SCOPE | Ratings

Climate-change risk (CCR) Framework

Corporates, Financial Institutions, Covered Bonds, Sovereign and Public Sector, Structured Finance, Project Finance

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1. Introduction

Climate change is reshaping the financial landscape - challenging the way we assess risk, value assets, and safeguard creditworthiness. As the world faces increasingly unpredictable weather events, evolving regulations, and rapid technological shifts, understanding climate-related risks is no longer optional - it's essential.

This framework presents Scope Ratings' answer to that challenge: **a unified, forward-looking approach for evaluating the impact of climate-change risk on credit risk** across issuers and asset classes. We describe the overarching principles, definitions and categories of our climate-change risk-assessment framework. Asset-class-specific supplements complete the general introduction to specific issuer types according to sector or purpose (transactions).

Our framework is grounded in the climate risk indicators published by the Network of Central Banks and Supervisors for Greening the Financial System (NGFS). The NGFS provides macroeconomic impacts (GDP, inflation, energy mix, emissions pathways); and physical and transition risk data projections up to 2050 for different scenarios (e.g., orderly transition, delayed transition, current policies). We complement NGFS data with additional sources, including for acute physical risk, ensuring a comprehensive assessment.

Integrating climate-change risk into credit risk assessments is essential due to its potentially material impact on the financial health and creditworthiness of all issuer types. The negative impact of increasing physical risk on economic growth is well documented in academic literature. See, for example, Burke et al. (2015, 2018), Nordhaus (2017), Hsiang (2016), Kotz et al. (2021), Krichene & Platteau (2023). Equally, while a robust climate response can help mitigate physical risk, the associated transition risk – such as regulatory changes and technological shifts - can also yield negative economic outcomes, as described in Hebbink (2018), Allen et al. (2024), Devulder & Lisack (2020).

These varied and interconnected economic effects can propagate into financial shocks as well (see, for example, Battiston et al. (2017), ECB (2021, 2024b). Therefore, many bank supervisors now conduct climate stress tests to understand the impact of climate risks on the financial system (e.g. Bank of England (2024), ECB (2024), US Federal Reserve (2023). Supervisors have also issued guidelines to better capture climate-change risks in financial risk management e.g. the ECB's assessment criteria for the inclusion of climate-change risks in creditworthiness analyses by ECAIs, the ECB's guide on climate-related and environmental risks, and the EBA's guidelines on the management of ESG risks.

Our framework **enables the identification and quantification of long-term risks that may not be visible in short-term financial metrics**. As such, we can characterize risks due to structural breaks that can impair asset value, cash flow, or a borrower's ability to repay.

We apply this framework to assess climate-change risk and produce issuer specific **"Key Climate Risk Indicators" (KCRI).** which can be used to assess the impact of climate-change risk on assets in structured finance, covered bond, and project finance transactions as well as its impact on the creditworthiness of corporate, financial institution, sovereign and public sector issuers. This document does not constitute a rating methodology. It describes a general framework that can be used across different types of sectors to **quantify climate-change risk under multiple stress test scenarios, such quantification being summarized in the relevant KCRI(s).**

KCRIs can be used to:

- Identify issuers with high exposure to climate-change risk,
- Provide an input to assess the impact of climate change in absence of mitigants, and/or
- Disclose the most relevant climate-change risk factors

The framework aims to bring greater coherence, transparency, and comparability to how climate risks can be factored into credit evaluations across sectors and geographies. As climate science, regulatory expectations, and market dynamics continue to evolve, our framework is designed to be adaptable - serving as a foundation for resilient credit risk practices and iterative improvement in the face of ongoing change.

2. Key principles of our climate-change risk analysis

Climate-risk assessment is fraught with **timing, magnitude, and policy response uncertainty**, which challenges traditional credit analysis and financial risk modeling. These include:

- **Policy and regulatory uncertainties**: It is unclear how fast and forcefully governments will act to address climate change. Future carbon pricing, emissions regulations, disclosure requirements, or bans on high-emission activities can dramatically alter an issuer's revenue/cost structure or market access. **Timing, application and extent of enforceability can change at short notice** and have drastic effects.

