected impact on the Net Asset Value (%) of the corporate bond portfolio under the delayed transition scenario, by time horizon (2025, 2030 and 2050). The values reflect the estimated losses due to transitional climate stress relative to the current policy baseline.



Year	Δ Net Asset Value [%]	Δ Net Asset Value [€]
2025	-0.6%	- 138,914,962 €
2030	-0.7%	- 155,061,394 €
2050	-4.9%	-1,095,737,591 €

(loss or increase in NAV) of the climate transition risk under the chosen scenario.

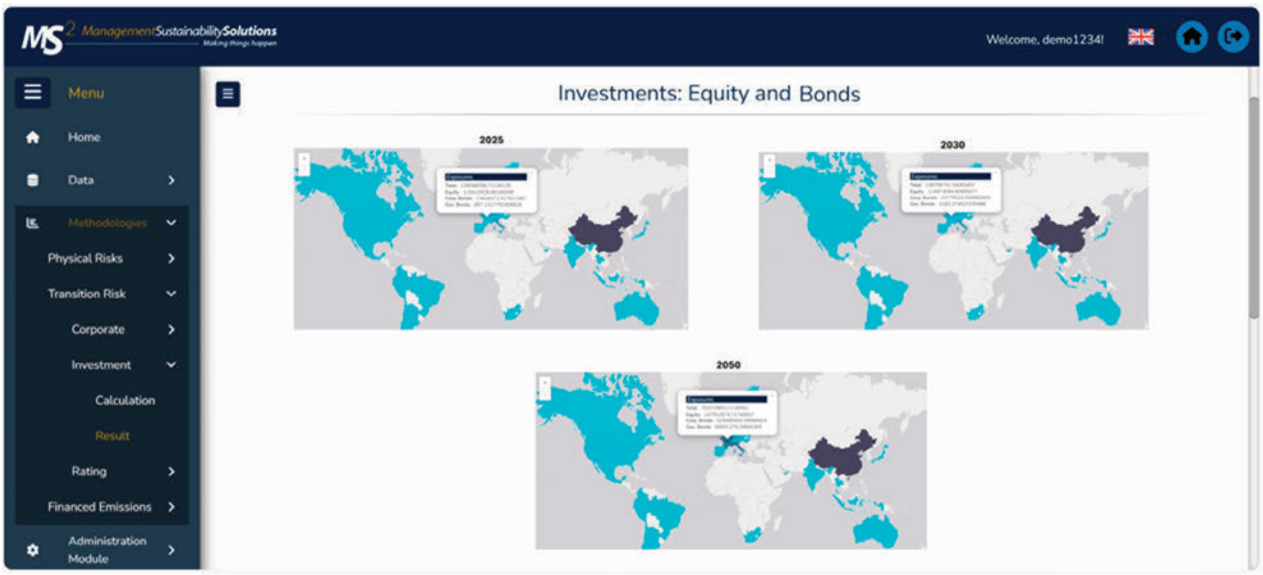
As shown in Figure 28, the NAV of the analyzed corporate bond portfolio experiences a loss in line with the trend predicted in the delayed transition scenario. This scenario predicts a more significant climate transition risk in the long term, with an estimated loss of 4.9% in 2050, while the predicted impacts for 2025 and 2030 are significantly lower, reaching only 0.6% and 0.7% respectively. This is because in this scenario no significant changes in decarbonization policies are expected before 2030. As a result, the economic sectors do not show any significant impacts until this year.

From 2030 and during the 2030-2050 period, a disorderly transition is projected due to the need to implement stricter policies to meet climate objectives. This process will have a negative impact on certain sectors of the economy, while other sectors will see opportunities arising from the environmental transition. These effects, whether positive or negative, will vary according to the specific characteristics of the issuing counterparties and will have a differentiated impact on the value of the portfolio's assets.

The time trend described above is also observed in Figure 29, which shows the evolution of risk over the three years

[70] The intensity of the risk varies according to the geographic exposure of the portfolio, influenced by the specific composition of the portfolio and the different ambitions and pace of implementation of climate policies in each region within the scenario used. The image was created using the Management Sustainability Solutions (MS^2).

