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.

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[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

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[43] The number associated with each RCP represents the level of radiative forcing in the year 2100, expressed in watts per square meter (W/m²), 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.

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[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			

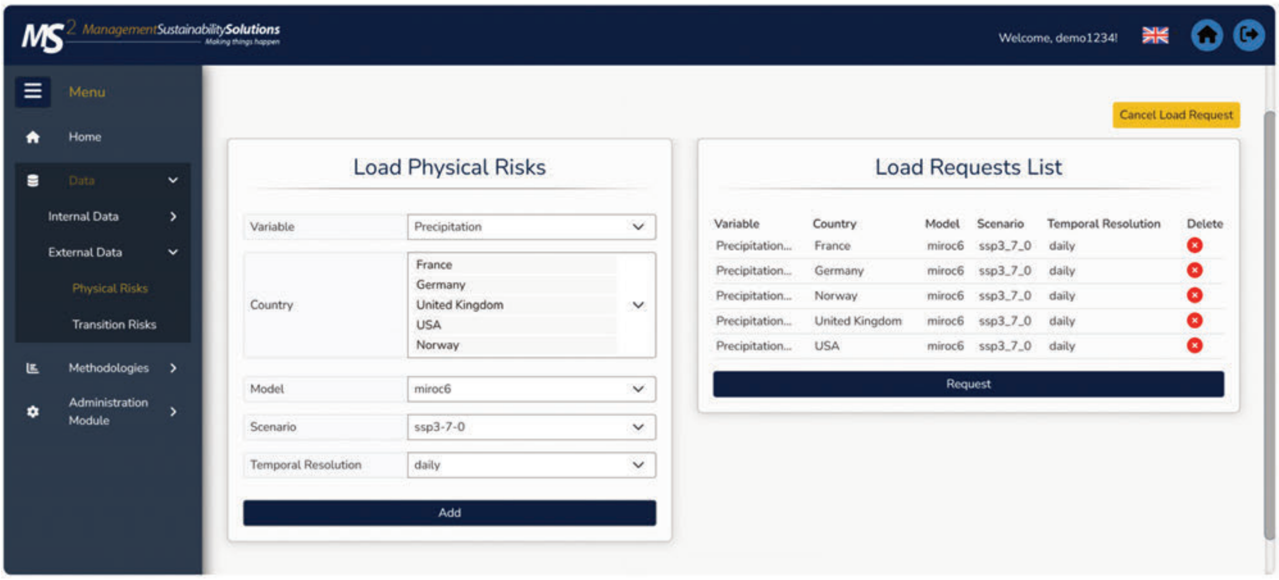
materialize, taking into account one or more physical variables. This allows the physical risk event (hazard) to be managed as a dichotomous variable (see some illustrative examples of thresholds in Figure 6).

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 (MS²). 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. MS² 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).

Figure 8: Example of loading physical scenarios in the MS² tool.



Load Physical Risks

Variable: Precipitation
Country: France, Germany, United Kingdom, USA, Norway
Model: miroc6
Scenario: ssp3-7-0
Temporal Resolution: daily

Load Requests List

Variable	Country	Model	Scenario	Temporal Resolution	Delete
Precipitation...	France	miroc6	ssp3_7_0	daily	✕
Precipitation...	Germany	miroc6	ssp3_7_0	daily	✕
Precipitation...	Norway	miroc6	ssp3_7_0	daily	✕
Precipitation...	United Kingdom	miroc6	ssp3_7_0	daily	✕
Precipitation...	USA	miroc6	ssp3_7_0	daily	✕

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[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.

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).

