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Foreword

As climate-related events become ever more frequent and policy landscapes evolve, credit institutions are under increasing pressure to consider a broader spectrum of risks, including physical risks from extreme weather events and transition risks associated with regulatory changes. This study examines how credit institutions are adapting their risk management frameworks and capital adequacy strategies to better account for such emerging risks. Via semi-structured interviews with 30 risk experts and a review of institutions' disclosure reports, we consider two key questions: (i) how are institutions integrating climate risks into their risk management frameworks, and what challenges are they encountering?; (ii) to what extent are climate risks being incorporated into capital considerations, and through which mechanisms are they influencing the determination of capital requirements? By highlighting both the approaches taken and the challenges faced by institutions, this work sheds light on the different ways in which climate risks are reshaping risk management practices. A simple but telling example in this context is that of stress tests, where climate risks are prompting credit institutions to extend the time horizons they typically consider in such exercises — from the traditional 3-5 years to up to 30 years — in order to better account for potential long-term impacts.

This work aims to provide a detailed analysis of institutional practices and regulatory developments that we hope will be of value to academics, industry practitioners and policymakers engaged in this field. By presenting concrete examples of approaches used by large credit institutions in the European Union, enriched with insights from risk experts, our study also provides guidance for the climate risk integration efforts of smaller credit institutions that may be in the early stages of their "journey". Importantly, this work aims to paint an objective picture of current developments and does not advocate for a particular policy stance. As this book is the result of an extensive research project, its structure is similar to that of a research paper, including a comprehensive discussion of the theoretical background, covering key regulatory and supervisory developments, and a short literature review describing the empirical evidence on the growing relevance of climate risks for financial institutions and supervisors. Before presenting the results, a methodology section outlines the empirical approach and the conceptual framework that guides our analysis. We conclude with a discussion of limitations and recommendations for further research and policy initiatives.

This project was made possible by the support of a number of contributors, to whom we express our sincere gratitude. First and foremost, we would like to thank the risk experts who participated in our interviews and provided very valuable insights into current practices and challenges. Their contributions add a practical, hands-on dimension to our study that enhances the relevance of the findings. We would also like to thank the Frankfurt Institute for Risk Management and Regulation (FIRM) for facilitating the dialogue with key stakeholders whose expertise was instrumental to this research. We are thankful for financial support from the German Federal Ministry of Education and Research (BMBF) through the funding measure "Climate Protection and Finance" (KlimFi). While the BMBF had no direct involvement in the design and implementation of this research, the funding (grant no. 01LA2210C) greatly contributed to enhancing our research in the area of climate-related scenario analysis, stress testing and transition planning. This funding also facilitated collaborative research initiatives and exchanges with the Frankfurt School of Finance and Management and the German Institute for Economic Research (DIW).

We are also grateful for financial support from CRIF GmbH, which made it possible to publish this research as open access. We firmly believe that an effective and scientifically-grounded integration of climate risks into risk management depends on the availability of research findings to a wide audience, including practitioners, researchers, and policymakers. CRIF's commitment to fostering best practices in climate-related risk management aligns with the goals of this work. Lastly, we thank the University Library and the Giessen Graduate Centre for Social Sciences, Business, Economics and Law of the Justus-Liebig-University Giessen for providing additional funding for the publication of this work via open access.

Sincerely,

Alix Auzepy
Christina E. Bannier

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List of abbreviations

A-IRB	Advanced Internal Ratings-Based Approach
BCBS	Basel Committee on Banking Supervision
CCF	Credit Conversion Factor
CET1	Common Equity Tier 1
CQS	Credit Quality Step
CRD	Capital Requirements Directive
CRR	Capital Requirements Regulation
CSRD	Corporate Sustainability Reporting Directive
EAD	Exposure at Default
EBA	European Banking Authority
ECB	European Central Bank
ESG	environmental, social and governance
ESMA	European Securities and Markets Authority
EU	European Union
F-IRB	Foundation Internal Ratings-Based Approach
GDP	Gross Domestic Product
GVA	gross value added
ICAAP	Internal Capital Adequacy Assessment Process
IEA	International Energy Agency
IFRS 9	International Financial Reporting Standard 9
ILAAP	Internal Liquidity Adequacy Assessment Process
IPCC	Intergovernmental Panel on Climate Change
IRB	Internal Ratings-Based Approach
ITS	Implementing Technical Standard
KRI	Key Risk Indicator
LCR	Liquidity Coverage Ratio
LGD	Loss Given Default
LSI	Less Significant Institution
M	Maturity
MoC	Margin of Conservatism
NGFS	Network for Greening the Financial System
P2G	Pillar 2 Guidance
P2R	Pillar 2 Requirement
PD	Probability of Default

RCP	Representative Concentration Pathway
RSU	Rating Service Unit GmbH & Co. KG
RWA	risk-weighted assets
SR	Sparkassen Rating und Risikosysteme GmbH
SREP	Supervisory Review and Evaluation Process
SSM	Single Supervisory Mechanism

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1 Introduction

If left unaddressed, today's risks can easily turn into tomorrow's losses. It is therefore vital for credit institutions[1] to have in place a robust and comprehensive risk management framework, including models and processes that ensure a clear understanding of risks and effective mitigation strategies. Nevertheless, even the most flawless risk management cannot fully eliminate the possibility of losses. Thus, a key imperative for these institutions is also to hold sufficient capital to be able to absorb losses exceeding expected levels (Holscher et al. 2022). This can be achieved by ensuring that capital requirements are met and that capital adequacy is maintained on an ongoing basis.[2] In addition, maintaining sufficient capital is essential for institutions to support their business models and pursue their strategic objectives (Gruenewald et al. 2023).[3]

The risks posed by climate change, including transition and physical risks, have in recent years contributed to reshaping the risk landscape known to credit institutions. Physical risks, such as acute and chronic weather events, and transition risks, including the economic impacts associated with the process of adjustment towards a lower-carbon economy, are receiving increasing attention from civil society, regulators and investors alike (Demekas & Grippa 2022).[4] There are also concerns that such risks may change the distribution of losses that banks face (Holscher et al. 2022). In an evolving risk landscape, institutions need to adapt their risk management practices and continuously assess the robustness of their overall risk strategies (Buch 2024). Climate risks, therefore, compel credit institutions to rethink their risk monitoring processes and to reassess their approach to capital adequacy from a new angle. However, as new (or "novel") risks, for which historical data provides limited insight into future developments, climate risks are, by definition, inherently uncertain (Buch 2024, ECB 2024*c*). Accounting for such risks therefore also poses significant conceptual, analytical and data challenges (Demekas & Grippa 2024).

This study seeks to contribute to the discussion on climate risk integration by addressing two key broad questions. First, how are credit institutions integrating climate risks into their

[1] In ECB (2020*b*), supervised credit institutions are commonly referred to as "institutions". Throughout this study, we use the terms "credit institutions", "banks" and "institutions" interchangeably.

[2] Capital adequacy refers to the degree to which risks are covered by capital (ECB 2018).

[3] The weaker an institution's capital base, the more difficult and costly it may be to pursue its strategy. For example, lower capital levels may lead investors and counterparties to demand higher risk premiums, thus reducing profitability (Gruenewald et al. 2023).

[4] Acute physical risks stem from extreme events such as droughts, floods and storms, while chronic physical risks result from gradual changes, such as rising temperatures and sea levels. Transition risks stem from shifts in climate-related policies, technological advancements or changes in market sentiment and preferences (ECB 2020*b*).

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risk management frameworks, and what challenges are they encountering? (*"Question 1"*). Second, to what extent are climate risks being incorporated into capital considerations, and through which mechanisms are they influencing the determination of capital requirements? (*"Question 2"*).[5]

To address these questions, we examine institutions with total assets of more than EUR 30 billion, focusing particularly on 15 credit institutions directly supervised by the European Central Bank (ECB) and subject to the Capital Requirements Regulation (CRR) and the Capital Requirements Directive (CRD). In recent years, the ECB has been at the forefront of defining strategies to address climate risks in the banking sector (Gruenewald et al. 2023). In November 2020, it published 13 broad supervisory expectations regarding the management of climate-related and environmental risks (ECB 2020*b*). These expectations are to be fully implemented by the end of 2024, making ECB-supervised institutions an ideal context for examining how banks are incorporating climate risks into their overall risk management practices. In 2022, the ECB conducted both a climate stress test and a thematic review of climate-related risk management practices. The ECB found that most institutions had implemented at least "basic practices" across most areas of the expectations, but also voiced "significant supervisory concern" about the institutions' ability to achieve a higher level of implementation (p.2 & p.5, ECB 2022*e*).

Among these institutions, we conduct a series of semi-structured interviews with 30 respondents. Our interviewees have expertise in risk management, risk controlling, risk modeling, stress testing and related fields. Although the ECB has set out clear supervisory expectations, it does not prescribe specific approaches for their implementation. Our interviews therefore allow us to gain in-depth insights into to the various — and often heterogeneous — approaches for integrating climate risks, reflecting both current practices and ideas for future developments. In addition, in light of the concerns voiced by the ECB, it appears crucial to shed more light on the specific challenges at hand. This study therefore presents a structured discussion not only of the climate risk integration approaches and their underlying rationale, but also of the barriers identified by respondents. Finally, given that these respondents play a crucial role in implementing the ECB's supervisory expectations, understanding their perspectives is particularly valuable. By better identifying and describing these challenges, we aim to contribute to a smoother, more effective integration of climate risks into banking practices.

[5] Capital requirements refers, in this context, to the determination of capital needs in a broader sense, i.e., amount needed to cover risks, rather than compliance with minimum capital requirements in a regulatory sense.

We complement the semi-structured interviews by a review of the institutions' disclosure reports ("Pillar 3" reports). An important development is that these reports are now required to include information on environmental, social and governance (ESG) risks,[6] with a particular focus on physical risks and transition risks (see Art. 449a of the CRR).[7] Specifically, qualitative disclosures are required to include information on risk management related to environmental risks, while quantitative disclosures cover exposures to transition risks, physical risks and mitigating actions. Even though these reports, particularly the qualitative sections, vary in their level of detail and do not directly highlight specific challenges, they provide a valuable overview of the climate-related risk management practices in place. The reports typically cover topics such as risk identification, materiality assessments, scenario analysis, stress testing, risk metrics, and integration into risk appetite. We therefore use the information from these reports to both inform our semi-structured interviews and complement interview findings.

Examining the integration of climate risks into risk management and capital considerations requires an understanding of the regulatory and supervisory frameworks governing financial institutions. These frameworks are shaped by a range of laws and regulations, largely derived from the Basel Accords ("Basel framework") (EBA 2022*b*).[8] In the European Union (EU), the Basel framework is implemented through the CRR and the CRD, and is further supported by technical standards and guidelines issued by EU bodies, such as the European Banking Authority (EBA) and national supervisors, such as the BaFin and Bundesbank in Germany.[9] It is widely accepted that climate risks are not a stand-alone risk category but act as drivers of "conventional" (i.e., prudential) risk types, such as credit, market and operational risks (BIS 2022*b*). As a result, it is useful to contextualize the integration of climate risks within the broader framework designed to manage these prudential risks.

To guide and structure our discussion, we therefore propose a conceptual framework aligned with core elements of the "Pillar 1" and "Pillar 2" of the Basel framework. Pillar 1, on the one hand, specifies standard rules for calculating minimum capital requirements relative to risk-weighted assets (RWA). In essence, riskier assets receive a higher risk weight, so that capital increases with risk (Holscher et al. 2022). These rules mainly apply to credit risk,

[6]Climate risks are typically treated as a subset of ESG risks, which falls under the environmental pillar.

[7]For the technical standards, see Implementing Regulation (EU) 2022/2453 of 30 November 2022 amending the implementing technical standards laid down in Implementing Regulation (EU) 2021/637 as regards the disclosure of environmental, social and governance risks.

[8]The Basel Committee on Banking Supervision sets standards for prudential regulation and serves as a forum for cooperation on banking supervision. It is composed of central banks and supervisory authorities. These standards are regularly updated, with the most recent series of reforms known as Basel III.

[9]For example, in Germany, even the MaRisk, referring to the minimum requirements for risk management, implement qualitative requirements derived from the Basel framework into German law.

market risk and operational risk. Examining the integration of climate risks within Pillar 1 is especially relevant for addressing *Question 2* on capital considerations. Nonetheless, since Pillar 1 defines minimum capital requirements, its outcomes also feed into broader capital considerations and risk management strategies under Pillar 2. Given the importance of climate risks primarily for credit risk, we focus on the standardized and internal ratings-based approaches — two credit risk-related methods for determining risk weights under Pillar 1 and capital requirements for credit risk (EBA 2023).

Pillar 2, on the other hand, consists mainly of the Internal Capital Adequacy Assessment Process (ICAAP) and the Supervisory Review and Evaluation Process (SREP).[10] The ICAAP is the process by which institutions assess the adequacy of their capital using their own internal methods and risk management processes (ECB 2018). It considers not only the risk types covered under Pillar 1, but also all other material risks to which the institutions are exposed. In this context, the capital considerations under the ICAAP go beyond the minimum capital requirements set under Pillar 1. The ECB expects institutions to achieve full integration of climate risks into the ICAAP by the end of 2024 (ECB 2022*e*). Examining such integration in the context of this study is therefore relevant for addressing both *Question 1* on risk management and *Question 2* on capital considerations. As the ICAAP is a multi-step process, we break down each of the key steps (e.g., risk identification and inventory, risk quantification, stress testing and capital allocation) and discuss the approaches and challenges involved in incorporating climate risks at each stage.

The ICAAP is reviewed by supervisors as part of the SREP, which is an annual process where supervisors evaluate, on a case-by-case basis, the risks institutions face and their ability to manage these risks in terms of risk management, capital, and liquidity (ECB 2023*g*). One key outcome of the SREP is the Pillar 2 Requirement (P2R), a binding capital requirement set by supervisors (ECB 2023*f*). This requirement can be applied, for example, if the ECB determines that an institution underestimates or inadequately manages certain material risks. As a result, the SREP process can shape institutions' risk management practices regarding climate risks and affect their capital requirements. Therefore, examining the role of climate risks within the SREP framework is also relevant for both *Question 1* and *Question 2*.

To structure our analysis, we categorize our results based on their main relevance to either Pillar 1 and/or Pillar 2. For example, the ICAAP is generally regarded as a process associated

[10] The Internal Liquidity Adequacy Assessment Process (ILAAP) is also part of Pillar 2, but is not covered in this study.

with Pillar 2 and, therefore, all results related to the ICAAP are classified under this pillar.[11] Within this conceptual framework of Pillars 1 and 2, our interview-based analysis delivers the following key takeaways and observations, which will be elaborated in more detail in the following sections:

- **Capital for credit risk - Internal ratings-based approach (Pillar 1)**: A key development is that the ECB expects that where climate-related risks drivers are "found to be material, institutions should include such risk drivers in their internal models" approved for use for the calculation of capital requirements for credit risk (ECB 2024*a*). The integration of climate risks into internal ratings-based models is still in its early stages, with a key challenge being the definition and assessment of materiality. While materiality assessments performed under the ICAAP are generally forward-looking, the quantitative integration of risk drivers into rating systems under Pillar 1 relies on statistical assessments and calibration requiring historical data. Short-term climate risks with financial impacts are considered by most respondents to be implicitly captured in the ratings, whereas medium- and long-term risks rely more heavily on ad hoc rating overrides and/or additional Margin of Conservatism (MoC). One institution quantitatively integrates climate risks into its ratings and Probability of Default (PD) estimates. Most institutions rely mainly on qualitative considerations, client engagement and apply rating overrides where necessary. The overrides are based on expert judgement derived from internal and highly heterogeneous climate-related scorecards, introduced by the institutions for risk management purposes. While overrides offer some flexibility and are based on a granular assessment of climate risks in the short term, they bear risks from a model validation perspective. They may also hinder a more systematic and consistent integration of climate risks into PD estimates.[12]

- **Capital for credit risk - Standardized approach (Pillar 1)**: At present, the main method to integrate climate risks into this approach is through external credit ratings. Institutions primarily rely on the three major rating agencies — Moody's, Standard & Poor's and Fitch. The broad coverage provided by these agencies is a key reason for their selection. Consequently, the extent to which climate risks influence risk weights and capital requirements largely depends on how these agencies incorporate climate factors into their assessments, rather than on an active decision by the institutions themselves.

[11] We note, however, that certain aspects of Pillar 1 are also relevant to the ICAAP and, by extension, to Pillar 2. For example, models developed for Pillar 1 may also find application in the context of Pillar 2.

[12] This study primarily focuses on PD considerations under Pillar 1. However, it is important to acknowledge that other credit risk parameters, including loss given default and the treatment of collateral values, also play a role in determining minimum capital requirements for credit risk.