Figure 29: Evolution of climate transition risk represented by a geographic map showing the distribution of risk over the three years analyzed [70].



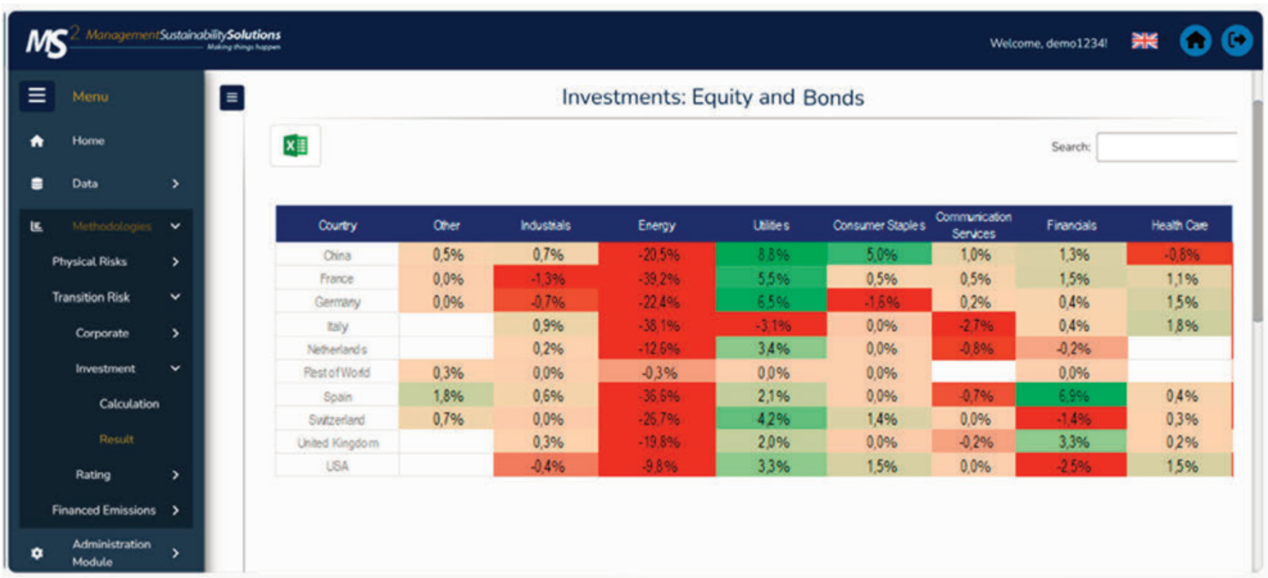
analysed on a geographical map. The figure shows a higher long-term risk, albeit at different levels depending on the geographical exposure of the portfolio. These differences are due both to the specific composition of the portfolio and the relative weight of the exposures in each region, as well as to the different ambitions and expected speed of adoption of climate policies in the scenario considered.

Finally, a more detailed analysis by country and major macro sector of the issuing counterparties is presented in Figure 30, which provides a granular view of the estimated impacts in the projection year 2050.

Figure 30 shows significant differences in projected impacts across countries, reflecting different expectations of future climate policies in each region. These differences are even more pronounced at the sectoral level. For example, the "Energy" sector in this portfolio consists mainly of bonds issued by companies linked to the fossil fuel sector, which faces a significant phase-out of fossil fuels in the scenario analyzed for 2050.

On the other hand, other sectors, such as the "Utilities" sector, have a potentially positive impact. This sector includes counterparties active in electricity generation, some of which use renewable source. These companies could benefit from the climate transition thanks to the projected increase in energy demand, driven by the electrification of the economy that will accompany the gradual phase-out of fossil fuels. For their part, sectors such as the "Financial" sector show a mixed behavior, since they can benefit from the opportunities arising from financing the transition, but they can also be affected in certain cases

Figure 30: Breakdown of the projected impact on the Net Asset Value of the corporate bond portfolio under the delayed transition scenario, presented according to the geographic and sectoral distribution of the issuing counterparties. The values shown are weighted percentages based on the portfolio value of each country - macro sector combination, highlighting the differences in the expected impacts according to the characteristics of each region and economic sector.