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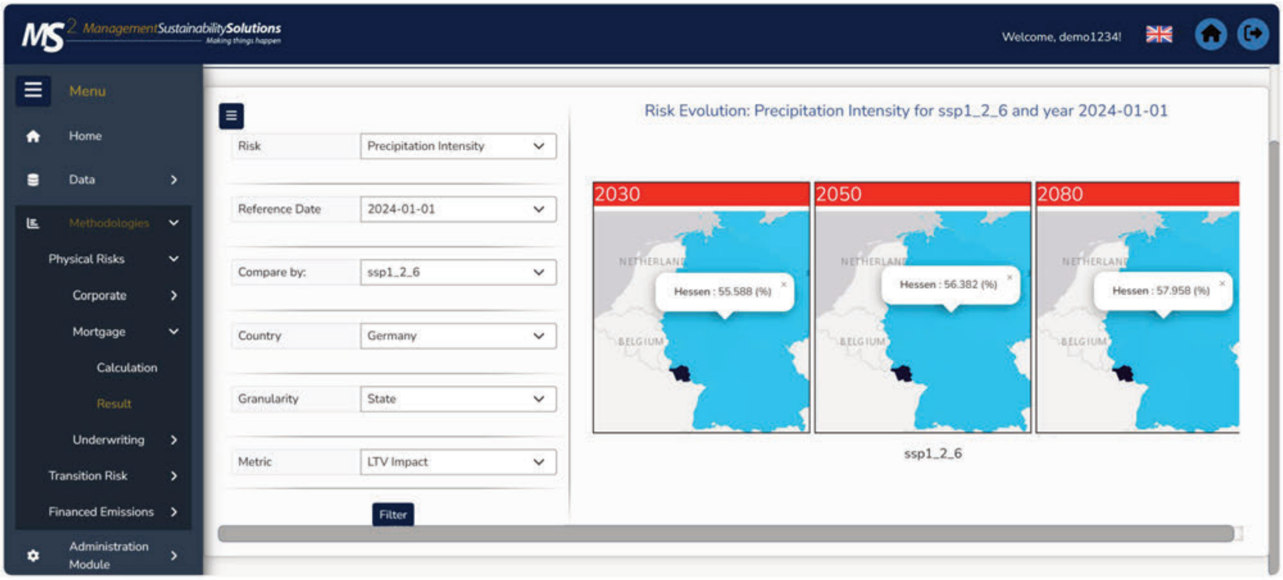
[48] UNEP-FI, U. N. (2024).

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 (MS²) tool.



Risk: Precipitation Intensity

Reference Date: 2024-01-01

Compare by: ssp1_2_6

Country: Germany

Granularity: State

Metric: LTV Impact

Risk Evolution: Precipitation Intensity for ssp1_2_6 and year 2024-01-01

Hessen : 55.588 (%)

Hessen : 56.382 (%)

Hessen : 57.958 (%)

ssp1_2_6

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.

Metric: PD & LGD

Reference Date: 2025-07-01

Risk: Precipitation Intensity

Compare by: ssp5_8_5

Sector:
ELECTRICITY, GAS, STEAM AND AIR CONDITIONING SUPPLY
REAL ESTATE ACTIVITIES
AGRICULTURE, FORESTRY AND FISHING
MINING AND QUARRYING

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

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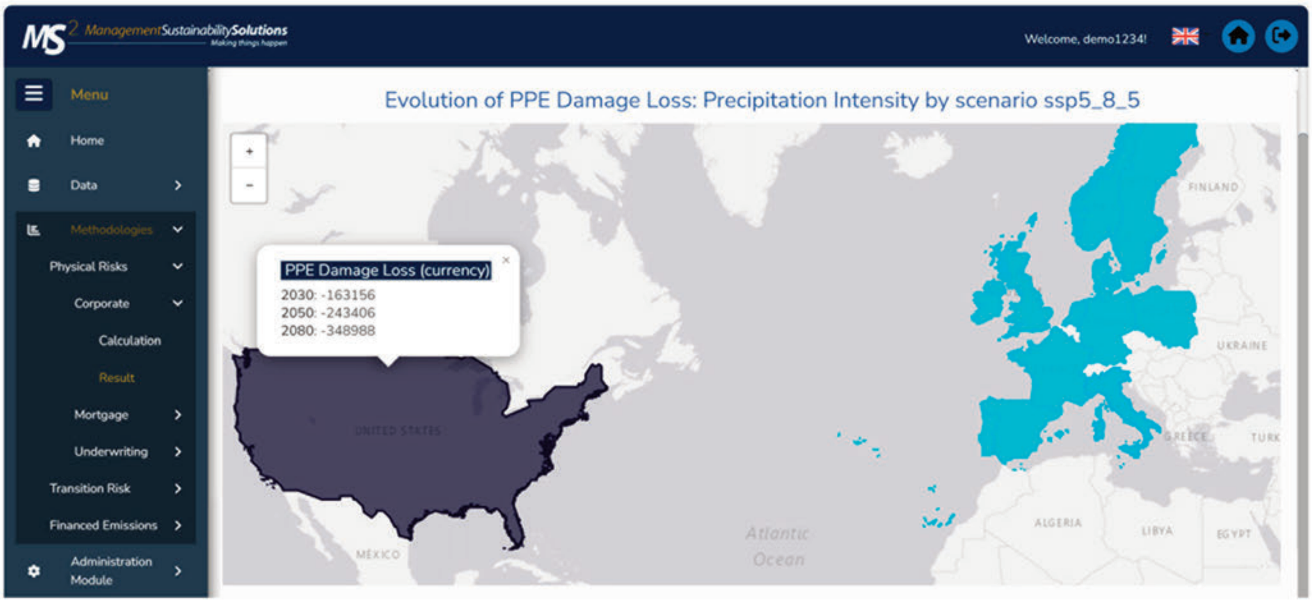
[49] A database containing high-resolution maps of national asset value estimates, distributed proportionally to a combination of nighttime light intensity and population data. https://doi.org/10.3929/ethz-b-000331316.