With the "output floor" coming into effect in January 2025, the standardized approach is expected to gain importance in the coming years and see even wider adoption. This shift is likely to let the role of external rating agencies and their methodologies become even more relevant in shaping minimum capital requirements in relation to climate risks.

- **ICAAP - Risk identification, materiality assessment and risk inventory (Pillar 2)**: Institutions are increasingly incorporating climate risks into their internal risk identification process and annual risk inventory as part of the ICAAP. This involves identifying relevant climate-related risk drivers and determining their materiality. A key challenge in this process is the materiality assessment, which is multifaceted and requires detailed, granular data from both internal and external sources to evaluate how different climate-related risk drivers will affect various portfolios and risk types over short-, medium- and long-term horizons. Most institutions rely on qualitative approaches, such as expert judgement, while some further substantiate their materiality assessments with insights from quantitative methods, such as risk-type-specific scenario analyses and exploratory stress tests. Approaches to defining materiality as well as the types of materiality thresholds applied vary widely, highlighting the complexity of integrating climate risks based on materiality considerations.
- **ICAAP - Risk quantification methodologies and data collection (Pillar 2)**: Institutions are increasingly using forward-looking simulation techniques to project changes in credit ratings based on climate scenarios. Some institutions are working to improve credit portfolio models by integrating climate risks, including through correlation factors. In addition, institutions are developing climate-related scorecards to quantify transition and physical risks at the individual client level. The scores resulting from these scorecards are also used in the context of rating overrides (see internal ratings-based approach under Pillar 1). The design of climate-related scorecards (e.g., criteria, weights) varies across institutions. Transition risks are assessed using criteria such as greenhouse gas emissions, technology risks and transition plans, while physical risks rely on criteria related to the regional or international nature of companies, geolocation and hazard-related data. Important data gaps remain, including on geolocation of corporate assets, production facilities and insurance coverage.
- **ICAAP - Risk quantification with climate stress tests (Pillar 2)**: Institutions are gradually integrating climate stress tests into their broader stress testing frameworks. While many have introduced climate stress tests as a separate scenario class, others have also incorporated climate-related elements directly into their quarterly, institution-wide stress assessments. Most institutions rely on publicly available external climate scenarios,

employing a diverse mix of short- and long-term scenarios, with considerable variation in scenario selection. Institutions make various adjustments to the scenarios, not only in terms of scenario expansion, but also by adding new assumptions, such as CO2 cost pass-through rates. A key challenge is the selection of an appropriate baseline scenario, with institutions adopting different approaches. Some institutions incorporate climate risks into the baseline macroeconomic forecast, while others use a dedicated climate scenario as the baseline. Modeling dynamic balance sheet assumptions is another major challenge. Finally, to achieve a comprehensive assessment and granular quantification of climate risks, institutions tend to combine top-down and bottom-up modeling approaches.

- **ICAAP - Internal capital adequacy and climate-related capital buffers (Pillar 2)**: Several institutions use a combination of exploratory scenarios, which focus on specific risks such as credit or operational risk, and comprehensive scenarios, which encompass multiple risk types while considering macroeconomic impacts. Climate-related aspects, including CO2 prices, are increasingly incorporated into these comprehensive scenarios, supporting both capital adequacy assessments and capital planning efforts. Due to modeling uncertainties — particularly the limitations of traditional risk models in capturing medium- to long-term climate risks — some institutions have started to introduce climate-specific capital buffers. These instruments, often precautionary and based on expert judgement, vary in form, including general buffers, economic capital add-ons and adjustments to management buffers. One institution combines an economic capital add-on for climate risks under the ICAAP with a management overlay for expected loss models.

- **Risk appetite, risk metrics and limit systems (Pillar 2)**: Institutions are increasingly integrating climate risks into their risk appetite frameworks, including their credit risk appetite. Some institutions have formalized their climate objectives within their risk appetite statements, linking these objectives directly to risk metrics and limits. Institutions are also introducing a wide range of Key Risk Indicators (KRIs) specifically designed to track climate risk exposures and setting specific limits within their risk appetite frameworks. These limits vary in scope and focus, but typically target sectors and activities most exposed to transition and physical climate risks.

- **Integration of climate risks into loan pricing (Pillar 1 & 2)**: Institutions are increasingly incorporating climate risks into loan pricing by factoring in credit risk costs, funding costs and capital costs. While climate risk-based pricing is still in its infancy, some institutions use innovative tools, such as green refinancing curves and margin premiums linked to internal ESG scores and loan maturities. Scenario analysis is also becoming increasingly used for loan pricing purposes, allowing institutions to develop default probabilities that are conditional on climate scenarios and determine credit provisions based on such scenarios. One institution includes climate risks into macroeconomic scenarios used for expected credit loss.

- **SREP, P2R and P2G (Pillar 2)**: Climate risks are now integral to three critical SREP components: business model assessment, governance and risk management assessment and risks to capital assessment. The business model assessment holds particular importance, as supervisors increasingly evaluate institutions' strategic and operational plans, as well as their ability to assess climate risks from a business model perspective and to integrate them into broader business strategies. This qualitative integration of climate risks into the SREP framework influences SREP scores and is expected to more directly shape P2R levels over time. The Pillar 2 Guidance (P2G) is expected to play a greater role in the future as well and to further integrate climate risks into capital recommendations.

Our study contributes to the growing body of literature on the role of climate risks in the banking sector, particularly in the context of banking supervision. To date, the ECB has published good practice reports on climate-related risk management and stress testing (ECB 2022*c*,*d*). The EBA has also issued several reports on the integration of climate risks into Pillar 1 (EBA 2022*b*, 2023). We add to this literature by providing a comprehensive analysis that highlights the interplay between Pillar 1 and Pillar 2. Furthermore, our study contributes to the growing empirical literature on both the relevance and the implications of climate risks for financial institutions. We discuss the existing empirical literature in more detail in Section 2.2.

The remainder of this study is organized as follows. Section 2 offers an overview of the latest regulatory and supervisory developments related to climate risks. Furthermore, it reviews the literature and examines the relevance and implications of climate risks for financial institutions and supervisors. In Section 3, we describe our data and sample, and outline the conceptual framework used to structure our analysis. Section 4 presents our findings. Note that within the results section, each sub-section is designed to be largely self-explanatory. Section 5 discusses the limitations of our study and concludes.

2 Theoretical background

2.1 Regulatory and supervisory developments

The management of climate risks has received considerable attention from legislators and supervisors, especially in Europe. In particular, there has been growing interest and work by these actors on the extent to which climate risks are captured and addressed (or not) within the prudential framework.

The European legislator has issued several mandates related to the integration of climate risks into the three pillars of the Basel III framework, making these risks a key supervisory concern (Gruenewald et al. 2023). For example, the EBA has a mandate under the CRD to issue guidelines to credit institutions in all EU member states on minimum standards for the identification, measurement and management of ESG risks.[13] Between 2021 and 2023, the EBA published, by exercising its mandate, various discussion papers and reports exploring the justification for a prudential, risk-based approach to ESG risks (EBA 2021, 2022*b*, 2023). These reports address the integration of environmental risks, including transition and physical risks, into Pillar 1 (EBA 2023) and into risk management practices under Pillar 2 (EBA 2021). Similarly, the Basel Committee on Banking Supervision (BCBS) released a report in December 2022, outlining how climate risks may be more consistently incorporated into the existing Basel framework and reflected within existing Pillar 1 standards (BIS 2022*a*). In the same year, the European Commission adopted new rules requiring additional disclosures under Pillar 3, including both qualitative information on ESG risk management and quantitative information on transition and physical risks.[14]

In line with these developments, the ECB has increasingly incorporated climate and environmental considerations into its supervisory practice. The ECB has made the management of climate and environmental risks one of its supervisory priorities for 2024-2026 (ECB 2024*f*). Through its role in the Single Supervisory Mechanism (SSM), the ECB monitors how significant institutions in the euro area address climate risks (ECB 2020*b*). To support this, the ECB published a guide setting out 13 supervisory expectations for the integration of climate and environmental risks (the "ECB Guide"). It also set staggered deadlines for supervised institutions to comply with these expectations by the end of 2024. In terms of content, these

[13] See Directive 2013/36/EU on access to the activity of credit institutions and the prudential supervision of credit institutions and investment firms.

[14] See Implementing Regulation (EU) 2022/2453 of 30 November 2022 amending the implementing technical standards laid down in Implementing Regulation (EU) 2021/637 as regards the disclosure of environmental, social and governance risks.

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expectations focus primarily on Pillar 2 aspects, including risk management and internal capital adequacy assessment process. Specifically, institutions are expected to consider climate risks in their business strategies, risk appetite frameworks and credit processes, while assigning clear responsibilities for managing these risks. They are also required to collect and report relevant data internally, incorporate climate risks into capital adequacy considerations and conduct stress tests that include these risks. Finally, institutions are expected to consider the potential impact of climate risks on their liquidity position, business continuity and reputation.

Another important supervisory development is the growing number of climate stress tests initiated by central banks, supervisors and regulators. In Europe, the ECB conducted one of the most comprehensive tests in 2022, building on earlier national-level efforts. De Nederlandsche Bank, the Dutch central bank, was among the first to introduce a mandatory stress test focused on transition risks in 2018, while the Banque de France launched a voluntary exercise in 2020 (Alogoskoufis et al. 2021). In 2021, the Bank of England followed with a stress test for major UK institutions, covering both transition and physical risks, and the EBA initiated an EU-wide pilot climate exercise that same year. Outside Europe, central banks in Canada (2020), Australia (2021), Singapore (2022) and the United States (2023) also conducted climate stress tests (AFME 2023). Moreover, over the past few years, more than 100 central banks and financial supervisors have joined the Network for Greening the Financial System (NGFS), a forum aimed at enhancing supervisory practices for managing climate risks and developing climate scenarios (NGFS 2024*a*).[15] This trend once again highlights the growing importance of climate risks for regulatory authorities and supervisors.

However, integrating climate risks into the broader risk management framework is particularly challenging because climate risks act as risk drivers for existing risks, rather than being a separate, stand-alone type of risk. For example, both physical and transition risks can impact institutions by reducing borrowers' ability to repay loans or by affecting the pricing of different asset classes (e.g., equities, bonds and commodities), thereby affecting loan books and trading books (Acharya et al. 2023). As illustrated in Figure 1, climate risks therefore materialize through "conventional" risk types such as credit, market and operational risks, and can affect both their likelihood and severity in different ways. As a result, incorporating climate considerations into risk management requires a nuanced, yet broad and comprehensive approach. This also requires a deep understanding of how climate risks interact with and amplify conventional risks, as well as evaluating where climate-related factors may be inadequately addressed in current risk models and processes.

[15] We discuss some of the NGFS scenarios in Section 4.3.4.2.

In this context, regulators and supervisors have emphasized that climate risk integration should focus on identifying and monitoring those risks that have, or may have, a material impact on institutions' financial health — i.e., their financial position (balance sheet and capital resources), financial performance (profits and losses) and liquidity position (BaFin 2020, BIS 2022*b*). In essence, the primary objective is to raise awareness among institutions about climate risks and their transmission channels, particularly those that manifest through conventional risk types and ultimately affect balance sheets, profitability and liquidity. In terms of conventional risks to focus on, the EBA has particularly stressed the relevance of credit risk in the context of climate risk integration for EU institutions (EBA 2023). This emphasis stems from the fact that their activities and capital requirements are primarily driven by credit risk, as opposed to market or operational risks (EBA 2023). As a result, this study pays particular attention to the relationship between credit and climate risks, especially when discussing Pillar 1 considerations.

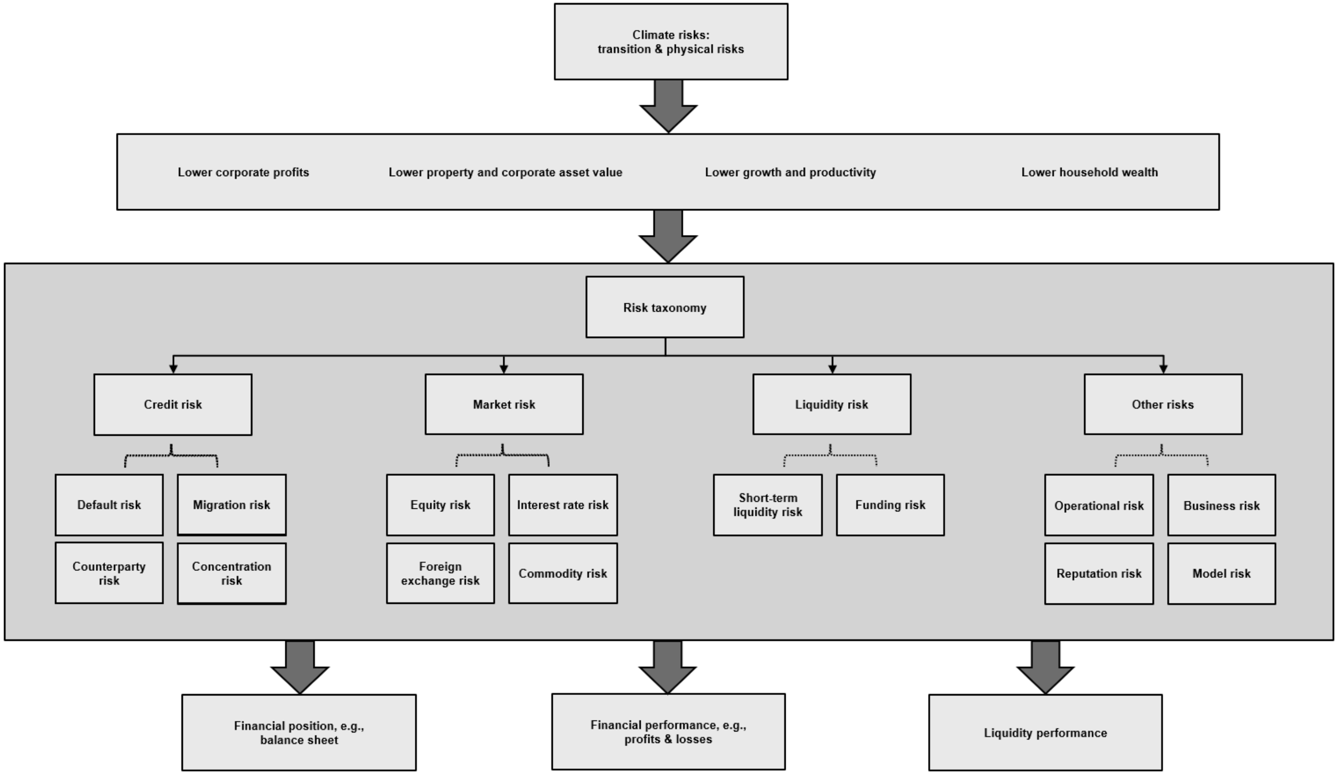

Figure 1: Climate risk transmission channels. The figure illustrates the channels through which climate risks may affect prudential risk types and, in turn, the financial position, financial performance and liquidity performance of institutions. Based on BaFin (2020), EBA (2022*b*), BIS (2022*b*), Acharya et al. (2022). Note that the risks included in the taxonomy are not exhaustive.

2.2 Literature review

What are the motivations for supervisors and credit institutions to integrate climate risks into their prudential and risk management frameworks? In this section, we discuss the growing empirical literature on both the relevance and the implications of climate risks for these actors.[16]

While the scope of their involvement remains a subject of ongoing debate (see e.g., Hellwig 2022, Demekas & Grippa 2022 and Demekas & Grippa 2024), central banks are key actors in the discussion on climate-related risk management. Climate risks are becoming increasingly important to these institutions on two fronts: price stability and financial stability. In the euro area, the ECB has a primary mandate to pursue price stability by ensuring that inflation remains low, stable and predictable.[17] An emerging strand of literature shows that climate risks can contribute to inflationary pressures, making these developments relevant for the ECB to monitor and incorporate into its inflation forecasts. Thus, the ECB's price stability objective is seen as part of the justification for the climate-related policies it has introduced in the last years (Faccia et al. 2021, van 't Klooster & de Boer 2022).[18]

On the one hand, climate change, in particular its physical manifestations, may disrupt supply chains and production processes and reduce agricultural yields, all of which have important implications for inflation dynamics and economic output (Acharya et al. 2023). For example, Pankratz & Schiller (2022) show that weather shocks (extreme heat and floods) negatively affect the financial performance of suppliers and that the financial impact of these shocks is transmitted to customers through existing supply chain links. Faccia et al. (2021) provide evidence for the impact of extreme temperatures on price development as captured by different measures of prices, including consumer and producer prices. Ciccarelli et al. (2024) assess the four largest euro area economies (Germany, France, Italy and Spain) and find that hotter summers lead to upward pressures in terms of food inflation and service inflation. De Winne & Peersman (2021) report that extreme weather events, such as droughts and heatwaves, influence fluctuations in global agricultural commodity prices and impact economic activity of both advanced and developing countries. Finally, Bilal & Känzig (2024) find that every additional 1°C rise in the average temperature on earth means a 12 percent

[16]For extensive literature overviews on the effects of climate risks on financial market participants, see de Bandt et al. (2023), Eren et al. (2022) and Giglio et al. (2021).