- **Technological change**: The pace of innovation in clean energy, carbon capture, or alternative materials could shift the competitive landscape. An issuer reliant on outdated or carbon-intensive technologies may face obsolescence more quickly than expected, but it is **uncertain which technologies will scale and when**. Direct and indirect effects are difficult to predict and will need to be carefully observed, ranging from possible commercial pressure to abide by technological standards to secular price changes across global supply chains for individual technologies.
- **Physical climate uncertainties:** While long-term climate trends are clear, **location-specific impacts,** like floods, droughts, or hurricanes, are hard to predict with precision. This makes it difficult to assess the timing and severity of risks to assets (real estate, plants, vehicles), supply chains, or operations.
- **Market and consumer behaviour:** Consumer preferences and investor sentiment are shifting towards sustainability, but the speed and scale of these changes are uncertain. This **affects demand for products and services, especially for issuers in carbon-intensive or environmentally sensitive sectors**. Importantly, transmission mechanisms into financial metrics will invariably travel through price signals, some of which may affect global markets, and individual products. Identifying these price effects and who ultimately bears their cost/benefit impact will be key.
- **Liability risk**: Litigation risk around climate disclosure and environmental impact is growing, but legal outcomes and exposure levels are unpredictable and already vary. This creates potential financial risks that are hard to quantify. Additionally, **definitions of liability may change as price signals become more precise and related cost allocation becomes more clearly enforced** by policy and regulation. In turn, these effects will likely transmit to both cashflow and balance-sheet constructs central to credit analysis.
- **Data limitations**: Reliable, granular data on emissions, negative externalities, supply-chain exposures, and climate-related financial metrics are **often incomplete or inconsistent across issuers or asset classes**. Scenario models (e.g., NGFS, IEA) offer pathways but they carry assumptions and cannot fully capture complex economic feedback loops or non-linearities (see 'tipping points').

Integrating climate-change risk into credit assessment requires a **careful articulation of relevant analytical horizons**. The way climate-change risk materialises can be very different across alternate asset classes. Notwithstanding such disparities, it is important to consider climate-change risk as consistently as possible. **This is particularly important for investors faced with complex investment decisions** over several asset classes. This climate-change risk framework does not provide details on how climate-change risk is integrated into specific asset classes but aims to establish a common set of principles to deal with the challenges listed above. Dedicated Supplements describing the detailed application of the general framework to produce KRCIs for each asset class will be published to complement this document.

2.1 Double Materiality: Risk

Double materiality is a concept that broadens traditional financial materiality by recognising that environmental, social and governance (ESG) factors are significant not only because of their impact on a company's financial performance (**outside-in**), but also for the impact the company has on society and the environment (**inside-out**). In the context of a debt issuer, this means evaluating both risk materiality and impact materiality.

From a risk materiality perspective, the issuer must assess how ESG issues such as climate change, regulatory shifts, or labour practices might affect its creditworthiness, operating performance, or ability to repay debt.

From an impact materiality perspective, the issuer is also responsible for understanding and disclosing how its activities contribute to broader ESG outcomes, such as greenhouse gas emissions, biodiversity loss, or social inequality. This matters to investors and stakeholders who seek alignment with sustainability goals, ethical investing principles, or regulatory reporting frameworks like the EU's Corporate Sustainability Reporting Directive (CSRD).

This climate-change risk framework **only addresses outside-in risk aspects** and focuses mostly on environmental factors, although some climate-related factors may spill over to other ESG categories, such as increases in carbon taxation resulting in lower disposable incomes for households.

2.2 Climate-change risk categories

In line with the European Central Bank's guidance on climate-related and environmental risks[1], we consider two main categories of risk with regard to climate change:

[1] bankingsupervision.europa.eu/ecb/pub/pdf/ssm.202011finalguideonclimate-relatedandenvironmentalrisks~58213f6564.en.pdf

- Physical risk. Because of climate change, average temperatures are expected to continue rising and extreme weather events are expected to become increasingly frequent and severe[2]. **This will lead to increases in both chronic and acute physical risks**. Examples of chronic risks include changes in temperature or sea level rise; acute physical risks entail extreme weather events (floods, wildfires, subsidence, tropical cyclones, etc).
- Transition risk. To counter climate change, the Paris Agreement on climate change set a goal of limiting climate change at below 1.5°C above pre-industrial levels[3]. **This requires economies to transition away from greenhouse gas (GHG)-emitting activities**. Associated risks include changes of regulations, technology, and consumer and investor preferences[4].

Both risk categories are expected to lead to **greater economic risks through macroeconomic and microeconomic transmission channels**. Microeconomic transmission channels include damages to assets, the risk of stranded assets, disruptions to processes, relocations of economic activities and the impact on household budget[5]. Macroeconomic transmission channels include the effects on prices, productivity, socioeconomic changes, and changes in trade or capital flows[6].