Country	Other	Industrials	Energy	Utilities	Consumer Staples	Communication Services	Financials	Health Care
China	0,5%	0,7%	-20,5%	8,8%	5,0%	1,0%	1,3%	-0,8%
France	0,0%	-1,3%	-39,2%	5,5%	0,5%	0,5%	1,5%	1,1%
Germany	0,0%	-0,7%	-22,4%	6,5%	-1,6%	0,2%	0,4%	1,5%
Italy		0,9%	-38,1%	-3,1%	0,0%	-2,7%	0,4%	1,8%
Netherlands		0,2%	-12,6%	3,4%	0,0%	-0,8%	-0,2%	
Rest of World	0,3%	0,0%	-0,3%	0,0%	0,0%		0,0%	
Spain	1,8%	0,6%	-36,6%	2,1%	0,0%	-0,7%	6,9%	0,4%
Switzerland	0,7%	0,0%	-26,7%	4,2%	1,4%	0,0%	-1,4%	0,3%
United Kingdom		0,3%	-19,8%	2,0%	0,0%	-0,2%	3,3%	0,2%
USA		-0,4%	-9,8%	3,3%	1,5%	0,0%	-2,5%	1,5%

(for example, if they have holdings in industrial groups with high emissions). The industrial and productive sectors also show different impacts depending on the type of issuing counterparty.

It should be noted that the results show an aggregate value that takes into account a large number of bonds and counterparties, each with specific characteristics in terms of geographical location, sectors of activity, financial structure and resilience to climate transition risks. The methodology used allows each bond and counterparty to be evaluated individually, starting with a granular analysis that ensures a high level of detail.

However, by consolidating the results into an aggregated view, although some of the specificity of each asset is lost, an overall perspective is obtained that facilitates the identification of the materiality of the risks and the main drivers of the projected impact. This approach, which combines granularity and aggregation, provides a comprehensive view of the climate risks associated with the portfolio.

This practical exercise has demonstrated how the methodology described in section "Measuring the impact on the investment portfolio of financial assets" can effectively assess the impact of transition risk in a corporate bond portfolio. The results highlight that sectors such as energy, particularly those linked to fossil fuels, face significant negative impacts under decarbonization scenarios, while other sectors may benefit from the opportunities associated with the electrification of the economy and increased demand for renewable energy. The granularity of the analysis was key to identifying specific counterparties with increased vulnerability, underscoring the importance of a detailed approach to risk management.

The integration of quantitative analysis such as this is essential for incorporating climate transition risks into strategic portfolio management. This approach not only facilitates regulatory compliance, but also strengthens the financial resilience of institutions in the face of climate challenges. It also makes it possible to anticipate potential losses and adjust exposures according to projected scenarios.

Conclusions

"Companies that anticipate and manage climate risks will be rewarded; those that do not will cease to exist".
Mark Carney[71]

The analysis developed throughout this publication highlights the strategic importance of addressing climate and environmental risks as a central element in the financial management of institutions. The findings show that these risks pose significant challenges to the stability of the financial system, particularly in the context of increasing climate uncertainty and regulatory pressures. The ability to quantify the impact of extreme events, as well as regulatory and market changes resulting from the transition to a low-carbon economy, has become an imperative for financial institutions.

The methodologies and models available today are important and accessible tools for addressing complex climate and environmental challenges, enabling effective integration of these risks into financial analysis and supporting strategic decision-making in a changing environment. The implementation of these methodologies, coupled with technological advances such as the tools described in this paper, provide a solid foundation for overcoming current barriers related to a lack of granular data and consistent metrics, thereby enabling more accurate and useful analysis.