[17]See Art. 127 (1) of the Treaty on the Functioning of the European Union (TFEU). Price stability is currently defined by a 2% inflation target over the medium term.

[18]The ECB's second mandate to support broader economic policies by and in the EU is also partly seen as an element of this justification, although we do not discuss this mandate in detail (van 't Klooster & de Boer 2022).

hit to global Gross Domestic Product (GDP), arguing that the macroeconomic effects of climate change have so far been largely underestimated.

On the other hand, climate change may also pose a threat to the overall stability of the financial sector. As noted earlier, climate risks represent a new risk driver that can affect institutions' financial position (balance sheet), financial performance (income statement - P&L) and liquidity position.[19] In this context, these risks are not only of concern to central banks in their role as supervisors, but also a factor that institutions are increasingly required to take into account. In terms of mechanisms, there are three key channels through which climate risks are expected to affect institutions: the credit, market and liquidity risk channels (Acharya et al. 2023, de Bandt et al. 2023).

To illustrate the credit risk channel, climate risks may affect loan books, with both transition and physical risks reducing borrowers' ability to repay their outstanding loans and increasing their default rates (Acharya et al. 2023, Cepni et al. 2024). For example, this may hold for loan exposures to borrowers in sectors with high carbon emissions, facing higher operating costs as a result of regulatory interventions. Similarly, extreme weather events may lead to the destruction or depreciation of physical assets, resulting in higher default probabilities for corporate loans and mortgage loans (Cepni et al. 2024). Ultimately, this may potentially translate into increased loan losses for the banks (Brei et al. 2019).

Nevertheless, the empirical evidence on the credit risk channel is mixed. In particular, while transition and physical risks are a source of financial risk for borrowers (see e.g., Ehlers et al. 2022, Seltzer et al. 2020), the effects on institutions' financial position and financial performance are contrasted. This may be due to factors such as composition and maturities of loan portfolios, but also to differences in the types of institutions (large, well-diversified institutions versus smaller and more local ones) and the wide range of climate risks considered (carbon taxes, heat, flood, etc.). So far, a large strand of the literature has focused on the link between physical risks and institutions' profitability. For example, Blickle et al. (2021) report that weather disasters in the last quarter century had limited effects on U.S. banks' performance. The authors find that loan losses tend to be offset by an increase in loan demand after the disasters, boosting profits at larger banks. On the contrary, Schubert (2021) reports that flood shocks negatively affect U.S. banks' performance, as

[19] To understand the potential effects of climate risks on institutions' financial position and financial performance, it is useful to recall the structure of banks' balance sheets and the link with their P&L. On the asset side, institutions typically hold cash, loans (loan book) and trading assets (trading book). On the liabilities side, institutions typically have deposits, short-term and long-term debt (e.g., obligations and commitments related to derivatives contracts) and equity. Net income (from the P&L) increases equity, while a net loss decreases it.

measured by the return on assets (ROA). Ge et al. (2022) and Sastry et al. (2024) observe that the underlying assets of U.S. institutions with large real estate portfolios in climate-vulnerable regions (e.g., coastal areas prone to sea-level rise) are at risk of increased losses due to rising trends in insurance premiums, insurance company withdrawals and a decline in the quality of insurance quality. Vollmar & Wening (2023) analyze the effects of heat on regional institutions in Germany and find a negative impact in terms of profitability (ROA) for institutions servicing industries in heat-affected regions compared to institutions in less heat-affected regions. On the transition risks side, while there is evidence that institutions are managing these risks, including by adapting their lending, re-balancing their portfolios within borrower industries and adjusting their pricing (see e.g., Chava 2014, Delis et al. 2019, Ivanov et al. 2023, Martini et al. 2023), their impact on bank performance is less evident. For example, Jung et al. (2023) find that the credit exposures of U.S. institutions to transition risks are modest and, on average, do not exceed 14% of their loan portfolios under several scenarios. Referring to an ECB study, the authors also underscore that "expected losses of European banks' credit portfolios are minimal, around 0.7% of the total loan exposure under both the accelerated and the delayed transition scenarios" (Jung et al. 2023, Emambakhsh et al. 2023).

While the credit risk channel is widely regarded as the most relevant one for banks (EBA 2023), market risk is considered the second most critical. Market risk refers to the potential for losses arising from fluctuations in market prices, including the risk of losses from trading assets held in the trading book and the potential for losses due to foreign-exchange risk or commodity risk from assets in the banking book (EBA 2023). Bonato et al. (2023*a*) analyze the role of climate risks in forecasting realized volatility of exchange rate returns of major fossil fuel exporters and find that climate risks (temperature, wind, precipitation) have incremental out-of-sample predictive value for exchange rate volatility. In a follow-up study, Bonato et al. (2023*b*) report that climate risks have predictive value for realized stock market volatility at the U.S. state-level. Bertolotti et al. (2019) analyze the impact of physical events on the stocks of U.S. electric utilities and find significant market price reactions after hurricanes. Furthermore, since climate risks are anticipated to affect future cash flows, market risk also relates to the effects of such risks on the present-day values of financial assets (Acharya et al. 2023). For example, if climate risks are considerably under-priced, changes in investor perception may lead to re-pricing of assets and, potentially, to losses for asset holders such as banks (Demekas & Grippa 2024). A large strand of the literature therefore focuses on the extent to which climate risks explain stock market returns (see e.g., Bolton & Kacperczyk 2021, Ardia et al. 2023, Aswani et al. 2023), are priced on stock and bond markets (e.g., Huynh & Xia 2020, Painter 2020, Acharya et al. 2022) and affect investor beliefs (e.g., Bakkensen & Barrage 2021, Ceccarelli & Ramelli 2024).

Finally, in addition to credit and market risks, there is also a potential liquidity risk channel to consider (Acharya et al. 2023). However, this channel appears not very well understood to date and research remains limited (de Bandt et al. 2023). So far, there is empirical evidence that climate risks may lead to both decreases and increases in deposit withdrawals after major disasters. For example, Choi et al. (2022) find that institutions with a poor environmental reputation are more likely to face a decline in their branch deposits in regions exposed to severe physical risks. In some cases, climate risks, particularly physical risks, are shown to increase loan demand, which offsets losses but puts pressure on liquidity buffers. Brei et al. (2019) report that following natural catastrophes (hurricanes) institutions face large deposit withdrawals and experience a negative funding shock to which they respond by reducing their loan supply and drawing on their liquid assets. Koetter et al. (2020) study the role of German local banks in the context of natural disasters (flooding) and find that local banks that are domiciled in unaffected counties but are exposed to disaster-ridden firms in affected counties lend 3% more in the post-flood period compared with unexposed local banks. Cortés & Strahan (2017) find that institutions are incentivized to cut lending from markets unaffected by natural disasters in order to have enough liquidity to support disaster-affected markets facing increased credit demand.

3 Research method and sample

3.1 Semi-structured interviews

We adopt an empirical approach based on semi-structured interviews with risk experts, combined with insights from archival data, primarily from Pillar 3 reports. This approach allows us to gather information on both the climate-related risk management practices of institutions and the experiences and views of practitioners. We also use data from the Pillar 3 reports to guide and refine our interviews. This data proved particularly helpful in gaining an overview of the climate-related risk management processes in place. Finally, we analyze supervisory and regulatory guidelines to gain a deeper understanding of the expectations and recommendations set by supervisors and regulators.

We conducted semi-structured interviews with risk experts mainly from significant institutions that are directly supervised by the ECB and subject to the CRR. The ECB maintains and regularly updates a public list of these institutions (ECB 2024*d*). For our study, we used the list as of January 1, 2023 and selected institutions classified as "credit institutions". We particularly focused on institutions established in Germany due to our geographical proximity and personal contacts, which contributed to a higher response rate. As of January 1, 2023, the ECB's list of supervised entities included 18 SIs established in Germany. Our sample covers experts from 12 of these institutions (approximately 67%). Furthermore, we also targeted experts of large credit institutions established in France and the Netherlands. Our sample covers three of these institutions. In addition, our sample includes one expert from a Less Significant Institution (LSI) in Germany that is preparing for ECB supervision and thus actively integrating climate-related risks.[20] Finally, we conducted one interview with an expert in PD modeling and stress testing from a large German institution that is exempt from the scope of the CRR, but is subject to key banking regulations and supervised by the German banking supervisory authorities. To sum up, our sample includes 17 institutions, of which 15 are credit institutions currently directly supervised by the ECB.

We identified respondents through LinkedIn and via personal recommendations. Employees of relevant institutions were screened on LinkedIn using keywords such as "climate risk", "ESG risk", "credit risk", "credit risk modeling", "risk controlling", "risk management", "stress testing", "scenario analysis", "IRB", "rating", "PD model", "environmental risk". This process led to 62 potential respondents being contacted. Overall, 30 risk experts par-

[20] LSIs have been explicitly invited by the ECB to apply its climate-related expectations in a manner that is proportionate to the nature, scale and complexity of their activities (ECB 2020*b*). Furthermore, 79 LSI participated in the 2022 thematic review on climate-related and environmental risks (ECB 2022*e*).

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ticipated, which corresponds to a high response rate of 48%. The breakdown of respondents is presented in Table 2. To maintain full anonymity, the names of the respondents and their institutions are not disclosed. Furthermore, we deliberately use the pronoun "they" instead of "she" or "he". Each respondent is assigned a "respondent ID", and each institution receives an "institution ID", which are used to present our findings. As can be seen, our sample includes experts from various risk-related functions, offering different perspectives on climate risk integration, covering both Pillar 1 and Pillar 2 aspects. Furthermore, our sample includes a wide range of large private commercial institutions (53%), public institutions (35%) and cooperative institutions (12%), with total assets ranging from EUR 30 billion to over EUR 1,000 billion.

The decision to use semi-structured interviews, rather than a traditional survey with a set of pre-defined answers, provided several important advantages for our research. First, this approach allowed us to ask detailed questions about climate risk integration and thus better capture the complexity of the topic at hand. In addition, by allowing respondents to freely express their thoughts and views, we encouraged a more open and nuanced discussion, shedding light on the challenges currently faced. Second, the flexibility of the interviews enabled us to tailor questions to each respondent's specific background, responsibilities and expertise. While we adhered to a core set of questions, some respondents had specific expertise in areas such as stress testing, while others had broader risk management roles, allowing us to explore certain topics in more depth in individual interviews. Importantly, we carefully selected respondents to ensure they had substantial expertise in their respective fields. Third, the interviews allowed respondents to introduce additional topics or concerns. This approach enabled us to incorporate insights from earlier interviews into subsequent ones, integrating emerging themes as they arose (Hummel & Bauernhofer 2024).

The interviews were conducted in German or French and structured around open-ended questions. Each interview lasted approximately 60 minutes. The interviews were conducted between February and November 2024. Prior to the interviews, respondents were asked for their consent to be recorded using an audio recorder. We transcribed the interviews vebatim, resulting in about 500 pages of text. Key excerpts from the interviews were later translated into English. Thematic analysis was undertaken based on the interview transcripts (Braun & Clarke 2006). Using the software program MAXQDA Plus 2020, we carefully examined each interview transcript to perform qualitative data coding. This process allowed us to identify significant themes and refine our conceptual framework, presented in Section 3.3. This framework serves as the foundation for the structure of this study.

Table 2: Sample composition.

Respondent ID	Respondent expertise and/or role	Institution ID	Total assets	Country
A1	Director Regulatory Policy, Capital & Liquidity	A	EUR 30-50 bn	Germany
A2	Senior Stress Testing Expert	A	EUR 30-50 bn	Germany
A3	Risk Expert Stress Testing Expert	A	EUR 30-50 bn	Germany
B1	Director Risk Methods, Risk Controlling	B	EUR 30-50 bn	Germany
B2	Manager Risk Management	B	EUR 30-50 bn	Germany
C1	Executive Director, Climate Risk	C	EUR 50-75 bn	Germany
C2	Expert Credit Risk and Market Capital	C	EUR 50-75 bn	Germany
D1	Senior Project Manager, Group Credit Risk Management	D	EUR 300-500 bn	Germany
D2	Expert Risk Management	D	EUR 300-500 bn	Germany
E1	Head of Department, Overall Bank Risk	E	EUR 50-75 bn	Germany
F1	Director Strategic Analytics	F	>EUR 1,000 bn	Germany
G1	Head of Stress Testing Methodologies and Models	G	>EUR 1,000 bn	France
G2	Senior Risk Manager, Physical Risk Lead	G	>EUR 1,000 bn	France
H1	Expert ESG Risks	H	EUR 500-1,000 bn	Germany
H2	Risk Manager Group Risk Controlling	H	EUR 500-1,000 bn	Germany
H3	Head of Department Stress Tests and Scenario Analysis	H	EUR 500-1,000 bn	Germany
H4	Stress Testing Expert	H	EUR 500-1,000 bn	Germany
H5	Expert Risk Controlling, ICAAP, ESG Risk Management	H	EUR 500-1,000 bn	Germany
I1	Expert Rating Methodology, Risk Controlling & ESG Risk	I	EUR 150-300 bn	Germany
I2	Group Manager Risk Controlling	I	EUR 150-300 bn	Germany
J1	Head of Strategic Risk Control	J	EUR 30-50 bn	Germany
J2	Director ESG Risk	J	EUR 30-50 bn	Germany
K1	Head of Model Risk Management and Validation	K	EUR 75-100 bn	Germany
K2	Expert Risk Controlling, Non-Financial Risk and Sustainability Risk	K	EUR 75-100 bn	Germany
L1	ESG Stress Testing Expert	L	EUR 30-50 bn	Germany
M1	Expert Risk Controlling, Credit Risk Stress Test and PD Modeling	M	EUR 500-1,000 bn	Germany
N1	Managing Director Risk Controlling	N	EUR 150-300 bn	Germany
O1	Global Head Risk Control	O	EUR 100-150 bn	Germany
P1	Team Lead ESG Risk Management	P	EUR 500-1,000 bn	Netherlands
Q1	Expert ESG Risk and Climate Risk	Q	EUR 150-300 bn	Netherlands

3.2 Archival data

We reviewed the 2023 Pillar 3 reports from the institutions in our sample. Although Pillar 3 reports (also known as regulatory disclosure reports)[21] were not the focus of specific interview questions (e.g., we did not ask the respondents to discuss the preparation of these reports or the challenges their institutions face in disclosing climate-related information), we used the content of these disclosures to gain insights into the institutions' climate-related risk management practices and to guide our interview questions. In addition, we used the qualitative information from the disclosures to complement our interview findings and offer a more comprehensive perspective of the risk management approaches employed by the institutions in our sample.

Under the CRR, Pillar 3 disclosures are mandatory disclosures for significant institutions (see Art. 431 of the CRR) and must be published at least annually (see Art. 433 of the CRR). The content of the disclosures is also largely determined by the CRR, which specifies technical criteria for the disclosure of risk management objectives and policies (see Art. 435 of the CRR), own funds (see Art. 437 of the CRR), capital requirements (see Art. 438 of the CRR), capital buffers (see Art. 440 of the CRR) and leverage (see Art. 451 of the CRR), among others. Thus, Pillar 3 reports contain important information on both Pillar 1 and Pillar 2 aspects. In addition to the above, these reports are typically organized by risk type (e.g., credit risk, market risk, operational risk, liquidity risk, reputational risk, model risk, etc.) and provide specific information on the institutions' exposure to and management of each risk type.

An important development is the requirement for Pillar 3 reports to include detailed information on ESG risks,[22] with a particular focus on physical risks and transition risks. Institutions whose securities are admitted to trading on a regulated market in the EU have to comply with the disclosure requirements pursuant to Art. 449a of the CRR.[23] In January 2022, the EBA published the final Implementing Technical Standard (ITS) (EBA ITS 2022/01) on prudential disclosures on ESG risks, which defines the nature of these disclosure requirements and forms the basis for Implementing Regulation (EU) 2022/2453.

In particular, this ITS specifies the set of qualitative and quantitative information to be disclosed by institutions regarding ESG risks. Qualitative disclosures include information

[21] Pillar 3 of the Basel framework focuses on market discipline through prescribed public disclosures.

[22] Climate risks are typically treated as a subset of ESG risks and fall under the environmental pillar.