Micro and macroeconomic changes can lead to changes in credit risk over the long term, e.g. by increasing default probabilities of households or firms or by decreasing the value of collateral, which also impairs credit quality.

2.3 Scenario analysis

Analysis of associated risks needs to consider several types of uncertainty. The first major type relates to the precise impact of greenhouse gas emissions on biophysical variables, and is mitigated by several research groups globally running and maintaining a global circulation model (GCM), which can simulate future physical variables under different emission scenarios. Simulations are typically based on several runs. Hence, given a certain emission scenario, several measures for quantifying the uncertainties can be estimated.

The second type of uncertainty relates to future emissions of greenhouse gases, given socioeconomic and technological changes. To deal with this type of uncertainty, scenario analysis can be useful to provide insights around how economic variables might evolve under a certain transition pathway and an associated change in biophysical variables.

For each of the categories we identified, the **associated risks are analysed along three primary climate scenarios: orderly, disorderly, and hot house**. These are broadly based on the scenarios by the NGFS. See Appendix 1 for a description of the NGFS scenarios and our main adaptations. We chose these three scenarios as we consider them plausible, and at the same time they span the wide range of risks climate change can entail, from short-term transition risk and lower physical risk (orderly) to a strong medium-term shock in transition risk and higher physical risk (disorderly), and no transition risk but high physical risk (hot house).

The NGFS provides a set of reference scenarios and considers both transition and physical climate impacts for many economic and financial-market variables across referenced scenarios. However, the outcome of a scenario analysis based on NGFS data does not consider stresses under the most-extreme scenarios of how climate change might play out, even though for some issuers and transactions, the occurrence of events with very-low likelihoods could have very large credit consequences.

We consider the macroeconomic and financial consequences of the scenarios and how this may be different compared against a counterfactual where no climate-change risk is assumed. We expect that the **resulting climate scenario analysis may be skewed to the downside, but there is, nonetheless, a possibility of upside impacts on credit risk** for borrowers experiencing opportunities from climate change.

We will thus provide an analysis of climate-change risk under three scenarios but without assigning any likelihood to each of them.

2.4 Materiality of climate change-related risks

The climate risks outlined above may manifest in various ways, depending on the characteristics of the transactions or issuers involved. For example, increases in energy prices will obviously have a strong effect on the input costs of energy-intensive companies but only a moderate direct impact on less energy-intensive industries. The way that energy price increases affect credit quality is likely to be altogether different for sovereign borrowers, for example by reducing output growth because of lower household purchasing power or, conversely, by increasing growth because of higher government spending to shield consumers and companies from price rises. A

[2] report.ipcc.ch/ar6syr/pdf/IPCC_AR6_SYR_LongerReport.pdf
[3] unfccc.int/sites/default/files/english_paris_agreement.pdf
[4] ngfs.net/sites/default/files/medias/documents/ngfs_conceptual-framework-on-nature-related-risks.pdf
[5] ngfs.net/sites/default/files/medias/documents/ngfs_conceptual-framework-on-nature-related-risks.pdf
[6] ngfs.net/sites/default/files/medias/documents/ngfs_conceptual-framework-on-nature-related-risks.pdf

structured finance transaction may be more significantly affected by other channels, for example by higher household default probabilities.

Different issuer types embody different fundamental risk-return constructions. Sovereign issuers and large financial institutions arguably face diversified and systemic exposure to climate risks and responses. By contrast, most corporate issuers only represent a narrow fraction of large (and frequently global) supply chains over which they exert limited control but through which substantial cost pass-through currents may well manifest.

Transmission mechanisms are therefore not only between climate and credit as distinct fields of analysis but also **across issuers and issuer types within credit analysis**. Climate risk is systemic but existing tools for credit analysis are not; they are articulated by issuer type. Ultimately, this framework should thus also serve to advance the analytical conversation on how and where to reconcile the systemic risk-return calculus around climate, with individual risk-return considerations.

2.5 Management and mitigation

Whereas climate-change risks create exposures, **issuers or transactions can to some degree manage, adapt to or mitigate some of those exposures**. There is a regulatory impetus to improve on both climate-change risk management and ESG risk management in the broader sense. One major development in this regard is the European Banking Authority's[7] consultation on guidelines around the management of ESG risk. Proper risk management could mitigate some of the risks associated with climate change. It is therefore important to include an assessment of climate-change risk management for asset classes where this is relevant.