In this context, institutions need to strengthen their internal governance to ensure that climate and environmental risks are managed as a strategic priority. Investing in technology, such as specialized tools capable of processing and analyzing large volumes of climate data, will enable these factors to be more effectively integrated into decision-making. In addition, collaboration between financial institutions, regulators and technology companies is essential to overcome current limitations in data quality and availability.

The next steps require a strong commitment from the sector to align its practices with international regulatory standards and to develop stress tests that incorporate long-term climate scenarios. The progressive integration of advanced metrics and measurement methodologies aligned with regulatory requirements will help strengthen institutions' ability to anticipate climate and environmental impacts.

In short, the financial sector is at a critical juncture. Advancing the management of climate and environmental risks will not only protect their balance sheets and strengthen their resilience, but will also position institutions as key players in the transition to a more sustainable future, generating positive impacts for the economy, society and the environment.

[71] Mark Joseph Carney (2015), former Governor of the Bank of England and Chairman of the Financial Stability Board.

Glossary

Climate risk. The likelihood that climate change-related phenomena (such as extreme weather events, temperature increases, changes in precipitation patterns, and sea level rise) will have adverse impacts on economic, social, and environmental systems.

CSRD. The Corporate Sustainability Reporting Directive is a European Union directive adopted in 2022, which aims to improve and expand the sustainability information that companies must disclose. This regulation requires European companies to provide detailed and standardized information on their environmental, social and governance (ESG) impacts.

Ecosystem services. Benefits that humans obtain from natural ecosystems. These services include a variety of functions essential to human well-being and the economy.

ESRS. The European Sustainability Reporting Standards are a set of standards developed under the guidance of the European Union as part of the CSRD. Their purpose is to define the specific information requirements that companies must disclose in their sustainability reports, covering environmental, social and governance (ESG) issues.

ESS. Ecosystem Service Shock refers to a sudden interruption or significant degradation of the services that ecosystems provide, which are essential for human well-being and economic functioning. These shocks can be triggered by extreme natural events or by human activities that degrade or destroy key ecosystems, affecting their ability to provide services on an ongoing basis.

IPCC. The Intergovernmental Panel on Climate Change is a United Nations agency that assesses the science related to climate change. Its mission is to provide the world's governments with clear and up-to-date scientific assessments of climate change, its impacts, future risks and options for mitigation and adaptation.

ISSB. The International Sustainability Standards Board is a body established to develop global standards for sustainability disclosure. Its mission is to create a set of sustainability standards that complement existing financial standards and help companies disclose their environmental, social and governance (ESG) impacts in a clear, consistent and comparable manner.

Natural risk. Risk associated with financial impacts derived from the degradation of nature and the loss of biodiversity.

NGFS. Network for Greening the Financial System is a global network of central banks and financial supervisors that was founded in 2017 to promote sustainable financial practices and to help mitigate climate and environmental risks affecting the financial system.

Physical risk. Refers to the direct and material impacts that climate change can have on assets, operations and communities.

RECs. Renewable Energy Certificates are market-based instruments that represent ownership of a megawatt-hour (MWh) of electricity generated from renewable energy sources, such as wind, solar, geothermal, hydroelectric or biomass. RECs are used to track and verify renewable electricity in the electricity system and allow companies and institutions to claim green power usage, even when their direct power supply comes from mixed sources.

TCFD. Task Force on Climate-related Financial Disclosures working group created to develop a disclosure framework to help companies report on climate-related financial risks and opportunities.

TNFD. Taskforce on Nature-related Financial Disclosures is a global initiative launched in 2021 that aims to develop a disclosure framework for companies and financial institutions to report on their nature-related risks and dependencies. Inspired by the TCFD, the TNFD seeks to facilitate the integration of broader environmental factors, in addition to climate change, into financial decisions.

Transition risk. Risk associated with economic, regulatory, technological and market changes that arise in the process of transition to a low-carbon economy. Includes the financial and operational impact that companies and institutions may suffer as a result of decarbonization policies, technological innovations or changes in consumption preferences.

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