[23] While Art. 449a of the CRR itself does not specify the content of the ESG risk disclosures, it refers to Art. 98 (8) of the CRD, which, in conjunction with Art. 434a of the CRR, gives the EBA a mandate to develop an Implementing Technical Standard (ITS).

on business strategy, governance and risk management related to environmental risks, while quantitative disclosures cover exposures to transition risks (templates 1 to 4), exposures to physical risks (template 5) and mitigating actions (templates 6 to 10).[24]

3.3 Conceptual framework

Analyzing the interaction between climate risks and conventional risk types, as well as the integration of climate-related considerations, requires an understanding of the theoretical foundations of institutions' capital requirements and risk management. This brings the banking prudential framework (the "Basel framework") into focus (Redondo & Aracil 2024, EBA 2021, Gruenewald et al. 2023).[25]

The Basel framework, developed by the BCBS, is an internationally agreed set of measures and standards for prudential regulation. The EBA participates as an observer in the Basel Committee and plays a crucial role in implementing the Basel standards within the EU (EBA 2024). Far from being a set of loose guidelines, the Basel framework is directly applied in the EU through the CRR and the CRD.[26] The institutions in our sample operate under both the CRR and the CRD, making the Basel framework applicable to them. The framework itself is structured around three fundamental pillars, which we explore further in this study. Specifically, we use key elements of Pillar 1 and Pillar 2 to guide our discussion of climate risk integration, as illustrated in Figure 2.

[24] See Implementing Regulation (EU) 2022/2453 of 30 November 2022 amending the implementing technical standards laid down in Implementing Regulation (EU) 2021/637 as regards the disclosure of environmental, social and governance risks.

[25] The Basel I Accord, introduced in 1988, established a framework for minimum capital requirements based on risk-weighted assets to ensure institutions held adequate capital to cover credit and market risks. In 2004, the Basel II Accord expanded this framework by adding operational risk alongside credit and market risks, introducing three pillars: minimum capital requirements (Pillar 1), the supervisory review process (Pillar 2), and market discipline through transparency (Pillar 3). The Basel III reforms, developed in response to the 2007-2008 financial crisis, aim to enhance institutions' resilience to financial and economic shocks by further strengthening risk management and addressing liquidity and funding risks.

[26] See Regulation (EU) No 575/2013 on prudential requirements for credit institutions and investment firms and Directive 2013/36/EU on access to the activity of credit institutions and the prudential supervision of credit institutions and investment firms.

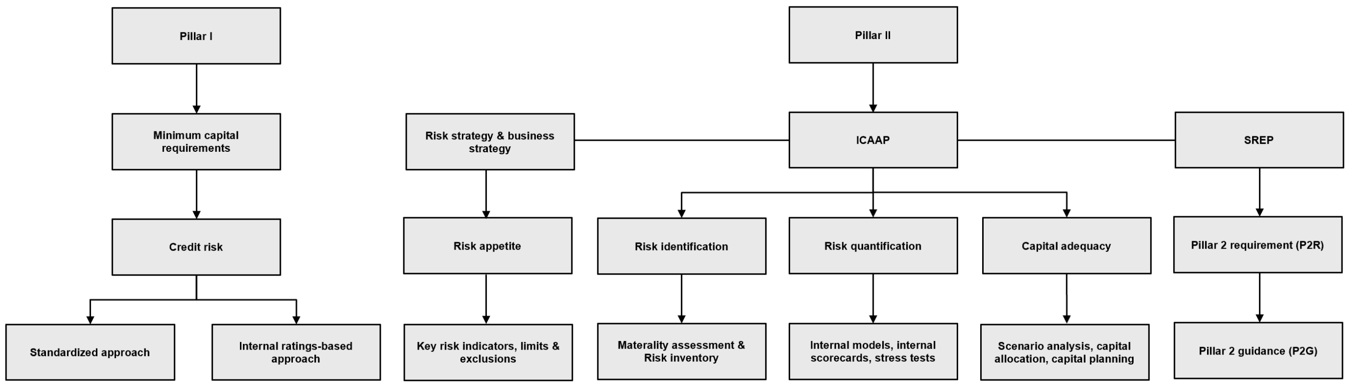

Figure 2: Conceptual framework. Own illustration.

There are important differences between the two pillars, leading to different approaches, but also challenges, in integrating climate risks. Pillar 1 of the Basel framework focuses on minimum capital requirements for credit, market and operational risks. Capital requirements are determined as fixed percentages of RWA. The RWA is a measure of an institution's assets adjusted for the level of risk inherent to those assets. This level of risk is partly determined by a risk weight. The key idea is therefore to capture the relative riskiness of various assets on an institution's balance sheet (Holscher et al. 2022). The calculation of RWA is governed by a set of rules applied uniformly across institutions, aiming to establish consistent regulatory standards for risk-based capital requirements. An important metric under Pillar 1 is the Common Equity Tier 1 (CET1) ratio, which compares an institution's CET1 capital to its total RWA (i.e., the sum of credit RWA, market RWA and operational RWA). The primary goal of minimum capital requirements, along with regulatory buffers, is to ensure that institutions can absorb losses beyond expected levels and thus maintain an amount of capital necessary to be regarded as a viable going concern by creditors and counterparties (Holscher et al. 2022). Expected losses are typically covered ex-ante by risk-based pricing and through loss provisioning under International Financial Reporting Standard 9 (IFRS 9). Expected credit loss provisions are deducted from capital (Krüger et al. 2018).[27]

In recent years, both the BCBS and the EBA have published discussion papers on incorporating climate risks into the Pillar 1 framework (EBA 2022*b*, BIS 2022*a*). However, unlike credit, market and operational risks — where clear rules for calculating RWA are already well-established — neither the BCBS nor the EBA have proposed new, specific capital requirements, such as dedicated risk weightings, for assets exposed (or less exposed) to climate risks under this pillar.[28] Instead, the emphasis has been on how these risks can be more consistently integrated into the existing frameworks and models, with a focus on credit risk and, to a lesser extent, market risk. For example, the ECB issued in 2024 an updated guidance on internal models, requiring institutions to incorporate material climate-related risk drivers into their existing Pillar 1 models for credit and market risks (ECB 2024*a*).

Integrating climate risks into the existing Pillar 1 framework presents challenges due to several factors, including the framework's rigidity, its short-term focus and its reliance on

[27]More specifically, expected credit losses provisions are deducted from accounting equity, which is the starting point for regulatory capital, e.g., CET1. Provisions are not covered in detail in this study, but we touch upon some aspects in Section 4.3.5.3 and Section 4.5.3.

[28]For example, the EBA has so far ruled out the introduction of a green supporting factor, which would lower capital requirements for environmentally sustainable exposures by reducing risk weights or adjusting the RWA calculation (EBA 2023). A similar instrument already exists under Pillar 1, however for small and medium-sized enterprises and infrastructure projects, allowing institutions to apply a discount factor, resulting in a downward adjustment in risk weights for SME and infrastructure-related exposures meeting certain eligibility criteria (EBA 2023).

historical data for calculations (Gruenewald et al. 2023). In addition, a less explored issue in the literature is the potential for double counting. For example, internal models under Pillar 1, which are designed to quantify the specific risk of an exposure, already incorporate various risk factors that may implicitly account for some climate-related risks (EBA 2022*b*). This broader context raises important questions about where climate risks may already be captured implicitly and where a more explicit approach is necessary.

In contrast, Pillar 2 of the Basel framework encourages institutions to implement individual risk management strategies for identifying, measuring and monitoring their risks beyond minimum regulatory requirements. Key components of this pillar include the ICAAP and the SREP. The ICAAP is characterized by an internal capital adequacy concept comprising an internal capital adequacy calculation, stress tests and capital planning processes (BaFin 2018). It is closely linked to the development of both business and risk strategies, as well as risk management processes (BaFin 2018). Supervisors evaluate the soundness of an institution's ICAAP and overall risk management framework through the SREP. Based on their assessment, supervisors may prescribe or recommend the institution to hold additional capital (e.g., via the Pillar 2 Requirement or Pillar 2 Guidance) or take other corrective actions.

Compared to Pillar 1, the treatment of climate risk integration is more concrete for Pillar 2 (Smoleńska & van 't Klooster 2022, Gruenewald et al. 2023). The ECB's 13 supervisory expectations regarding the integration of climate risks into risk management practices have placed significant emphasis on Pillar 2, particularly on the integration of these risks into the ICAAP. Notably, the ECB highlighted that the Guide on climate-related and environmental risks should be considered alongside the ECB guide to the ICAAP, indicating that these two guides are complementary (ECB 2018, 2020*b*). As the ICAAP is an internal and individual process, this also suggests that the integration of climate risks requires tailored approaches across institutions. Finally, the treatment of climate risk under Pillar 2 is also influenced by the integration of climate risks into the SREP, where the ECB now plays a critical role in reviewing how institutions manage these risks (Gruenewald et al. 2023).

What does the combined consideration of Pillar 1 and Pillar 2 imply for the integration of climate risks? Standardizing the treatment of such risks under Pillar 1 would likely contribute to establishment of consistent regulatory standards across all institutions, potentially resulting in higher minimum capital requirements for institutions exposed to climate risks. As Pillar 1 capital calculations often serve as the basis for further risk assessments under Pillar 2 (BaFin 2018), a more systematic integration of climate risks into Pillar 1 may indirectly raise the baseline requirements and also impact capital considerations under Pillar 2.

The current guidelines and expectations for both Pillar 1 and Pillar 2 provide institutions with large flexibility in terms of implementation. This highlights the need to examine how individual institutions are integrating climate risks and the specific challenges they face in doing so. Furthermore, where climate risks act as drivers of other risk types, an important question emerges: to what extent, and how, are climate risks being factored into institutions' risk management and capital considerations? If climate risks are (or are to be) incorporated, it is crucial to understand the mechanisms through which this integration occurs, as well as how institutions and supervisors determine the capital resources needed. To support this analysis, Figure 2 illustrates the conceptual framework of our study and outlines the key areas that were the focus of our interviews.

4 Results

4.1 Pillar I: Integrating climate risks into the standardized approach (SA)

4.1.1 Background and rationale

We start by discussing important features of Pillar 1 and explore both potential and existing approaches for integrating climate risks. As noted in Section 3.3, Pillar 1 focuses on the establishment of minimum capital requirements for three primary types of risk: credit risk, market risk and operational risk. Under this framework, capital requirements are calculated as fixed percentages of RWA based on these risk types (Holscher et al. 2022).[29]. The EBA describes climate risks as a particularly relevant driver of credit risk, which in turn accounts for the largest share of institutions' total capital requirements (compared to the capital requirements resulting from market and operational risks) (EBA 2022*b*).[30] As a result, our analysis of Pillar 1 focuses primarily on the interaction between climate and credit risks.

In this section, we delve into a key approach to credit risk: the standardized approach. Given its importance in determining capital requirements for credit risk under Pillar 1, we explore the main channel for integrating climate risks into this approach and address the challenges involved. As of June 2023, the standardized approach represented on average 54% of all credit risk-weighted exposure amounts in the EU (EBA 2023). Several participants (A1, B1) pointed out the increasing regulatory shift towards this approach over internal models (further discussed in Section 4.2). A notable example of this shift is the introduction of an "output floor", applicable as of January 2025, designed to prevent institutions from using internal models to significantly lower their capital requirements compared to the standardized approach (Smoleńska & van 't Klooster 2022). Specifically, with the introduction of the output floor, the RWA calculated using internal models will not be allowed to fall below 72.5% of those calculated by the standardized approach, limiting the potential capital benefit from internal models to 27.5%. The respondents observed that this restriction makes using internal models more challenging, which is likely to drive wider adoption of the standardized approach in the coming years.

Under the standardized approach, the RWA resulting from credit risk are calculated as the

[29]For example, all institutions must hold capital equivalent to at least 8% of total RWA.

[30]The EBA notes that "credit risk is considered the most relevant part of the prudential framework, with RWAs attributable to credit risk accounting for over 80% of total RWAs" of credit institutions in the EU (see p.24, EBA 2022*b*).

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product of the exposure value (net of credit risk mitigation instruments) and a specific risk weight, as illustrated in Figure 3. A key feature of this approach is the reliance on external credit assessments (i.e., external credit ratings) to determine the risk weight (see Art. 135 of the CRR). These external credit assessments reflect an agency's opinion about the issuer's (i.e., the borrower's) ability to meet its financial obligations on time and in full. Each external credit assessment is assigned to a Credit Quality Step (CQS). The CQS, together with the exposure class, determine the risk weight. The exposure class depends on the type of issuer, such as corporate, retail or public sector entities (see Art. 112 of the CRR).

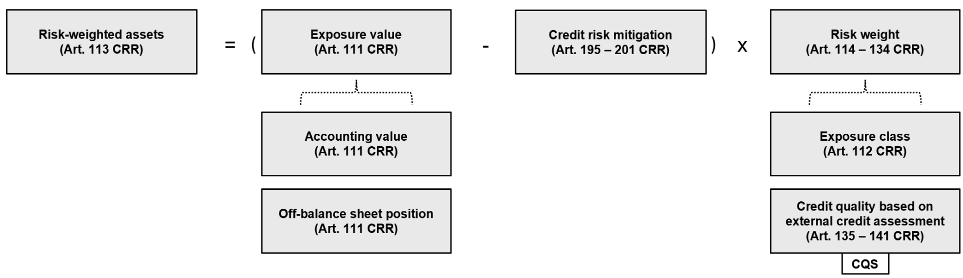

Figure 3: Calculation of risk-weighted assets (RWA) under the standardized approach for credit risk. Based on Regulation (EU) No 575/2013 on prudential requirements for credit institutions and investment firms (CRR).

Only credit assessments from external credit rating agencies explicitly approved by the regulator are permitted.[31] Under the standardized approach, institutions have to formally nominate a rating agency whose credit ratings they will use. Consequently, the degree to which climate risks are integrated into the standardized approach — and thus into the calculation of the risk weight and, indirectly, the minimum capital requirements for credit risk — largely depends on the selected agency, its methodologies and its approach to incorporating climate-related factors into credit risk assessments.

The EBA has already extensively discussed this issue, identifying two primary challenges in this context (EBA 2022*b*, 2023). First, the degree to which credit rating agencies incorporate climate risks into their credit assessments varies significantly from one to the other, leading to an inconsistent treatment of such risks across the industry. Second, the EBA also pointed to a lack of transparency in the methodologies used by credit rating agencies. In particular, the specific ways in which these agencies incorporate climate risks into their ratings are often unclear, making it difficult for institutions to fully understand whether and how climate-related factors influence their final rating decision.

[31] A list of such rating agencies is published by the EBA and regularly updated (see Art. 135 of the CRR).

4.1.2 Credit ratings and dialogue with rating agencies

In our sample, all but one institution (A) rely on internal models to calculate capital requirements for credit risk. In this section, we build on the EBA's earlier observations by adding two key insights shared by a respondent (A1) from this institution and exploring the challenges that were highlighted.

First, the respondent stressed that large, globally operating institutions heavily rely on the three major credit rating agencies — Moody's, Standard & Poor's and Fitch. This expert noted that their institution uses ratings from all three, rather than opting for smaller, less established agencies that have more limited coverage. Currently, the broad coverage provided by these agencies is considered to outweigh concerns about their treatment of climate risks. Therefore, the extent to which climate risks are integrated largely depends on how these three leading agencies, in particular, incorporate such factors into their ratings:

> *"If you are a globally operating bank, then there is a certain expectation in the market that you will use these rating agencies [Moody's, Standard & Poor's and Fitch]. But if you are a specialized bank, such as the Umweltbank, where sustainability is part of the core strategy, then I could imagine that you might try to take a closer look at the sustainability criteria applied by the rating agencies and their coverage of climate risks. In this case, you might also select a smaller agency with a stronger sustainability focus."* **(A1)**

At this stage, it is also important to note that the European Securities and Markets Authority (ESMA), which oversees the rating approval process, conducted an assessment in 2019 of the extent to which credit ratings take into account ESG factors (ESMA 2019). The ESMA concluded that such factors, including climate-related factors, are taken into account in credit ratings, but that their importance and incorporation varies across asset classes. In addition, the ESMA advised against amending the regulation governing credit rating agencies to more explicitly account for ESG-related factors in credit risk assessments (ESMA 2019).

Our respondent also pointed out that direct dialogue between institutions and rating agencies regarding their methodologies is rather rare. In practice, external ratings are imported into internal systems that assign the appropriate risk weights. As a result, this respondent believed it is unlikely that an institution could influence a rating agency's methodology to better incorporate climate risks unless the agency is already doing so.