This provides a further **qualitative complement to climate change-related risk analysis. Such a qualitative assessment is outside the scope of the KCRIs** being defined for each asset class and should be done at the level of the issuer or transaction.

2.6 Time horizon of climate-change risks

Choosing the time horizon to assess the impact of climate change on the credit risk of an issuer/transaction is crucial but challenging. It depends on balancing the nature of climate risks, the issuer's characteristics, and the decision usefulness for creditors. Many climate-related risks materialise only over very long-run horizons linked to net-zero commitments, NGFS provides long-term physical and transition impacts to 2050, whereas debt maturity profiles may be shorter. To this end, in its consultation on guidelines concerning the management of ESG risk, the EBA[8] states that institutions should have an approach to the management and mitigation of ESG risks over the short, medium, and long term, including a time horizon of at least 10 years. We therefore believe **indicators for several time horizons, including over 10 years, are necessary** but the choice for the most pertinent time horizon is done per asset class as described in its dedicated Supplement.

2.7 Entity-specific versus sectoral assessments

Climate-risk **exposures differ for entities in different sectors but also within a given sector**. For example, a utility mainly using renewable power will have a very different risk-exposure profile than a utility mainly relying on coal-fired power. The materiality assessment of climate-change risk can be done within each asset class, leveraging the different rating methodologies to allow proper identification of the key risk drivers. But it should leave room for different degrees of exposure for a given entity within a specific asset class.

However, it can be hard to obtain the relevant data that leads to a granular enough assessment at entity level. Therefore, given the importance of analysing granular details of risk exposures, we prefer entity or transaction-specific analysis. But we would include sector assessments when data availability allows for more detailed analyses.

2.8 Quantitative versus qualitative factors

Academic focus on climate change and its consequences has led to significant improvements in the available quantitative tools to analyse climate-change risk. Yet, **climate-change risks can be non-linear or very hard to quantify**. For example, the effect of a natural disaster on a facility can be quite different depending on the nature of the facility, and some effects could be of a second-order nature.

Nevertheless, given the detailed data already available and the pitfalls of a purely qualitative approach (inconsistency, subjectivity), **we prefer quantitative approaches to measure climate-change risks** via the outlined sensitivity-analysis framework where possible. This allows us to produce dedicated KCRIs for each issuer as detailed under their Supplement. However, qualitative adjustments to capture risks that are very hard to quantify are allowed to adjust KCRIs when needed.

[7] eba.europa.eu/sites/default/files/2025-01/fb22982a-d69d-42cc-9d62-1023497ad58a/Final%20Guidelines%20on%20the%20management%20of%20ESG%20risks.pdf
[8] eba.europa.eu/sites/default/files/2025-01/fb22982a-d69d-42cc-9d62-1023497ad58a/Final%20Guidelines%20on%20the%20management%20of%20ESG%20risks.pdf

2.9 No double counting of climate-change risk

In some cases, there is a risk of a double counting of climate-change risk. For instance, if a specific climate-change scenario (e.g. net zero) is used when assessing the credit quality of an issuer, the quantitative metrics, the KCRIs, produced for such issuer **need to discount the risk of such a scenario and be adapted to their use**. If climate-change risk is already included in the credit assessment of an issuer, the credit assessment of a repackaged note of the bond of that issuer should not use any additional KCRIs as the issuer credit assessment has already incorporated climate-change risk.

However, it is possible for an issuer or transaction to be exposed to the same risk through more than one channel. For example, changes in energy prices could have macroeconomic implications for a corporate but also lead to changes in aggregate energy costs. Even though the transition risk is the same (changes in energy prices), this would not constitute double counting as the corporate is effectively doubly exposed. For each asset class, the materiality assessment provides a degree of guidance to prevent double counting.

3. Introducing the Key Climate Risk Indicators

Our emphasis on quantitative approaches entails the production of **quantitative metrics under different climate-change scenarios and time horizons, which can be incorporated in the credit assessment of an issuer/transaction**. Such quantitative metrics could be the change of output of a scorecard or a quantitative model, caused by inputs stressed by climate-change risk; or the change in key risk drivers, a.k.a key financial ratios, required over-collateralisation ratios, etc.