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.



Evolution of PPE Damage Loss: Precipitation Intensity by scenario ssp5_8_5

PPE Damage Loss (currency)
2030: -163156
2050: -243406
2080: -348988

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

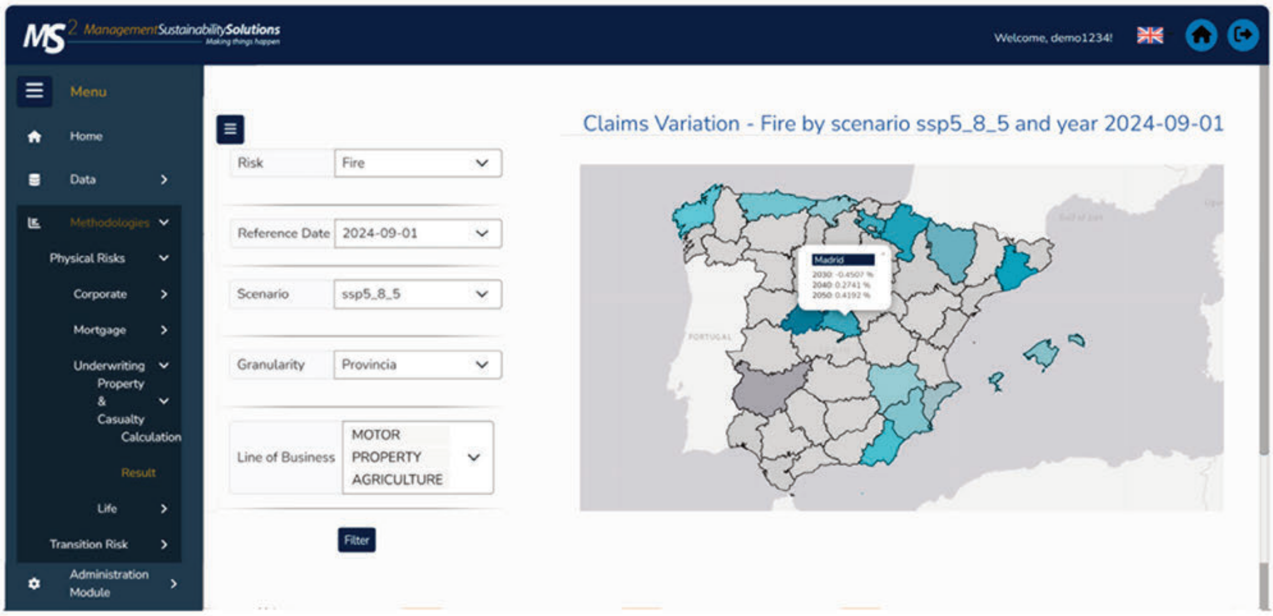
The physical risk analysis for the property and casualty (P&C) underwriting portfolios is based on an estimate of the expected increase in claims experience. The main assumption of this methodology is that the pricing and reinsurance ratios remain unchanged compared to the current scenario. Depending 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 (MS^2) tool. Note: simulated data, for illustrative purposes only.