An exception to this may arise with the implementation of the CRR III, which is due to take effect in January 2025. Specifically, the CRR III amends Article 138 of the CRR, restricting the use of credit ratings that include assumptions of implicit government support. While this regulation applies to credit ratings for certain financial institutions rather than corporates, the respondent viewed it as an opportunity for institutions to re-examine rating methodologies more broadly:

> *"New regulations could drive a broader discussion on rating methodologies. A clear example is the implementation of CRR III, where institutions, when assessing other institutions as counterparties, will only be allowed to use ratings that exclude embedded government support. This is likely to prompt institutions to engage with their credit rating agencies and take a closer look at the underlying methodologies, as such ratings are currently quite limited."* **(A1)**

4.2 Pillar I: Integrating climate risks into internal models (IRB)

4.2.1 Background and rationale

Most institutions in our sample use internal models under Pillar 1 to calculate RWA from credit exposures. This section outlines the key features of these internal models for credit risk, while the following sections consider approaches to integrating climate risks and discuss the main challenges highlighted by our respondents.

With internal models and the Internal Ratings-Based Approach (IRB), institutions use their own modeling techniques and internal data to estimate key credit risk parameters. There are two types of internal models for credit risk: the Foundation Internal Ratings-Based Approach (F-IRB) and the Advanced Internal Ratings-Based Approach (A-IRB). Under the F-IRB, institutions model only the PD using their internal approach. In contrast, under the A-IRB, institutions can also estimate their own Loss Given Default (LGD) and Exposure at Default (EAD). Both approaches share the common feature that institutions develop their own PD models for credit risk exposures based on internal ratings, which help categorize borrowers by their risk of default. These models are subject to supervisory approval and have to fulfill a set of requirements set forth in the CRR.

Figure 4 illustrates the calculation of RWA under the internal ratings-based approach. As shown, the credit risk parameters associated with the internal rating play a key role. The input parameters PD, LGD and Maturity (M) influence the risk weight and ultimately determine the RWA.[32]

[32] Note that several parameters, including PD, LGD, M and Credit Conversion Factors (CCFs), are involved in credit risk modeling (see EBA 2023). This study focuses on the integration of climate risks into internal ratings, particularly in relation to PD considerations.

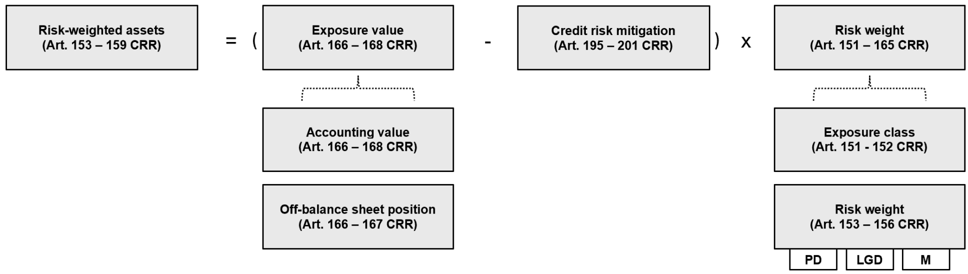

Figure 4: Calculation of risk-weighted assets (RWA) under the internal ratings-based approach (IRB) for credit risk. Based on Regulation (EU) No 575/2013 on prudential requirements for credit institutions and investment firms (CRR).

An important development introduced in the latest revision of the ECB guide to internal models is the expectation that institutions incorporate material climate risks in their internal models for credit risk (ECB 2024*a*). Specifically, the ECB stated that "where climate-related and environmental risks drivers are found to be relevant and material, institutions should include such risk drivers in their internal models approved for use for the calculation of own funds requirements for credit and market risk" (p.13, ECB 2024*a*). In addition, the EBA also commented on the integration of climate risks into internal models for credit risk and formulated specific recommendations (EBA 2023). In particular, the EBA noted that as the "impact of climate risks on defaults and loss rates becomes available, institutions should reflect these risks in their PD and LGD estimates through a re-development or recalibration of their rating systems in the long term" (p.58, EBA 2023).

Overall, these expectations and recommendations have important implications, both in terms of Pillar 1 and Pillar 2 aspects. The direct implication is that institutions are required to test and evaluate whether climate-related risk drivers are a material predictor of credit risk within their portfolios. If they are, the ECB guide to internal models suggests that climate risks should be incorporated into internal ratings-based models and thus into PD modeling (and LGD modeling, depending on whether F-IRB or A-IRB is in place), requiring a comprehensive review of the modeling process. In addition, it also raises important questions about how climate risks are to be incorporated, e.g., by adding risk factors quantitatively into the models or indirectly through the use of overrides and additional margins of conservatism.

Institutions face further implications. For example, testing whether climate risks are a material predictor of credit risk requires access to comprehensive, high-quality data on relevant risk drivers integrated into a reference data set (EBA 2023). In cases where such quantitative data is lacking, institutions have to establish processes and implement tools to collect the necessary climate-related information. These tools and processes are essential components of the risk identification, risk inventory and risk quantification processes under Pillar 2, as discussed in Section 4.3.2. While the ECB stresses the importance of integrating "material" climate risks into the models, it does not prescribe specific approaches for assessing materiality. As shown in Section 4.3, institutions have adopted different approaches to evaluate the materiality of climate risks.

Finally, another important consideration, raised by several respondents, is that while institutions may use internal models for credit risk, the models themselves may not always be developed in-house, but rather provided by external vendors. For example, they noted that many German "Landesbanken", which are supervised by the ECB, rely on a rating tool developed by Rating Service Unit GmbH & Co. KG (RSU). Similarly, German savings institutions ("Sparkassen") commonly rely on a tool developed by Sparkassen Rating und Risikosysteme GmbH (SR) for their rating systems. To ensure that these institutions integrate material climate risks into their capital considerations under Pillar 1, it is therefore essential to also assess the methodologies of these external model providers.

In the following sections, we examine the approaches described by the respondents for integrating climate risks into internal ratings-based models and discuss the associated challenges and implications, with a primary focus on PD considerations. Figure 5 provides a simplified representation of the rating process in the context of internal ratings-based approaches, illustrating the link between the rating and the final PD (see EBA (2017) for a detailed explanation of the PD estimation process). Ratings are typically based on a combination of quantitative and qualitative rating criteria or risk drivers, which we discuss in Section 4.2.3. One approach to integrating climate risks is to incorporate climate-related factors quantitatively, either as new risk drivers or through adjustments to existing rating criteria. Institutions may also apply overrides in the rating process when "individual circumstances, related to a given obligor or exposures, cannot be reasonably captured by the model" (p.12, EBA 2017). These overrides offer an indirect way of accounting for climate risks. In addition, model recalibration may be necessary, meaning that the weights assigned to certain risk drivers may need to be adjusted to better account for climate risks as reflected in historical data. The final PD typically includes a MoC to account for uncertainties in the best estimate of the risk parameter (EBA 2017). This margin may also be applied to address data limitations, such as inadequate or incomplete climate-related data, and other sources of uncertainty (BIS 2022*a*).

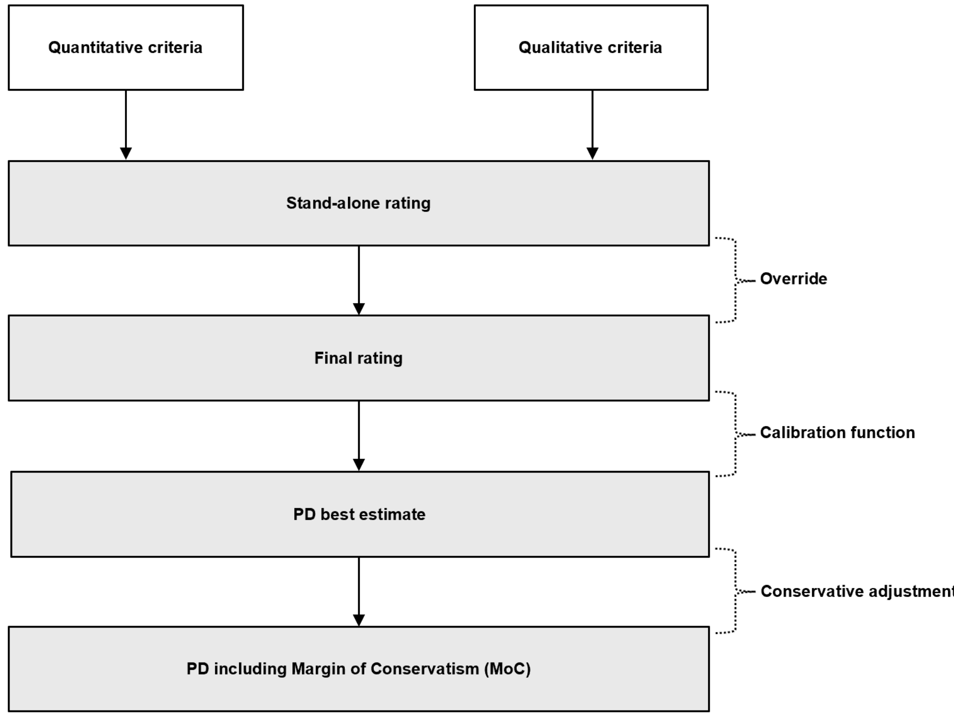

Figure 5: From stand-alone rating to PD estimation under the internal ratings-based (IRB) approach. Adapted from Prof. Dr. Stefan Reitz and based on EBA (2017).

4.2.2 Materiality

As outlined in Section 4.2.1, the ECB expects internal ratings-based models to incorporate climate risks when they are identified as material risk drivers (ECB 2024*a*). This expectation brings the concept of materiality into focus and calls for a discussion of its interpretation in the context of the Pillar 1 framework. Our analysis shows that nine institutions in our sample report in their Pillar 3 disclosures that climate risks are considered to be material for credit risk exposures. Of these, one institution (C) quantitatively integrates climate risks into its PD models (for corporates) under Pillar 1. One of the respondents (C1) from this institution explained:

> *"We incorporate climate risk into our ratings. The assessment feeds into the models. The corporate rating model/PD including a climate risk assessment is used for capital calculations under the foundation IRB approach approved by the ECB. Therefore, we consider a climate risks assessment to calculate capital."* **(C1)**

The remaining institutions adopt a more indirect approach, primarily through the use of rating overrides,[33] as discussed in Section 4.2.4. At present, although all institutions in our sample have developed some form of internal climate (or ESG) scoring methodology, these scores are generally not quantitatively integrated into PD models under Pillar 1. Some institutions (e.g., D) indicate in their disclosure reports that climate risks only become material over a period of at least five to ten years. However, even among those institutions (e.g., I) that find a material effect of climate risks over a shorter time horizon of one to five years, these risks are not directly integrated into the models as a distinct risk factor. For example, one of the institutions (B) states in its Pillar 3 report that both physical and transition risks exhibit "relevant impact correlations" for credit risk. An expert (B1) from this institution offered a counter-argument regarding the quantitative integration of climate-related risks in the Pillar 1 framework:

> *"If a supervisor were to question our model and ask why climate risk is not considered material, I would argue that we have not observed climate-related defaults in the past. It doesn't show up significantly in our historical data, and so from a statistical perspective, I can't incorporate it into the model as a material risk driver (...). What we are doing now is looking at the defaults that occurred last year, for example, and also looking at whether they were driven by climate risk. In this way, we can practically build a*

[33] An override is a manual upgrade or downgrade of a stand-alone rating. See Figure 5 for an illustration.

> *dataset step by step that we can use as a basis for modeling purposes in the future. However, this process will take time, likely more than a year or two, because we still lack sufficient default rates and empirical data to produce statistically reliable results. It is a gradual process."* **(B1)**

Similarly, another institution (H) highlights in its disclosure report that the impact of transition and physical climate risks on credit risk is considered material over the short, medium and long term. A risk expert (H1) from the institution stressed the need to distinguish between a "forward-looking" and a more "backward-looking" definition of materiality. Most materiality assessments — and the corresponding statements — focus on future impacts and forward-looking assessments.[34] In contrast, the definition of materiality under Pillar 1 is one that is more grounded on historical data and thus based on backward-looking assessments:

> *"We are not including the ESG scorecard in our PD model as it stands today. In other words, we say it is not material at this point. I am aware that we have written in another document that climate and environmental risks are material to us. Let me clarify this contradiction. In PD models, you have to look at which risk drivers explain which aspects in the past. In particular, which risk factors help to distinguish clients who have not defaulted from clients who have defaulted in your historical data. All of the aspects that help explain this distinction are essential and have to be included in the models (...). Again, it is based on historical data. However, we believe that climate risk is a phenomenon of the future. It is not a phenomenon of the past. And this line of reasoning leads us to say that climate-related credit risks are not a material aspect in terms of Pillar 1 and in terms of historical time series. Therefore, we do not think it is appropriate to include them in our models today. So why do we talk about material risks in this risk inventory? It is explicitly about forward-looking risks. And we definitely see climate risks as a material risk driver in the future."* **(H1)**

Overall, the materiality debate highlights a discrepancy between the forward-looking and backward-looking perspectives. The absence of significant climate-related defaults in historical data sets makes it difficult for some institutions to justify the inclusion of these risks into current models, even though their materiality is expected to increase in the future. This discrepancy may diminish over time as climate risks become more apparent in the data. Furthermore, the fact that one institution has already begun to quantitatively integrate climate

[34] See Section 4.3.2.2 for a discussion of current approaches to materiality assessments.

risks into its PD models shows that such integration is possible and is likely to become more widespread in the future.

4.2.3 Rating criteria and climate-related scores

As shown in Figure 5, institutions using the internal ratings-based approach rely on their own rating systems and data to estimate a client's PD. In addition to these rating systems, all institutions in our sample have developed and implemented internal ESG scoring methodologies, including climate-related scores, to assess and quantify climate risks. These climate-related scores are generally evaluated alongside credit ratings. In this section, we explore key considerations related to these climate scoring methodologies and discuss some of the challenges they present from a Pillar 1 perspective.

Institutions' internal rating systems have to ensure a meaningful assessment of client and transaction characteristics, a clear differentiation of risk levels and consistent quantitative estimates of risk (see Art. 144 of the CRR) (ECB 2024*a*). At the PD model level, this requires an appropriate selection and calibration of relevant risk drivers. In particular, the selected risk drivers have to contribute to the discriminatory power of the rating system, ensuring that such system is able to consistently and accurately distinguish between defaulted and non-defaulted obligors (ECB 2024*a*). As of today, there is no mandatory list of specific risk drivers to be incorporated into internal rating systems. However, risk drivers are expected to capture relevant information on financial and non-financial characteristics of clients that are indicative of their creditworthiness.

Figure 6 provides a simplified illustration of key risk drivers for PD estimation, including quantitative and qualitative factors, such as financial ratios and competitive positioning (ECB 2024*a*). For PD models targeting exposures to large corporates, key risk drivers also include the industry, the country (or global region), and company size (e.g., total turnover) (ECB 2024*a*). Institutions are also required to take into account "significant changes in the economic, legal or business environment within the historical observation period" (p.69, EBA 2017). Typically, the business and financial risk profiles are quantitatively integrated into the internal rating process, directly impacting stand-alone ratings and PD estimates.

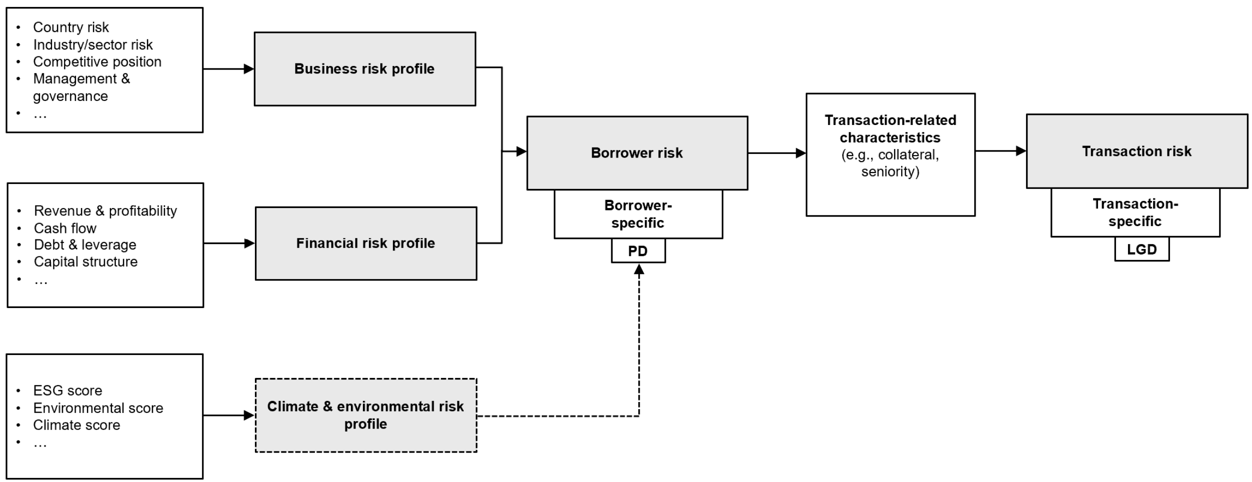

Figure 6: Illustration of risk drivers for PD and LGD estimation. Based on EBA (2017) and ECB (2024*a*).