We call those quantitative metrics our **"Key Climate Risk Indicators"**. They are produced under several sets of assumptions, with regards to the climate-change scenarios and the time horizon to be considered. For a more detailed list of KCRIs per each asset class, we refer to the relevant Supplement, which provide a detailed description of the respective KCRIs, their definition and computation. The remainder of this section describes the common features of our KCRIs.

3.1 Climate-change scenario analysis

We consider climate risks based on the three NGFS scenarios, which are designed to create a common basis for analysing climate risks for the economy and financial system with a consistent set of variables and assumptions for analysing climate risks. The scenarios cover 2020-2050. The NGFS defines the three scenarios used in this study as follows[9]:

- **Orderly** scenarios assume **climate policies are introduced early and become gradually more stringent**. Both physical and transition risks are relatively subdued. Within this category we adopt the 'Net Zero 2050' scenario.
- **Disorderly** scenarios explore **higher transition risk due to policies being delayed or divergent across countries and sectors**. For example, carbon prices are typically higher for a given temperature outcome. Within this category, we adopt the 'Delayed Transition' scenario.
- **Hot house** scenarios assume that **climate policies are implemented in some jurisdictions, but global efforts are insufficient to halt significant global warming**. The scenarios result in severe physical risk including irreversible impacts like sea-level rise. Within this category, we adopt the 'Current Policies' scenario.

Whereas scenario analysis can give a degree of insight into how economic and financial variables might evolve under certain climate ecosystems, it is unclear which (if any) of the pre-defined scenarios will materialise. We do not currently assign a comparative likelihood of any of the three climate scenarios. Instead, **we consider the scenarios as a stress test of an issuer or transaction to determine how robust the fundamentals are to a certain climate-change scenario**. Our KCRIs connect the key risk drivers with the climate projections by defining the transmission channels.

The set of KCRIs produced for each asset class can be adopted in credit assessments to better identify the potential magnitude of climate-change risk on a credit-risk assessment and potentially adjust it following the integration of qualitative factors not considered in the definition of the KCRIs. Qualitative factors could be the presence of insurance contracts hedging against acute physical risks, outlines by management of issuers of adaptation plans to mitigate climate risks, a change of strategy, etc. This allows for a better understanding of climate-change risk at the issuer/transaction level while still retaining consistency across asset classes.

This remainder of this section provides more detail on our framework and how we define the KCRIs. The process starts by determining the materiality of climate-change risk for all key risk drivers, stress testing key drivers that are materially affected.

[9] Network for Greening the Financial System (2022), NGFS Scenarios for central banks and supervisors.

3.2 Determining materiality of climate-change risk for key risk drivers

Each asset class has idiosyncrasies that affect how climate-change risk affects credit quality. Hence, we define the KCRIs for each asset class based **on a sector specific materiality assessment geared towards key risk drivers**, which we assumed are material and exposed to climate-change risk. For example, when considering commonly used debt/EBITDA ratios, we could consider Scope definitions and potential adjustments to both debt and EBITDA calculations before integrating climate-change-induced variations into this ratio. When we do integrate climate-change-induced impact on the likelihood of household defaults, the KCRIs can be defined as the change resulting from such a change using the same tools, assumptions and models as the one defined under the relevant methodology.

3.3 Stress testing materially exposed key rating drivers

For the risk drivers we deem to be materially exposed to climate-change risk, we provide an assessment of how the risk driver may change under a certain scenario. As described above, whenever possible we prefer a quantitative characterisation but can resort to qualitative adjustments if necessary.

We then consider how effects under a certain scenario may affect the key risk driver. For example, an RMBS transaction may have a default probability for each borrower depending on certain characteristics (e.g. disposable income). The applied stress can in this case be a shock to the disposable income (e.g. from carbon taxation or macroeconomic shocks), which translate in a shock in default probability.

For most climate-change effects, we assume that the baseline assumptions reflect the status quo and are calibrated on the historical evolution of the variables concerned. **As climate-change risk is not typically reflected in historical data, we consider the baseline a scenario without climate-change risk**. Adding shocks from physical or transition risk events then results in a stressed scenario. In case methodologies already reflect some climate-change effects, the counterfactual might be different to the standard no-climate change scenario and we adapt the shocks accordingly (see section 2.9 concerning avoidance of double counting).

As described above, some climate-change risks might only materialise over longer time horizons. Yet, the associated shocks remain relevant for investors. Even **events materialising beyond this time horizon can affect credit risk today**, as certain climate vulnerabilities in the future could affect the behaviour of stakeholders today, e.g. a company with high carbon emissions may see its bonds trade at a discount due to market expectations of potential losses ahead, something already being observed[10].