Risk: Fire

Reference Date: 2024-09-01

Scenario: ssp5_8_5

Granularity: Provincia

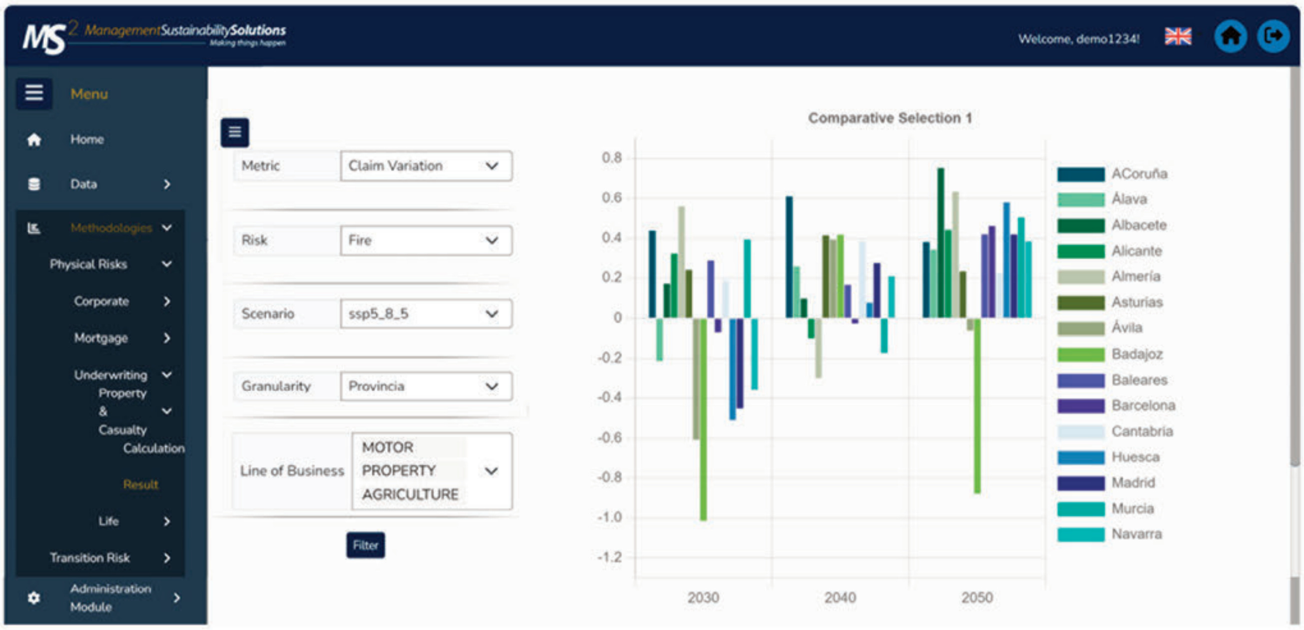
Line of Business: MOTOR
PROPERTY
AGRICULTURE

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 (MS^2) tool.