Several respondents (B1, D1, I1, O1) argued that climate risks are already captured by existing quantitative and qualitative rating criteria within current rating systems. Internal ratings typically take into account factors such as a client's financial performance, industry risk, business model and competitive positioning, as illustrated in Figure 6. As a result, climate risks that are financially material in the short term are implicitly incorporated into PD estimates. For example:

> *"Our internal rating procedures under Pillar 1 follow the foundation IRB approach. Climate risks are implicitly accounted for, as these procedures include an evaluation of the client's business model. This allows for the identification of clients operating in industries that are exposed to significant transition risks."* **(O1)**

> *"It is essential to incorporate all material factors influencing PD into the models — this is non-negotiable. The central question becomes whether there is any factor that is not yet in the model or implicitly included. For example, is there anything additional beyond what is already captured by financial ratios like operating profitability or current financial liabilities, or by qualitative factors such as market position? These aspects are already part of the rating process (...). Elements that affect sales, earnings and the financial structure are already embedded in our model."* **(I1)**

> *"Climate risks are reflected in the PD when they are quantifiable through other financial parameters. For example, if a client is known to need investments of a specific amount in the next year, this is a concrete, tangible factor — not a hypothetical scenario — which is included in the PD. In addition, climate risks, especially transition risks, are highly sector-specific. The sector is also an element that is already part of the ratings."* **(D1)**

In addition to this "implicit" integration, the institutions in our sample have all developed internal ESG scoring systems, where transition and physical risks are typically evaluated and scored as part of the environmental pillar at the individual client level. We refer to such scores as "climate-related scores".[35] As shown in Figure 6, climate-related scores (i.e., the climate and environmental risk profile) are generally derived from a separate evaluation and do not directly serve as quantitative risk drivers or rating criteria that directly feed into the PD estimates.

Specifically, all but one of the institutions in our sample incorporate climate risks into their

[35] The design of these climate-related scores is further discussed in Section 4.3.3.2.

risk classification through qualitative considerations derived from the climate-related scores and by applying rating overrides (see Section 4.2.4). Several respondents (D1, E1, K1) described the climate-related scores as a valuable approach for conducting a granular and structured analysis of climate risks at the client level, despite some overlap with several rating criteria (e.g., sector/industry) already included in the rating system:

> *"Some factors are fundamentally already incorporated into existing risk models. However, I see a difference in the level of granularity. There is a difference between broadly assessing whether a company has appropriate management practices and, alternatively, examining 15 specific detailed questions explicitly related to ESG and climate issues."* **(E1)**

> *"The scorecard allows us to assess each borrower in a structured and individual way, identifying the physical and transition risks that might arise over different time horizons and are potentially not captured in the quantitative data. This provides a complementary perspective."* **(K1)**

Climate-related scores are typically aligned with the internal rating process and are subject to internal review and approval. In addition, they are updated annually or more frequently if important changes occur. For example, one institution in our sample (J) indicates in its Pillar 3 report that ESG scoring is mandatory for all new business transactions. For existing clients, the score has to be updated at least once a year. The ESG scoring process is aligned with the rating process by having the second line of defence approve the results. The overall ESG score ranges from 1 to 6, with 1 being the highest grade. A new business opportunity with a score of 5 or 6 leads to a deal rejection unless mitigating factors are presented and explicitly approved by the voting members of the credit committee. Consistent with the previous observations, a respondent (J2) from this institution noted that the current ESG scoring system provides a score that is currently separate from the internal rating, but updated annually. Furthermore, another respondent (D1) described a similar approach:

> *"We developed a proprietary scoring tool to effectively capture ESG information. Our intention was to explore whether this information could become relevant to default risk in the medium to long term. Currently, the ESG scoring tool produces a score that is not equivalent to a probability of default and is not directly incorporated into our PD or LGD models (...). Going forward, our goal is to collect as much data as possible and continuously assess the relevance to default risk."* **(J2)**

> *"The climate risk score is updated annually alongside the internal rating for two reasons. First, because we recognize a certain connection with the probability of default, at least in theory. Second, because adjustments to the score may become necessary over time. Like the rating methodology, the climate score methodology is reviewed annually and modified if needed."* **(D1)**

Several respondents (D1, I1) pointed out that the climate-related scores are considered in transaction decisions and therefore influence the outcomes. For example, a below-average climate score may prompt a more detailed review of a transaction, even if the quantitative client's PD is deemed acceptable. In such cases, the transaction may be escalated to higher decision-making bodies, such as credit committees or even the board of directors. In addition, some institutions in our sample have reviewed their competence level systems so that the hierarchical level required to review and approve transactions increases if a client receives a poor climate-related score. For example:

> *"Our climate risk score complements the internal rating to reflect long-term climate risks that are not yet tangible. This score may not have a direct impact on the PD, but it does influence certain process requirements. For example, if the short-term PD is acceptable but the climate risk score is particularly poor, climate risks may need to be addressed more extensively in the credit analysis. In certain cases, the transaction may also have to be decided at a higher competence level, e.g., credit committee. For high-volume transactions, this could be discussed all the way up to the board of directors."* **(D1)**

> *"We have a formalized competence level system. Above a certain threshold of the ESG-score, certain hierarchical levels or committees have to review the transaction. For clients with a poor ESG score, the competence level increases by one level."* **(I1)**

The quantitative integration of climate-related scores into rating systems represents a key challenge and is, for most institutions, still in its early stages. Several respondents (B1, H1, H2, J2, K1, M1, N1, O1, P1) argued that integrating climate-related scores into ratings is premature due to scarce historical data, poor data quality and modeling uncertainties. Furthermore, one expert (K1) stressed the importance of keeping internal ratings and climate-related scores separate for now to maintain a more robust and transparent model validation process:

> *"From a validation perspective, I believe the best approach currently is not to automatically incorporate the ESG scorecard into the rating. This approach allows me to clearly separate the rating from the ESG scorecard and still understand why the analyst rated the borrower a certain way and applied a weighting within the scorecard that may or may not have led to an override. Separating these two steps makes a lot of sense from a validation perspective."* **(K1)**

> *"In our view, our ESG score is nowhere near the level of the Pillar 1 models due to modeling uncertainty and lack of data quality. Therefore, it is appropriate to assess such scores separately and not integrate them into PDs. I think it will happen eventually. But it makes sense that it hasn't happened yet because the ESG score is not that advanced in terms of data and also in terms of modeling."* **(H1)**

However, the use of separate climate-related assessments also has its limitations. For example, one expert (D1) highlighted that while such scores are currently useful for integrating climate-related considerations into new business assessments, the long-term priority should be to simplify the process and integrate all measurable and relevant factors into rating systems. In particular, this respondent cautioned against the trend of creating multiple separate scores:

> *"Why do we need the climate score? It has an important training effect for credit analysts. As an analyst, I need to understand how climate risk affects sector risk, sector by sector (...). My personal view is that a tool like the climate score is the right thing to have at the moment, because it helps the credit analysts and also our corporate relationship managers to think about these questions (...). At the end, we should aim to remove complexity. Anything that can be quantified should, in my view, ultimately be captured by our established models and made relevant to PD assessment. At the moment, the trend is the other way round. There is a tendency to have more and more scores. One for social, one for governance, one for biodiversity and so on. We are critical of this because, as risk managers, we obviously want to end up with one metric, one probability of default, that incorporates all these aspects, rather than ending up with 15 different scores."* **(D1)**

4.2.4 Override framework and margin of conservatism (MoC)

A key challenge related to the integration of climate risks into the Pillar 1 framework is the issue of time horizon. To comply with the Basel requirements, internal models for the parameters PD, LGD and CCF have to be developed using long-run average realized one-year default rates (PD), realized loss rates (LGD) and realized conversion rates (CCF) (EBA 2017). As a result, PD estimates not only rely on historical data, but also have a one-year time horizon, which is shorter than what is typically considered relevant for assessing climate risks. This creates a misalignment between the short-term focus of credit ratings and the longer-term nature of climate risk assessments (NGFS 2022, Gruenewald et al. 2023).

To address this challenge, the institutions in our sample use overrides as an additional approach to incorporate climate risks. An override is a manual upgrade or downgrade of a stand-alone rating (see Figure 5). Overrides may be applied when the stand-alone rating is considered inadequate, particularly when the predefined rating criteria fail to capture risks expected to materialize in the medium to long term. This issue often arises when certain risks, such as climate risks, are not adequately reflected in historical data.

> *"One possible approach is to adopt an expert-based, forward-looking perspective by applying upward or downward notching. In such way, the model generates an initial PD, and adjustments are then made if it is determined that certain factors are not adequately reflected in the historical data."* ***(N1)***

For example, the EBA considers that "an override would typically be appropriate if there are individual circumstances, related to a given obligor or exposures, which the model reasonably cannot take into account. Such adjusted risk parameters are then used for the purpose of calculating own funds requirements (...) which influences the level of own funds included in the calculation of capital adequacy ratio" (p.13, EBA 2017). Thus, overrides directly impact PD estimates, which in turn affect the risk weight of an exposure and, by extension, the capital requirements under Pillar 1 (see Sections 4.1.1 and 4.2.1 for a more detailed discussion of Pillar 1 capital requirements).

Institutions typically have internal override frameworks that provide guidance to rating analysts on when and how to effectively apply overrides. Several institutions in our sample have reviewed and refined their override frameworks to ensure that climate-related risks are addressed in such frameworks and that the associated requirements are well described (e.g., policies and criteria, scale and rationale, list of justifications, documentation, monitoring, etc.).[36] In this context, one respondent (K1) noted that overrides are gaining importance as a tool for integrating climate risks. They provide a way for institutions to address future risks that may not be captured in historical data, though the respondent also cautioned against excessive reliance on this practice:

> *"The option to apply an override is already available, allowing a rating analyst to make adjustments for various reasons, including ESG-related factors. In the current environment, I think overrides are taking on a new relevance in a way that they may not have had before (...). The result of such an override is a final rating that takes into account factors that might otherwise have been overlooked. However, it is important to note that this also has an impact on the PD best estimate."* ***(K1)***

In the same vein, one respondent (B2) expressed skepticism regarding the use of overrides, questioning whether this practice aligns with regulators' expectations from a Pillar 1 perspective. In particular, this respondent stressed that overrides, which directly affect the PD best estimate, may introduce elements of subjectivity and arbitrariness. In addition, this respondent highlighted the growing regulatory focus on enhancing the comparability of models results (and, by extension, of capital ratios) under Pillar 1. Similarly, another respondent (J2) stressed their understanding that overrides should be used sparingly, even in the context of climate risks:

> *"What you want is objective evidence that your model's results are statistically sound. When you introduce expert-based elements that can't be empirically shown to improve the model's discriminatory power, you enter a gray area of arbitrariness or model manipulation. Historically, as far as I know, supervisors have been hesitant to allow this. There is also growing pressure under the new Basel reforms to move away from internal models, particularly for portfolios with limited data. Take the example of so-called 'low default portfolios'. It is becoming increasingly difficult to get internal models approved under Pillar 1, and institutions are being encouraged to adopt the standardized or foundation approaches."* **(B2)**

> *"This can be done in exceptional cases, but it should remain the exception. If overrides occur too frequently, the supervisors will likely raise concerns that the models are not properly designed (...)."* **(J2)**

The respondents also mentioned the use of a MoC as another approach to account for

[36] See guidelines on human judgement in the application of risk parameters defined in EBA (2017).

climate risks in PD estimates. Given the potential for unpredictable errors in PD estimates, institutions are required to incorporate an MoC to reflect a likely range of errors (BIS 2022*a*). This conservative adjustment is shown in Figure 5. The EBA defines several categories of MoC to address distinct sources of uncertainty in the estimated parameters. Category A covers uncertainty related to the data and methodology deficiencies; category B covers the uncertainty related to changes in risk appetite and internal processes; while category C covers the statistical uncertainty from the estimated parameter (EBA 2017). This MoC is added to the PD best estimate, thus influencing the calculation of risk weights for exposures and, consequently, the capital requirements under Pillar 1.

In terms of climate risk integration, gaps in climate-related data may necessitate an additional MoC, particularly in Category A. Although none of the institutions in our sample currently apply an MoC specifically for climate risks, one respondent (K1) identified it as a potentially valuable approach for addressing climate-related uncertainties in PD estimates in the future:

> *"Another approach could involve addressing these uncertainties within the margin of conservatism. For example, one might argue that specific uncertainties, like the CO2 pathway, should be treated as model uncertainties and incorporated into the MoC. This would allow quantitative uncertainties to be managed within the MoC. These would then be factored into the capital requirements, even if they are not part of the PD best estimate. However, this is not a practice currently adopted in our organization. We typically conduct a qualitative assessment through the scorecard, which might lead to a downgrade via a rating override. That said, I do think the MoC approach is a good option. The ECB, naturally, is focused on ensuring the survival of institutions and therefore a strong focus on sufficient capitalization. I believe this approach could be a very good solution to propose to the ECB. One could highlight the uncertainties around future pathways — whether 1.5 degrees, 2 degrees, or other outcomes — and incorporate them into the MoC, since they are not captured in historical data. This approach could help to effectively meet regulatory requirements. But for now, this is something that we do not do internally."* ***(K1)***

In contrast, another expert (E1) stressed the strategic implications of incorporating climate risks into the MoC, pointing out that such conservative adjustment would have an effect on loan pricing (discussed further in Section 4.5) and potentially place an institution at a competitive disadvantage:

> *"When it comes to the future integration into Pillar 1, we as an institution are still at the very beginning. We haven't conducted any quantitative analyses yet, nor have we developed our internal models to the point where we can say that we are explicitly considering climate-related risks through specific factors in the modeling. A lot of foundational work is required first, and there are also business strategy implications. If I were to integrate such risk factors into my PD today, even if only through conservative add-ons, it would immediately impact the client, in particular the client's conditions. This creates a risk if we implement additional risk surcharges that our competitors have not yet adopted. This is, of course, a strategic business aspect that always needs to be taken into account."* ***(E1)***

4.2.5 Model calibration

One approach, and simultaneously a challenge, in integrating climate risks into ratings-based models is through the redevelopment or recalibration of these models. As noted earlier, internal models for the parameters PD, LGD and CCF have to be developed using long-run average realized one-year default rates (PD calibration), realized loss rates (LGD calibration) and realized conversion rates (CCF calibration) to comply with Basel requirements (EBA 2017). The calibration function for PD parameters is illustrated in Figure 5.

As climate risks start to impact defaults and loss rates, model recalibration may become necessary. A challenge is that the calibration of PD models has to be based on a "through-the-cycle" PD, which accounts for defaults over an entire business cycle, smoothing out short-term economic fluctuations. This approach is considered more stable and less sensitive to changes in economic conditions than a "point-in-time" PD (EBA 2017). A priority in this context is therefore to analyze available data, collected both via climate-related scoring tools and internal rating systems. Since both ratings and climate-related scores are updated annually, each new data point can potentially be used for further model recalibration, as one of the respondents (B1) explained:

> *"Every year we have another year of observation that we add to our empirical data. What we do is look at the model on a regular basis and recalibrate it (...). For example, adjusting the weights in terms of the ratio of qualitative to quantitative factors or, within the quantitative factors, looking at which ones should have more weight (...)."* **(B1)**

The fact that PD models have to be calibrated based on a through-the-cycle PD, particularly due to the number of observations required, represents a challenge when it comes to climate risk integration, as noted by several respondents (B1, I1, K1, M1, N1). For example:

> *"The issue is that IRB models require a data history that spans an entire economic cycle. Typically, data goes back at least to 2007 or 2008, sometimes to 2010. The minimum requirement is generally around seven years. Currently, we are simply facing a lack of historical data related to climate risks."* **(N1)**

> *"We have to develop statistically-based models. One challenge is that we have data that goes back 10 or 20 years, and the issue of climate risk was not as virulent then as it is now or as it will be in the next 5 to 10 years. So it is difficult to find many cases in the historical default data where we can say with confidence that they were driven by climate-related events (...). From a Pillar 1 perspective, we have the requirement to calibrate our models against long-term realized defaults and losses."* **(B1)**

> *"Ratings are trained on historical data including several business cycles. It is an open question whether the sustainable transformation of huge parts of the the economy in a relatively short period of time will follow a pattern similar to historical business cycles."* **(I1)**

In addition, several respondents (B1, C1, C2, I1, K1, M1) expressed uncertainty as to whether supervisors would approve an internal ratings-based model incorporating climate-related drivers without sufficient historical data. While acknowledging the ECB's expectation that material climate-related risk drivers should be incorporated into internal models (see ECB 2024*a*), they pointed out that the ECB has historically maintained strict standards on data quality and the use of historical data. Furthermore, while a number of institutions are already developing PDs conditional on climate scenarios[37] in other contexts (under Pillar 2), the respondents expressed uncertainty as to whether the ECB would allow PD models calibrated on the basis of forward-looking scenarios rather than historical data in the context of Pillar 1. For example:

> *"The ECB requires extensive historical data, and we have already undergone numerous ECB audits, each time with a strong emphasis on data requirements. After each audit, it is natural to anticipate the next one and to start thinking about how to address new issues, especially with regard to climate risks. Based on this experience, one would not*

[37]We discuss these approaches in Sections 4.3.3.1 and 4.5.3.