Yet, some sector-specific assessments may have a timeframe shorter than the one over which climate risks might materialise. To provide an assessment of climate-change risk for these cases, we provide KCRIs defined using shocks of later periods to the baseline assumptions. Whereas it creates a mismatch between the timing of the baseline and the timing of the shocks, the impact of this mismatch is relatively benign as we are only interested in the differential between the baseline and the climate stress scenarios. **To have a holistic understanding of the time dimension of climate-change risk, we look at three time horizons**: short (up to 5 years in the future), medium (10 to 15 years) and long (25-30 years).

Short term shocks can straightforwardly be interpreted as a stress on the current operating environment (mainly because of transition risk) and the associated impact on an issuer. Interpreting medium and longer-term shocks is a bit more complex. We see the stressed metrics as an indication of potential medium and long-term vulnerabilities, which could materialise if the risks are not managed. Whereas these shocks are often larger compared to short-term shocks, the longer time horizon allows issuers or transactions to mitigate the effects. The presence of climate-risk management plans can limit the magnitude of the shocks.

Therefore, whereas the KCRIs are defined in terms of the shocks to which they can be exposed in certain scenarios, the final consideration of climate-change risk will integrate both KCRIs as well as possible mitigants to this shock.

3.4 From climate shocks to a conditional sensitivity under each scenario

After defining the key risk driver stresses for each scenario and time horizon, we then compute the KCRIs under each climate scenario. **KCRIs should represent the sensitivity of the issuer to climate-change risk**, either at the level of the key risk drivers themselves or at the level of the quantitative credit assessment. For example, in the case of corporate credit assessment, the outcome of our previous step could be a debt/EBITDA with a stress to revenues due to a shock in transition and physical risk. In the case of sovereign credit assessment, the stress may be applied on the most material key drivers of the methodology, such as Gross Debt to GDP or real economic growth. In the case of an SME loan securitisation, this would be the impact on our quantitative modelling of the shocks on SMEs defaults and recoveries. Each asset class Supplement provides a full description of the relevant KCRIs.

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[10] ecb.europa.eu/pub/pdf/scpwps/ecb.wp2969~0f4c56a156.en.pdf?b6e005d7334de68ad976f24bd9ae5759

4. Data sources

A high-quality analysis of climate-change risk in the context of credit risk requires high-quality data from several sources. On the one hand, projections of climate-change risk-related variables considered to be credit-relevant are required to build an understanding and quantification of climate-change risk. On the other hand, issuer and transaction-specific data is required to assess the exposure to those risks. Both come with challenges.

Data sources can be both internal and external: internal in order to leverage our existing databases of issuer/issue set of information (financial metrics like leverage, margins, cash-flows, or business model and sectoral activity, geographical distribution of borrowers, energy efficiency certificates distribution of properties); and external e.g. climate scenarios, macroeconomic forecasts, energy prices or the likelihood of extreme natural events.

4.1 Climate-change risk-exposure data

Climate-change risk-exposure data enables an understanding of the risks to which an issuer or transaction is exposed. This consists of data on physical and transition risks. **We aim to use granular data**. For physical risks, this means data with a high enough geographical resolution to provide relevant risk exposures for location-based risk assessment. For transition risks, this includes projections of variables (e.g., price, volume, capacity) for alternate sources of energy.

We use several sources, including supranational organisations, research institutions, as well as internal model outputs when necessary. Appendix 3 provides a list of the main sources of information for our climate change data. Other sources can be considered if appropriate.

4.2 Issuer and transaction-specific data

Issuer and transaction-specific data allow for an understanding of the exposures to a certain climate-change risk. **In general, we are constrained by the level of disclosure by issuer or transactions**. For issuers, we can rely primarily on public and preferably audited disclosures. For corporate and financial-institution borrowers, this includes annual statements, as well as further regulatory disclosures, including on climate-change risk and broader ESG-related disclosures.

For issuers in the sovereign and public sector category, data sources include supranational organisations (such as the International Monetary Fund, the European Commission, the European Central Bank, the Organisation for Economic Co-operation and Development (OECD), the World Bank, and the Bank for International Settlements), national statistical offices, national or regional central banks, government agencies and ministries, and other generally accepted sources.

For transactions, data sources usually include information on collateral and borrowers, as well as information on the contractual and governance mechanisms of the transaction itself. Other information (e.g. information on counterparties) is also reflected.