Metric: Claim Variation

Risk: Fire

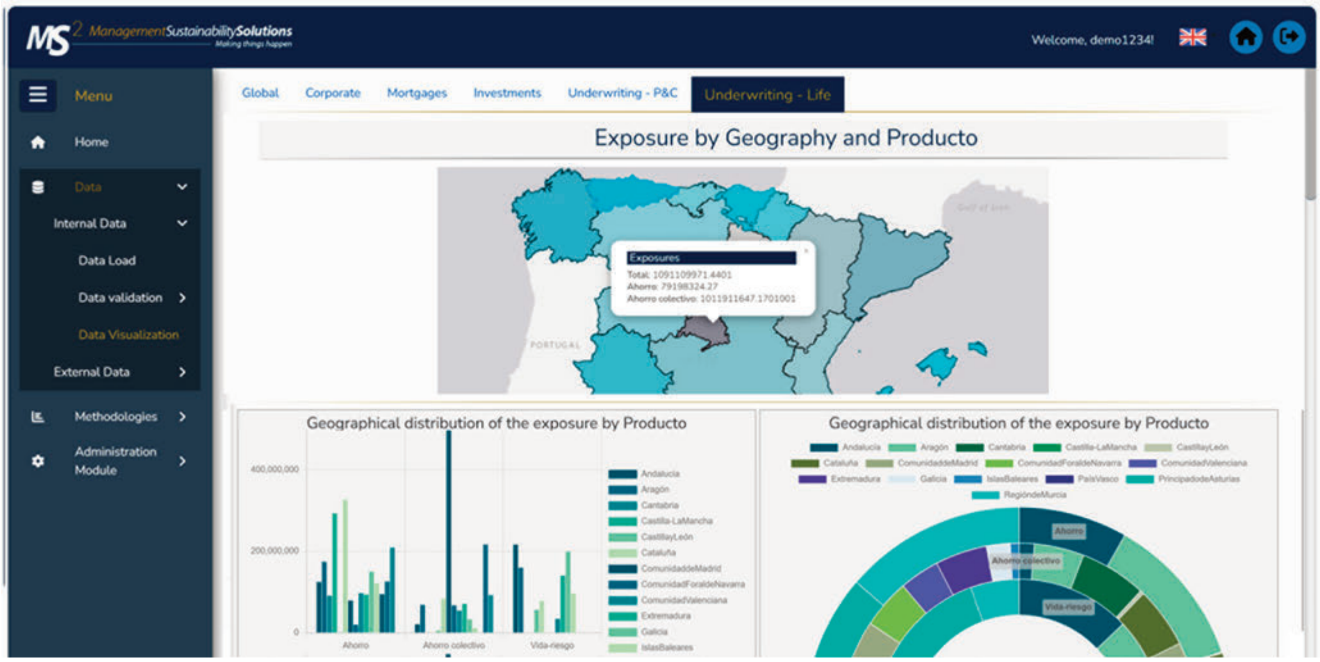
Scenario: ssp5_8_5

Granularity: Provincia

Line of Business: MOTOR
PROPERTY
AGRICULTURE

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.

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[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.

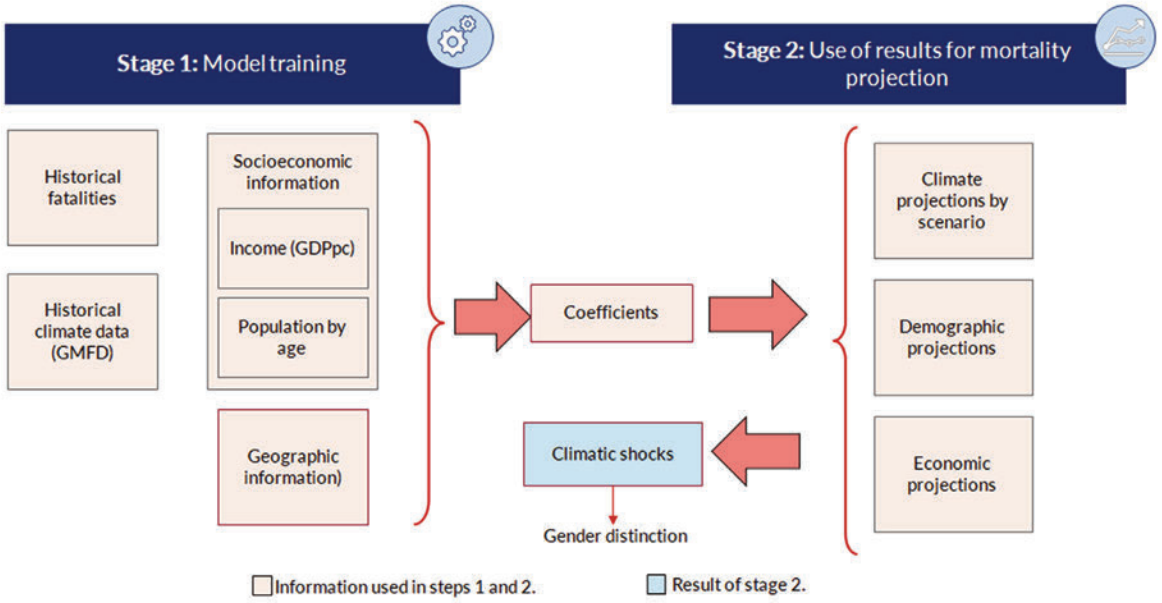

Figure 16: Examples of shocks and regional scale comparison of life portfolio mortality rates due to physical risk (heat waves) under the ssp5-8.5 scenario in 2025, 2030 and 2050 in the Management Sustainability Solutions (MS^2) tool.

Metric: Impact on Shock (%)
Risk: Heat waves
Scenario: ssp5_8_5
Country: Spain
Type of Product: Ahorro, Ahorro colectivo, Vida-riesgo
Age gap: >20 & <65
Gender: F, M
Granularity: State

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.