> *try to incorporate climate risks in a quantitative way at all costs, but rather focus on qualitative aspects (...). Regarding Pillar 1, my impression is that convincing the ECB requires a great deal of effort, particularly when it comes to persuading them that we are moving beyond historical data. It is possible to do so in Pillar 2 and we already do a great deal there, but not in Pillar 1. In addition, the ECB is a large organization with many stakeholders involved. Ultimately, what matters to us is what the auditor on site observes and what they write in the audit report about what we need to change. So far we experienced limited flexibility to such topics."* ***(K1)***

> *"It is very difficult, in particular for European institutions, because the ECB is so keen on having historical data. In contrast, other supervisors are somewhat more flexible (...)."* **(C1)**

For example, one respondent (G1) explained that their institution developed a methodology for credit risk provisions[38] that relies on default probabilities conditional on climate scenario:

> *"By the end of this year, we plan to integrate the impact of climate scenarios into the calculation of credit risk provisions. This will have pricing implications, as the effects of these scenarios will be felt from the moment a transaction is originated, and even for existing transactions in their internal billing. To implement this, we are developing default probabilities that are conditional on climate scenarios (...)."* **(G1)**

[38] This point is briefly addressed in Section 4.5 on loan pricing. However, credit risk provisions under IFRS 9 are not covered in detail in this study.

4.3 Pillar II: Integrating climate risks into the ICAAP and broader risk management

4.3.1 Background and rationale

We now turn to Pillar 2 of the Basel framework. A key aspect of Pillar 2 is the ICAAP. In accordance with Article 73 of the CRD, institutions are required to implement effective and comprehensive strategies for assessing and maintaining adequate capital amounts to cover both current and potential risks (ECB 2018). Consequently, the ICAAP represents a key internal process aimed at ensuring that institutions have sufficient capital to meet regulatory requirements and address other capital needs on an ongoing basis, including under stress scenarios (ECB 2018).

The key components of the ICAAP are illustrated in Figure 7. Alongside a governance and internal documentation framework, the ICAAP involves the development of processes for risk identification, methodologies for risk quantification and the evaluation of capital adequacy through stress testing. Furthermore, the ICAAP is intended to serve as a foundation for other key risk management processes and outputs, such as defining risk appetite, establishing risk metrics, setting exposure limits and allocating capital internally (ECB 2018). While being an internal process, the ICAAP also plays a key role in the dialogue with supervisors, as part of the SREP. The SREP is discussed in Section 4.6.

The ECB stressed that its guide on climate-related and environmental risks (described in Section 2.1) should be read in conjunction with the ECB guide to the ICAAP (ECB 2018, 2020*b*). The ECB guide to the ICAAP includes seven principles that promote a forward-looking, comprehensive approach to capital adequacy, focusing on risk identification, stress testing as well as governance and management frameworks (ECB 2018). Unlike the prescriptive nature of Pillar 1, Pillar 2 provides institutions with considerable flexibility in designing their ICAAP and selecting models and methodologies. This flexibility extends to how climate risks are integrated, resulting in a variety of approaches among the institutions in our sample.

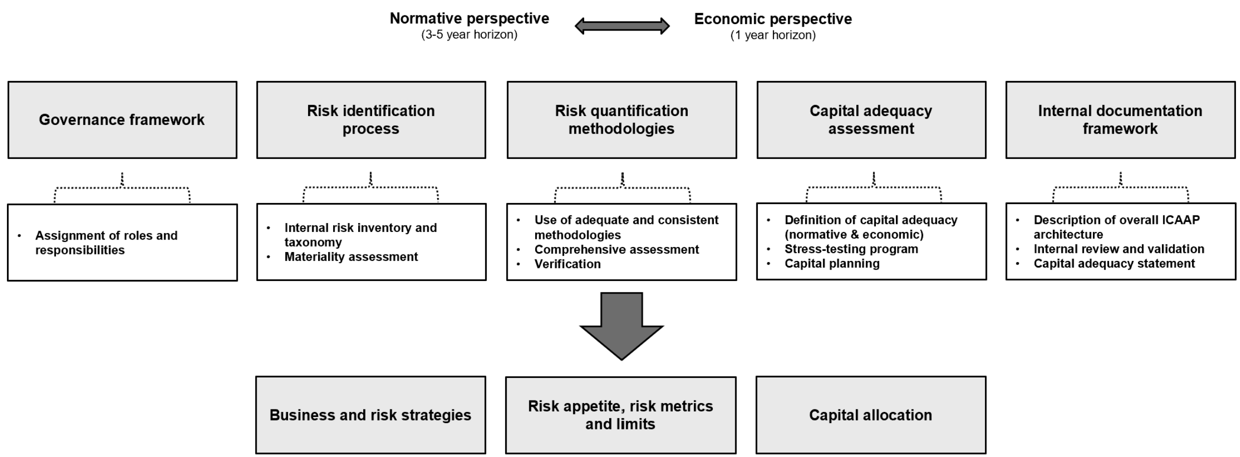

Figure 7: The key components and main outcomes of the Internal Capital Adequacy Assessment Process (ICAAP). Based on ECB (2018).

Another key feature of the ICAAP is the concept of "capital adequacy", which corresponds to the "degree to which risks are covered by capital" and is aimed at "maintaining adequate capitalization" on an ongoing basis (p.39, ECB 2018). It is informed by two distinct perspectives: a normative (regulatory) perspective and an economic perspective (ECB 2018). Institutions are required to ensure capital adequacy through both lenses, with each perspective complementing and informing the other (see also Section 4.3.3). The ECB also expects institutions to incorporate climate risks into both perspectives. Specifically, the ECB expects institutions to account for the potential impact of climate risks on economic value within the economic perspective (ECB 2020*b*). This involves quantifying the potential losses from material risks to capital based on value at risk approaches and comparing them with measures of internal capital. In addition, the normative perspective should consider the potential impact of climate risks on future regulatory and supervisory capital ratios, based on assessments of baseline and adverse scenarios (ECB 2020*b*). The integration of climate risks into the normative and economic perspectives is discussed in Section 4.3.5.4

In the following sections, we discuss approaches to account for climate risks in the ICAAP. Given their critical importance in the climate context, we focus on three ICAAP components: risk identification, risk quantification and capital adequacy assessment. These components are closely interconnected and form a sequential process as part of the risk management cycle, as shown in Figure 8. In addition, we discuss the risk appetite and risk management processes that result from these core elements.

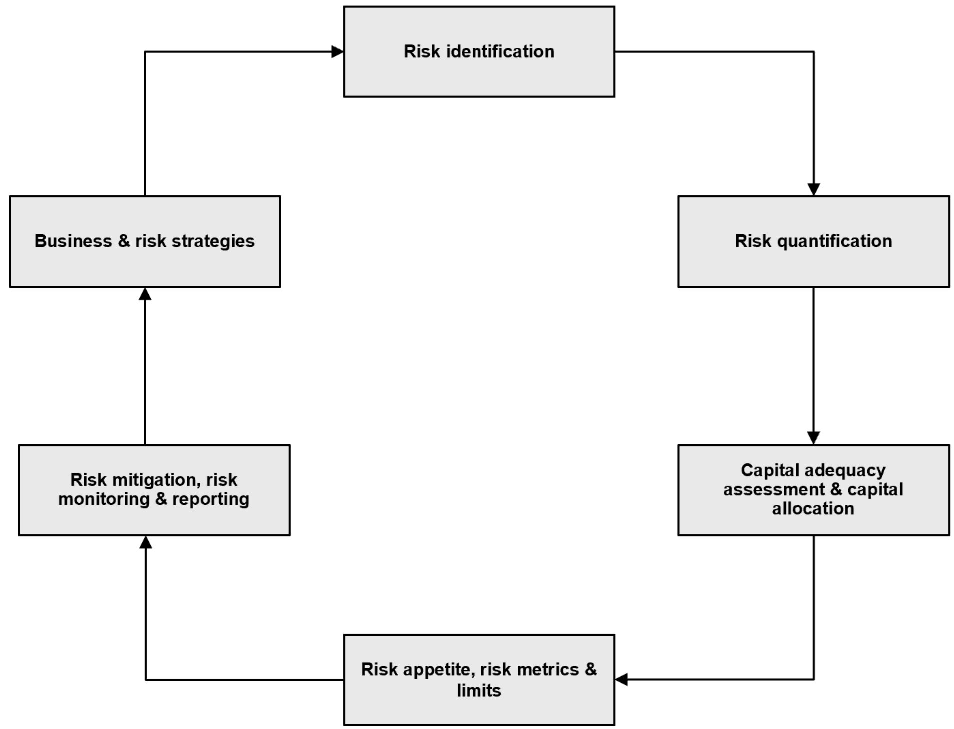

Figure 8: Risk management cycle. Based on ECB (2018) and ECB (2020*b*).

4.3.2 Risk identification, materiality assessment & risk inventory

We begin with the first key component of the ICAAP: risk identification. In this section, we highlight key features of this process (independently of climate risks), followed by a more detailed examination of how climate risks are integrated into this process in the subsequent sections.

As part of their ICAAP, all institutions in our sample conduct a regular, at least annual, process to identify all material risks to which they are exposed. This process not only includes climate risks, but more generally serves as a standard procedure for identifying material risks and their underlying drivers (ECB 2018). This process typically focuses on the short and medium term, covering at least the next three years. In practice, institutions rely on a time horizon of 3 to 5 years for non-climate risks, while for climate risks they are encouraged to consider potential developments over a longer period, extending up to ten years (EBA 2021).

The ECB defines a risk as material if "its materialization, omission or misstatement would significantly change or influence the capital adequacy, profitability, or continuity of the institution from an economic perspective" (p.27, ECB 2018). From a normative perspective, a risk is regarded as material if it significantly affects "relevant regulatory ratios, including own funds and risk exposure amounts over the planning period" (p.14, ECB 2018).

The risk identification process typically combines both qualitative and quantitative methods. In the initial step, it involves developing a comprehensive understanding of relevant risk drivers and assessing the channels through which the risks may materialize (ECB 2022*d*). In the next step, this process relies on the use of qualitative techniques, such as expert judgement, together with quantitative approaches, such as sensitivity analysis and stress testing, to assess risk levels against predefined materiality thresholds. This process is then expected to result in a comprehensive risk inventory outlining the identified risks and their characteristics (ECB 2018). These steps form the basis for determining the institution's risk appetite, which is further discussed in Section 4.4.

4.3.2.1 Identification of risk drivers and relevance assessment

In line with the ECB guide to the ICAAP (ECB 2018), the ECB expects institutions to develop a well-defined description of climate risks in their risk inventory (see expectation 4.1 of the ECB Guide, ECB 2020*b*), to have a holistic and well-documented view of the impact of climate risks on existing risk categories (see expectation 7.1 of the ECB Guide, ECB 2020*b*) and to include climate risks in their materiality assessments (see expectation 7.2 of the the

ECB Guide, ECB 2020*b*). All institutions in our sample already have a risk identification process as part of their ICAAP and have taken steps to define climate risks internally, identify relevant risk drivers, and assess how these risks could materialize and impact existing risk types. We therefore outline key steps of this process, providing examples of approaches and discussing challenges highlighted by our respondents.

To integrate climate risks into the regular risk identification process, several respondents (E1, H5, K2) noted that a key first step is to define and create a comprehensive list of potential climate-related risk drivers. This list typically distinguishes between transition risks and physical risks, along with their respective drivers. For example, one respondent (K2) stressed the importance of creating an internal taxonomy and definition of climate risks:

> *"First, we developed a taxonomy that clearly defines climate and environmental risks, along with the risk drivers associated with them. Our current framework categorizes these risks into 'physical', 'transition', and 'other', each with specific sub-drivers. This classification is essential for establishing a shared understanding, which forms the basis for analyzing our risk types and conducting associated stress tests. This step is crucial to ensuring a consistent understanding within our institution."* **(K2)**

The respondents noted that a common approach is to rely on external sources to establish an initial list of potential risk drivers. For example, sources mentioned by the respondents include the EBA report on the management and supervision of ESG risks (EBA 2021) and the ECB guide on climate-related and environmental risks (ECB 2020*b*), which provide information on various risk drivers, their transmission channels and their potential impact on prudential risk types.[39] In most cases, institutions classify climate risks as a subset of ESG risks, with the environmental dimension split into transition and physical risk drivers. These risk drivers, in turn, may affect the likelihood and severity of existing risk types (e.g., credit risk, market risk, operational risk).

Several institutions disclose key climate-related risk drivers in their disclosure reports, identified through their risk identification process. Overall, the list of climate-related risk drivers considered is typically quite standard and uniform across institutions. For example, one

[39]For example, the EBA recommends considering the following risk drivers for transition risks: policy risks (e.g., due to energy efficiency requirements, carbon pricing), legal risks (e.g., due to litigation), technology risks (e.g., innovation, new technologies replacing others), market risks (e.g., shifts in consumer choice) and reputational risks (e.g., difficulty in attracting or retaining customers). For physical risks, the main underlying risk drivers to be considered are acute physical impacts (e.g., storms, floods, fires) and chronic physical impacts (e.g., temperature changes, rising sea levels, reduced water availability).

institution (J) notes that it considers physical risk drivers, comprising both acute (e.g., natural disasters) and chronic (e.g., temperature changes) physical risks. In terms of transition risks, this institution considers several drivers, including political and legal pressures on EU banks' business models, green regulations (e.g., stricter environmental standards in sectors such as real estate, transport and energy), green technologies (e.g., the displacement of non-sustainable products and services, decarbonization), market sentiment and demand changes, ESG reputation (e.g., public boycotts due to ESG concerns), ecological protectionism (e.g., international trade conflicts triggered by environmental regulations) as well as biodiversity and ecosystem protection. Similarly, another institution (P) considers both physical (acute and chronic) and transition risk drivers, including climate-related policy changes (e.g., energy efficiency mandates, carbon pricing), technological shifts and market sentiment changes.

An institution's business model and portfolio exposures may also influence the initial scope of relevant risk drivers. For example, institutions with a regional focus may be able to narrow down the list to a smaller set of climate-related risk drivers, while those with global portfolios and activities are more likely to consider a wider range. Overall, the institutions in our sample exhibit a relatively high number of climate-related risk drivers. For example, one respondent (H5) reported that their institution had identified 26 risk drivers related to the climate dimension, as well as 13 additional risk drivers for the environmental and nature dimensions. Another respondent (E1) noted that his institution had so far compiled a list of about 110 risk drivers covering the environmental, social and governance dimensions, including at least 36 risk drivers related to environmental and climate aspects. Finally, another institution (P) has identified 26 risk drivers for physical risks (both chronic and acute) and other environmental factors, including water stress, pollution and waste, alone. The list of risk drivers is typically reviewed annually and adjusted if necessary:

> *"Various regulatory authorities have established standards in recent years. We have used these as a minimum benchmark and assessed whether any risk drivers might be missing from our perspective. Our comprehensive list of risk drivers is regularly reviewed. If all of your clients are only in Germany, you might not be so interested in analyzing tsunami risk as a potential risk driver. Although we have a strong focus on Germany, parts of our portfolio are globally diversified. We cover virtually all sectors and countries, even if only to a small degree. This means that, initially, we were able to filter out very few risk drivers. During the annual update, we review and discuss these risk drivers with internal experts, and a materiality assessment is also conducted annually."* **(H5)**

Institutions commonly further refine their list of relevant risk drivers by conducting a relevance assessment in collaboration with internal risk expert teams. For example, one institution (H) undertakes this analysis by breaking down its portfolio by sector and country, and assessing the exposure to various risk drivers within these segments. A respondent (H5) from this institution explained the approach as follows:

> *"We started with a large list of risk drivers and sought to identify the most relevant ones. Our approach involves assessing the relative portion of our portfolio potentially affected by each specific risk driver. We first ask ourselves: How large is this portion? We are able to segment our portfolio by industry and country across all risk types. For example, in the case of credit risk, we know the counterparty for each credit exposure, the industry it operates in, and the country where it is located. In parallel, we also collect information on which regions and industries may be impacted by specific risk drivers or remain unaffected. If the portion of our portfolio that is identified as potentially affected by both industry and country exceeds a specific threshold, we consider the risk driver as potentially relevant — though this is only a preliminary assessment. For example, if a certain threshold of the portfolio falls within a scenario where both industry and country could be potentially affected, the risk driver is considered potentially relevant. In the context of credit risk, we particularly focus on credit volumes. A more detailed evaluation may then follow, for example, as part of the bank-wide climate and environmental stress test."* **(H5)**

The relevance assessment also contributes to determining the amount of exposures in the banking book that is exposed to physical or transition risks on an annual basis (exposure analysis). For example, one institution (P) uses a physical risk heatmap and a transition risk heatmap, which are both based on a sector assessment (classified by the NACE economic sector). For the latest physical risk heatmap, ten relevant climate-related risk drivers were taken into consideration and mapped to the various sectors present in the institution's banking book. For each of the risk drivers, a low, medium or high score was attributed based on a qualitative assessment of expected severity (e.g., expert judgement by sector specialists). Any sector exposure at medium or high risk is considered sensitive to physical risk. For transition risk, a similar approach was adopted. The heatmap is based on seven relevant risk drivers related to policy changes, technological developments and shifts in market sentiment. For each of the relevant drivers, a low, medium or high score is attributed based on a qualitative assessment. The heatmaps then aggregate the results, providing an overview of the amount per sector exposed to medium, and high transition or physical risk. These relevance assessments and heatmapping exercises serve as the foundation for subsequent actions in terms of measuring the materiality of the risks and implementing effective risk management strategies.