Appendix 1. Scenario narratives

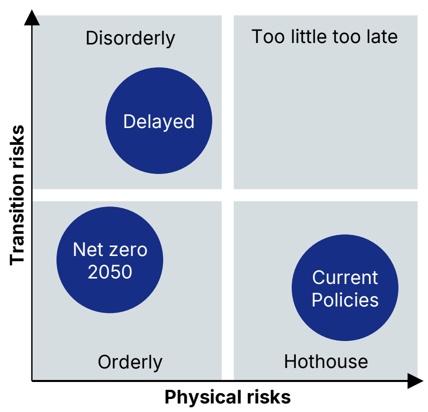
NGFS scenarios

We consider climate risks based on three NGFS scenarios. These scenarios are designed to provide a common basis for analysing climate risks for the economy and financial system with a consistent set of variables and assumptions for analysing climate risks. The scenarios cover the time periods 2020-2050. The NGFS defines the three scenarios used in this study as follows[11]:

- **Orderly** scenarios assume climate policies are introduced early and become gradually more stringent. Both physical and transition risks are relatively subdued. Within this category we adopt the 'Net Zero 2050' scenario.
- **Disorderly** scenarios explore higher transition risk due to policies being delayed or divergent across countries and sectors. For example, carbon prices are typically higher for a given temperature outcome. Within this category, we adopt the 'Delayed Transition' scenario.
- **Hot house** scenarios assume that climate policies are implemented in some jurisdictions, but global efforts are insufficient to halt significant global warming. The scenarios result in severe physical risk including irreversible impacts like sea-level rise. Within this category, we adopt the 'Current Policies' scenario.

Figure 1: NGFS scenarios at a glance

Scenario	Physical risk	Transition risk			
	Global warming	Policy reaction	Technological change	Carbon dioxide removal	Regional policy variation
Orderly	1.4°C	Immediate and smooth	Fast change	Medium-high use	Medium variation
Disorderly	1.6°C	Delayed	Slow then very fast change	Low-medium use	High variation
Hot House	3°C+	No ramp up in policies	Slow change	Low use	Low variation



Note: The cells in the table are coloured based on associated macroeconomic risks as determined by the NGFS with lower (green), moderate (yellow), and higher (red) risks.
Source: Network for Greening the Financial System

Scope Scenarios

Whereas our scenarios are based on the NGFS scenarios and adopt many of their aspects, there is one important difference. The NGFS scenarios have a static timeframe covering the period 2020-2050. This static timeframe does not fit well with our need for a dynamic and forward-looking timeframe.

For two reasons. The first relates to cliff effects. The NGFS projections currently run until 2050. This means that if by adapting the NGFS scenarios without modification, the timeframe on which our analysis is possible shortens every year, unless the NGFS starts projecting beyond 2050. This runs the risk that if the NGFS projection period remains the same, the analysis for a given time horizon cannot be guaranteed. For example, from 2026 onwards, data for a 25-year time horizon will not be available in absence of changes in the NGFS

[11] Network for Greening the Financial System (2022), NGFS Scenarios for central banks and supervisors .

projection horizon. This could lead to the need for change to Scope's own time horizon definitions because of data availability, which we consider undesirable.

Further, at the time of publication, we are already five years beyond the starting date of the NGFS baseline. This entails several complications in the analysis:

- The trajectory for all variables has already materialised for the period starting in 2020 until the present, and there should not be a difference in the past for these variables. The recalibration of variables is difficult due to the relative nature of many variables (e.g. percentage-difference in GDP, percentage-shock to inflation).
- The NGFS scenarios are designed in a way that presents different shocks in different timeframes. For example, the orderly scenario focuses on a short-term transition shock. One unintended consequence of using a timeframe different to the standard NGFS timeframes can be that a shock is missed altogether, painting a rosier picture than warranted.

Therefore, we modify the NGFS scenarios in two main ways:

- We use our own baseline of no-climate-change counterfactuals, which are based on the default values used in the credit rating process, except if the standard credit rating process already embeds a specific climate-change scenario.
- To this baseline, we add the shocks coming from the NGFS, but shift them: we set the starting year of our scenarios at the current year (denoted as T) and initialise the shocks for period T as the shocks defined for the NGFS in 2020, the shocks for T+1 as the 2021 NGFS shocks, etc.