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[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, MS^2 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

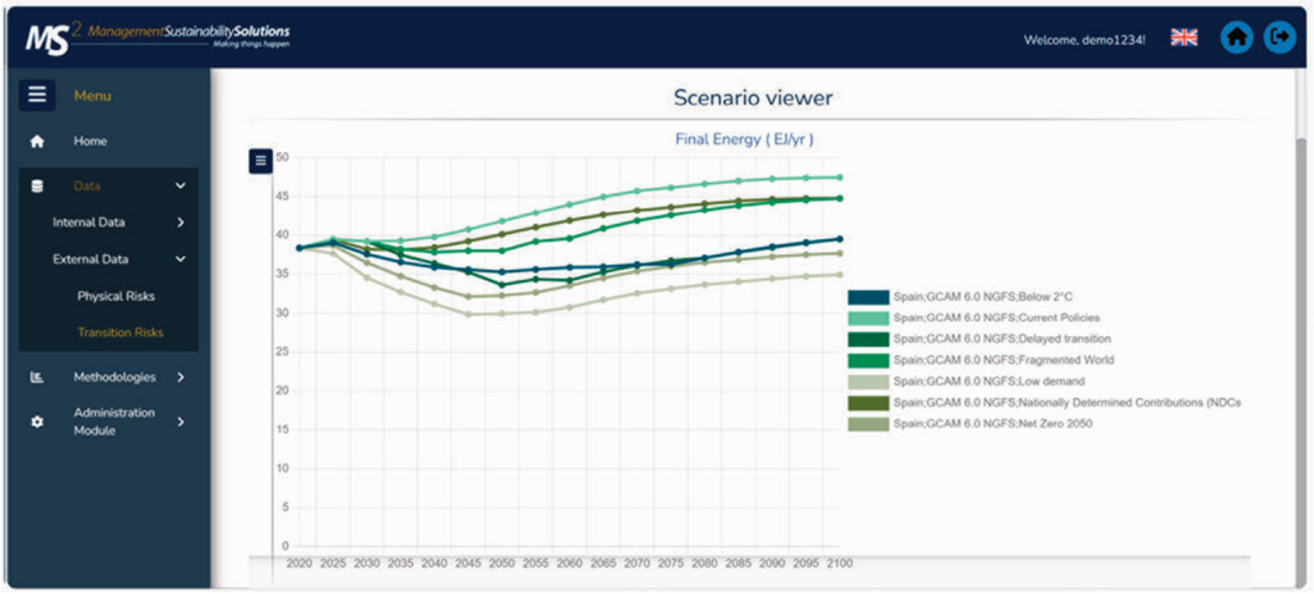
To assess the impact of transition risks on a credit portfolio, the methodology is aligned with the framework developed by UNEP-FI[54]. This approach leverages qualitative heat maps to quantify risks, which are specifically tailored to different economic sectors and geographic regions[55].

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.

Figure 18: Transition scenarios, example of display of the "Final Energy" variable in the MS^2 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.

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[54] UNEP Financial Initiative: Extending our horizons.

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

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.

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[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.

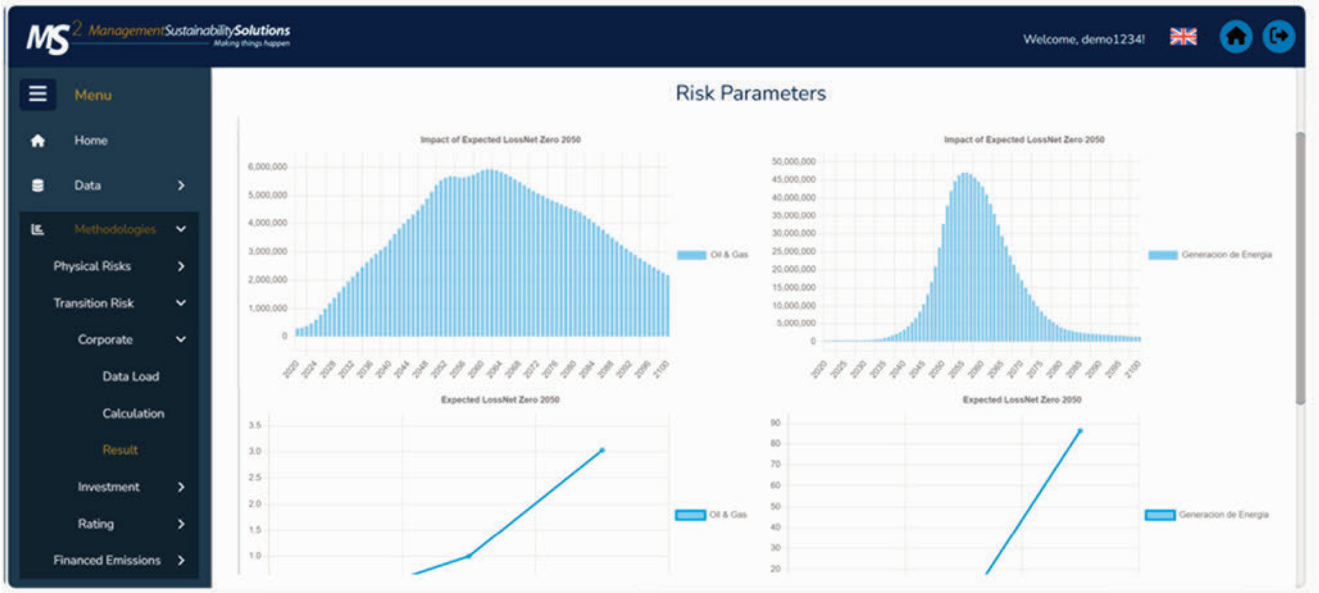
The methodology described in this section allows for a detailed analysis of the impacts of transitional climate risk at the individual exposure and counterparty level, facilitating the simulation of the effect of different trajectories of potential climate transitions on the credit risk parameters of 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 (MS^2) 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.