This modification solves the issues and provides scenarios in line with the NGFS narratives, which remain forward-looking. However, it does introduce a mismatch between when effects are expected to arise in the NGFS scenarios, and in the modified Scope scenarios. We argue that the impact is different for transition and physical risk:

In the case of transition risk, we consider the impact of changing the time horizon to be negligible. In the period 2020-2024, no large transition shock took place, which means that the three transition components of the scenarios considered (orderly: short-term transition, disorderly: transition in 10 years from the projection starting date, hot house: no transition beyond what already exists) are still plausible and relevant to analyse.

Further, we do not expect a material change in how macroeconomic variables would respond to a transition shock now compared to how they would have responded in 2020. Therefore, we consider the straight application of transition shocks from 2020 to the present year as having a very small impact.

For physical risk, the case is somewhat different. Even though most shocks provided by the NGFS are defined in relative terms, they are often calibrated on absolute underlying variables (e.g. percentage difference in GDP calibrated on temperature in °C). If the relation between these absolute variables and their relative macroeconomic effects are linear, a simple shift of a shock by a few years would also have no effect.

Yet much scientific evidence suggests that the relation between biophysical indicators and macroeconomic effects can be non-linear. By the proposed shift, we implicitly assume that the linear approximation resulting from our shift is a sufficiently accurate depiction of the underlying non-linear process. Given the relatively short time span between the start of the NGFS projections and the present day compared to the pace of biophysical changes, we consider this the case. However, we will continue to monitor scientific research on the subject and may adapt this approach if we no longer consider it suitable.

Non-NGFS Scenario mapping

We associate the following NGFS scenarios with our orderly, disorderly and hot house scenarios:

- **Orderly scenario:** Net zero 2050
- **Disorderly scenario:** Delayed transition
- **Hot house scenario:** Current policies

Whereas the NGFS provides projections of many macroeconomic variables, we require data from other sources for more specific stresses. In climate science, many projections are provided by the Shared Socioeconomic Pathways (SSP), which since the sixth[12] Coupled Model Intercomparison Project 6 (CMIP6) of the World Climate Research Programme (WCRP) are associated with a

[12] dkrz.de/en/communication/climate-simulations/cmip6-en/the-ssp-scenarios

Representative Concentration Pathway (RCP) to design a set of scenarios defining a socioeconomic trajectory and a climate forcing. If such data are used, we map the SSP scenarios with our scenarios as follows:

- Orderly scenario: SSP1-2.6
- Disorderly scenario: SSP2-4.5
- Hot house scenario: SSP5-8.5

In general, as opposed to many NGFS variables, almost all biophysical variables are expressed in absolute terms (e.g. temperature projections in °C, sea levels in m, …). The recalibration on past data is therefore less of a problem compared to the NGFS data.

Appendix 2. List of climate-change risk data

This appendix provides the main sources of climate-change risk data used in our analysis. This list is not exhaustive and can change over time if new information becomes available.

Macroeconomic data:

- NGFS :
  - GDP baselines
  - Physical and transition risk damage to GDP
  - Shocks to inflation, target policy rates, unemployment ...
  - Energy price projections
  - Carbon price projections
- OECD
  - Inter-Country Input-Output Tables
- ECB :
  - Policy rates
- EBA :
  - Transparency data
  - Risk monitoring
- Eurostat :
  - Energy data, e.g. energy use in buildings
  - Real estate indicators, e.g. house price indices
  - Macroeconomic indicators, e.g. disposable income
- European Commission :
  - Geographic Information System of the Commission (GISCO) : Administrative unit geodata
- Scope :
  - Macroeconomic Climate Stress Test : country-sector model providing sectoral revenue losses
- IMF:
  - World Economic Outlook
- IEA :
  - Energy supply & demand projections
  - Energy prices projections
  - Energy production capacity projections
- SSP :
  - Population projections
- Further academic research into macroeconomic impacts of climate-change risk

Climate & geographical data

- Copernicus Climate Change Service :
  - Biophysical indicators, e.g. Fire weather index, temperature, precipitation, subsidence …
  - Vegetation
  - Population
- NASA :
  - Elevation (GTOPO30)
  - Fire Information for Resource Management System (FIRMS)
- ETH Zürich :
  - Climada : tropical cyclone tracks
  - Damage functions
- The Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) :
  - Biophysical projections: river floods
- World Resources institute
  - River floodmaps
  - Coastal floodmaps
- Further academic research into climate change projections

Exposure data

- World Bank : gridded produced capital and GDP

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