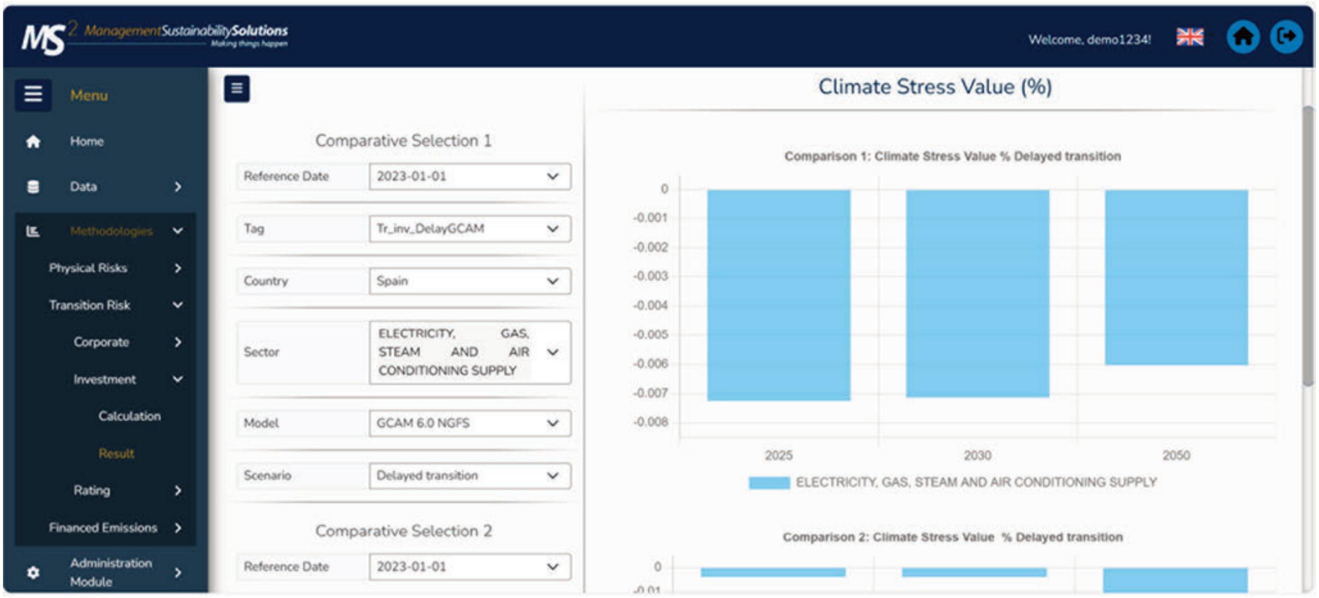
The trends observed in these climate variables - such as carbon prices, energy costs or regulatory changes - help determine how revenues could evolve under different scenarios.

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.



Comparative Selection 1

Reference Date: 2023-01-01
Tag: Tr_inv_DelayGCAM
Country: Spain
Sector: ELECTRICITY, GAS, STEAM AND AIR CONDITIONING SUPPLY
Model: GCAM 6.0 NGFS
Scenario: Delayed transition

Comparative Selection 2

Reference Date: 2023-01-01

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).