4.3.2.2 Materiality assessment

Materiality assessments are an important part of the risk identification process in the context of the ICAAP and build on the identification of relevant risk drivers discussed in the previous section (ECB 2018). In 2020, the ECB noted that institutions' methodologies for evaluating the materiality of climate risks were "limited in terms of depth and sophistication" (p.14, ECB 2020*b*). Furthermore, the ECB argued that most institutions lacked adequate tools to assess the impact of climate risks on their balance sheets. In this section, we discuss examples of materiality assessment approaches and examine key challenges reported by our respondents.

In its guide on climate-related and environmental risks, the ECB set the expectation that institutions explicitly integrate climate risks into their materiality assessments across all business areas, considering short-, medium-, and long-term horizons (see expectation 7.2 of the ECB Guide, ECB 2020*b*). In light of these developments, the institutions in our sample have implemented a variety of approaches to assessing the materiality of climate risks. A key observation is that institutions typically assess the materiality of climate risks by considering multiple climate-related risk drivers across various categories of prudential risk types. Since climate risks may increase the probability and severity of existing risk types, the materiality assessments generally focus on evaluating the potential effects of individual climate-related drivers from different angles.

Internal and external data points:

Given the wide range of risk drivers (e.g., floods, temperature changes, market sentiment, CO2 pricing, and energy efficiency) and their influence on different risk types (such as credit, market, operational or reputation risk), the respondents stressed that materiality assessments regarding climate risks require a highly granular and detailed approach. Such assessments typically involve analyzing different business lines, portfolios and incorporating different internal and external data points to capture the full range of potential risk drivers and risk effects. Some institutions disclose detailed information in their Pillar 3 reports on the data points used in their materiality assessments. For example, one institution (K) provides a table that highlights specific data points related to physical and transition risk drivers, such as client location data (to evaluate the link between physical and credit risks) and greenhouse gas emissions data (to assess the effect of transition risk to credit and market risks). Similarly, another institution (I) uses both internal data, such as greenhouse gas intensities, and publicly available data from sources (e.g., World Bank hazard maps) to assess transition and physical risk effects. Several respondents (E1, J2, O1, P1) described this process and highlighted its complexity, for example:

> *"When assessing credit risk, we examine, for example, our shipping and real estate portfolios. For instance, we have been collecting data on energy efficiency labels from a very early stage, and when these labels are not available, we derive them ourselves. This allows us to categorize our real estate portfolio according to energy efficiency classes. We can analyze the extent to which properties with lower energy efficiency are more exposed to transition risks compared to those with higher efficiency. In the case of our shipping portfolio, we proactively acquired external data early on, allowing us to assess how a particular ship aligns with the net zero trajectory. In addition, we have two specific ESG scenarios and also incorporate ESG factors into other scenarios. For example, our standard downside scenario includes long-term shipping forecasts, which take into account the potential decline in demand for certain ship classes. This scenario also provides us with quantitative results that we use in our materiality assessments."* **(J2)**

> *"For us, climate is not a separate risk category but rather a risk driver within the various types of risk. Therefore, we always need to assess how material a driver is for credit risk, market risk, liquidity risk, and so on. Within climate risks, we distinguish between physical and transition risks, and for environmental risks there are further subcategories, such as biodiversity. Even with physical risks, we delve deeper into aspects like storms, river floods, sea-level rise. This creates multiple dimensions that need to be considered, making the process quite complex. As a result, our methodology document is over 50 pages long."* **(O1)**

> *"In a first step, we conduct an assessment to identify potential risks that could be relevant to the bank. In the second step, a financial impact analysis is typically carried out, based either on expert judgement or on quantitative analyses. We interpret climate risk according to supervisory understanding, i.e., not as a separate risk type but as risk drivers that can impact existing risk types. For example, for flood risk, we assess*

> *whether floods may be material to credit risk, market risk and operational risk (...). We assess the quantitative impact, and if it exceeds a certain threshold, the risk driver is considered material. The outcome of this process is a materiality heatmap, which we produce annually. This is something we repeat every year. We currently perform this materiality assessment on a gross basis, without taking into account potential or existing risk mitigation measures, which are also technically relevant to credit risk, for example natural hazard insurance."* **(E1)**

Qualitative and quantitative approaches:

In addition to a wide range of data points, the institutions in our sample use heterogeneous approaches and methodologies to assess the materiality of climate-related risk drivers. Some of these approaches are purely qualitative, while others rely on quantitative assessments. The respondents noted that the choice of methodology largely depends on the time horizon considered (short, medium or long term), as well as the availability and quality of data. Overall, most institutions in our sample primarily rely on qualitative approaches and complement them with insights from stress tests and scenario analyses. A common qualitative approach involves relying on expert judgement. For example:

> *"As part of the risk inventory process, we conduct an annual review of individual risk drivers with the portfolio managers. The focus is primarily on a qualitative assessment of which risks are material and to what extent. The assessment is based on a scale of low, medium and high. This classification as low, medium or high is purely qualitative. At this stage, we do not estimate an RWA impact of X or a potential loss of Y, but rather make a qualitative assessment. We also take into account the findings of the ECB's climate stress test, in which we participated, which indicated a medium level of impact on credit risk. However, these are separate assessments and different components of the overall materiality assessment process."* **(N1)**

> *"We conduct an expert-based, qualitative assessment, primarily because our historical data does not allow for reliable quantification. However, we can make forward-looking assumptions. To support this, our colleagues are asked to evaluate risk drivers based on two dimensions: probability and severity, in terms of potential loss amounts. We provide them with predefined thresholds to guide their evaluations. Typically, we interview one individual from each risk department, usually the head of department."* **(B1)**

> *"In our materiality assessment, we also make a statement about different time horizons: Short, medium and long term. This is mostly based on expert judgement in our case."* **(H5)**

In terms of quantitative assessments, the most commonly used approaches for assessing materiality are sensitivity analysis and scenario analysis. In essence, sensitivity analysis, also known as a univariate stress test, assesses the isolated impact of an extreme change in a specific risk factor on a particular risk type (Gruber et al. 2010, Müller & Schöning 2012). In the context of climate risks, some institutions use this approach to assess portfolio sensitivity to climate-related risk drivers, such as CO2 prices. For example, institutions seek to estimate potential credit losses for specific corporate portfolios if the price of CO2 were to increase by a given amount per ton. The main advantage of sensitivity analysis is its simplicity, as it does not require assumptions about how risk factors interact under stress (Müller & Schöning 2012). However, its limitations include reduced explanatory power and the potential to overlook certain risk effects, making it primarily suitable for short- to medium-term assessments. In contrast, scenario analysis, also known as a multivariate stress test, examines the impact of changes in multiple risk factors simultaneously on one or more risk types. This approach offers a more comprehensive and realistic view of risks and portfolio behavior under stress conditions, allowing for longer time horizons to be considered (Müller & Schöning 2012). The challenge, however, lies in designing the scenarios and accurately mapping transmission channels (Gruber et al. 2010). We discuss scenario analysis and stress tests in detail in Section 4.3.4.

Several respondents (E1, H3, J2, K2) explained incorporating insights from sensitivity or scenario analysis into their materiality assessments. For example, one respondent (K2) highlighted the complementary use of a risk-type-specific approach and a scenario-based approach (through macroeconomic stress testing) in the context of materiality assessments. Another respondent (H3) also reported using insights from exploratory climate scenario analysis for risk identification purposes:

> *"The materiality analysis is conducted using two complementary components: a risk-type-specific approach and scenario-based analysis through macroeconomic stress testing. These two methods are considered across different time horizons. In the short and medium term, risk types (e.g., credit and market risks) are analyzed through various methods, including location analyses, sensitivity analyses and risk-type-specific scenario analyses. For each risk type, specific methods are applied within a defined*

observation period to assess which risk drivers could have a material impact. Quantitative thresholds help determine the materiality of these impacts. Our macroeconomic stress testing, which also takes into account second-round effects, provides insights for the medium to long term. In macroeconomic stress testing, we heavily rely on NGFS to derive our climate scenarios. In contrast, when it comes to risk-type-specific approaches, we also develop very individualized methodologies tailored to each risk type. For example, PD shifts represent one such approach for credit risk. For market price risk, we consider changes in volatility. This approach focuses specifically on individual risk types, whereas the climate scenarios within the framework of macroeconomic stress testing take a broader, economy-wide perspective (...).” **(K2)**

“We differentiate between two types of stress tests. The first type is what we call ‘exploratory climate scenario analysis’. This approach focuses on analyzing individual climate risk drivers to derive a materiality assessment. Although such exploratory analyses are climate stress tests, they differ from our typical stress tests, which usually try to encompass all effects, simulate the entire P&L and balance sheet, and produce a capital ratio result at the end. Instead, exploratory climate scenario analysis targets specific considerations (...). Essentially, with this approach, we assess capital losses from both normative and economic perspectives, compare them with thresholds and derive a materiality statement. The second type of stress test involves holistic scenarios. These are similar to our standard stress scenarios, but include climate aspects. However, this approach is still under development in our bank.” **(H3)**

Materiality thresholds:

Materiality thresholds are critical to determining the materiality of climate risks and making a final judgement (ECB 2022*d*). However, there is significant variation in how such thresholds are defined and applied across institutions. More generally, the EBA has acknowledged the absence of standardized materiality thresholds, noting that materiality is not a one-size-fits-all concept, but rather depends on institution-specific factors, such as its specific circumstances, risks and risk profile (EBA 2014). Consequently, what one institution considers material may differ from another, including in the context of climate risks. Materiality thresholds are generally set and defined in the risk appetite framework, which we discuss in Section 4.4.1. As noted by two respondents (K2, O1), assessing the materiality of climate risks involves evaluating different risk dimensions, with thresholds varying by risk type. This highlights the complexity of integrating climate risks based on materiality considerations:

> *"Materiality assessment approaches can differ significantly among institutions, and even within a single institution, there can be considerable variation depending on the type of risk. For example, in the context of operational risks with a short-term focus, the approach typically involves a detailed examination of key service locations, identifying associated physical risks, and assessing the mitigation measures in place. In operational risk management, this process often results in a color-coded system that categorizes severity based on potential damage and likelihood of occurrence. This method contrasts with the metrics and logic used for other types of risk, such as evaluating changes in CVaR for credit risk. In other words, different types of risk within the same institution require distinct approaches, metrics and thresholds. Consequently, a wide array of methods is employed across the risk spectrum."* **(K2)**

> *"We conduct a comprehensive climate stress test every two years, and the results are integrated into our risk inventory. We use multiple techniques to assess materiality and therefore we do not rely on a single threshold."* **(O1)**

As noted above, the institutions in our sample typically assess climate-related risk drivers in the context of specific risk types. As a result, materiality thresholds are sometimes aligned with the thresholds defined for those risk types. Particularly in the context of quantitative risk assessments, such as scenario analysis, these thresholds typically include an assessment of the overall impact on capital metrics and liquidity buffer:

> *"I am essentially just adding another risk driver to my risk assessment. However, I am not changing the point at which something becomes material for me. That doesn't change just because I am incorporating climate-related risk drivers. Of course, it is possible that an additional climate-related risk driver may push the total risk above the threshold. But if it stays below, it won't have any impact. I am not changing the risk thresholds because of that."* **(D2)**

> *"We define materiality based on risk-specific thresholds. The logic is quite simple. Let's take address risk and a medium-term perspective as an example. We have identified certain sectors that are particularly vulnerable to climate and environmental risks. We would assign a specific rating shift to the addresses (i.e., the business partners operating*

in these sectors), and then observe how our CVaR changes in this scenario analysis. Depending on the magnitude of the change, we determine whether the driver is material or not. These thresholds are not arbitrary; they generally align with established thresholds we already know from our risk inventory, typically around 5% of the risk metric. Sometimes, other metrics are used, so it is not always 5%, but this gives a rough idea of the scale." **(K2)**

"Our materiality threshold for risk assessment is defined by a CVaR threshold, which we review annually. We leverage our stress testing infrastructure for materiality assessments, analyzing different portfolios individually." **(D1)**

One respondent (C1) mentioned that their institution evaluates the materiality of climate risks using quantitative thresholds related to credit and market stress losses as well as liquidity outflows:

"To assess materiality, we use our established materiality assessment methodology. We have defined climate and environmental risks as risk drivers of existing risks, and therefore we have incorporated them into our risk taxonomy. We quantify stress losses for existing risks and compare them to our materiality thresholds. The metrics that we use are stress losses [for credit and market risk] and liquidity outflows [with respect to the liquidity position]. These metrics are anchoring the capital of our entity. This approach is consistent with our standard materiality assessment procedure." **(C1)**

One respondent (H3) highlighted that the materiality threshold is typically expressed as a capital figure (CET1) and also depends on the probability of a scenario:

"Our materiality threshold is a € figure, which is of course specific to our bank, based on the capitalization and our CET1 ratio that we have as a bank. It is about 2% of our Common Equity Tier 1 capital. We also take into account the probability of occurrence of a particular scenario in our materiality assessment." **(H3)**

For institutions that rely more on qualitative approaches in their materiality assessments, the thresholds and criteria for determining materiality tend to differ. For example, one expert (J2) described an alternative approach that does not rely on materiality thresholds based on capital or liquidity figures. Instead, this approach involves analyzing EAD within specific segments, using NACE codes, and determining whether these segments are exposed to transition risks based on analyses from regulatory authorities or reports from the International

Energy Agency (IEA). The institution then assesses which portion of the total EAD has a medium to high transition risk score. A score is calculated and subsequently monitored. This method is also employed by institution (P). While this approach provides an initial assessment of the potential materiality of climate risks in relation to credit risk, it is relatively similar to the exposure analysis described in Section 4.3.2.1.

> *"We apply different materiality thresholds for climate risks compared to those used for specific risk types. When assessing risk types independently of climate, we rely on materiality thresholds based on changes in the CET1 ratio or liquidity. These thresholds are appropriate at the risk type level. However, we do not consider this approach suitable for climate risks. If we were to use the same thresholds for climate, I believe very little would be considered material. For this reason, we have a separate methodology for climate."* **(J2)**

4.3.2.3 Risk inventory

The risk identification process is a standard procedure for all institutions and forms a core part of the ICAAP. The purpose of this process is to produce a comprehensive risk inventory. A risk inventory is defined by the ECB as a "list of identified risks and their characteristics" and "the result of the risk identification process" (p.43, ECB 2018). The ECB expects institutions to ensure that such risk inventory is kept up to date (at least annually) using the "internal definition of materiality" (p.25, ECB 2018). This section discusses some of the challenges and implications related to the risk inventory highlighted by our respondents.

In essence, the risk inventory is a comprehensive list of all risk categories and subcategories that are material to the institution and warrant ongoing monitoring. Such inventory typically includes the main risk types (such as credit risk, market risk and operational risk) as well as sub-categories of risks (such as concentration risk, country risk, credit spread risk, model risk etc.). The ECB also requires institutions to incorporate climate risks, including descriptions of these risks and their underlying drivers, into their risk inventory (see expectation 4.1 of the ECB Guide, ECB 2020*b*). Consequently, the institutions in our sample have either already integrated or are in the process of integrating climate risks into their risk inventories. One respondent (E1) noted that the traditional risk inventory process has typically been separate from the materiality assessment of climate risks. Therefore, a key objective of the institution (E) is to integrate this assessment into the overall risk inventory:

> *"The risk inventory is an annual process within our organization. Our goal is to incorporate the materiality assessment for ESG risks within the framework of the risk inventory. Until now, we have approached this assessments more on a project basis. For example, last year, we conducted a materiality assessment specifically for ESG risk drivers for the third time. The approach was similar to the traditional risk inventory: we first identified potential ESG risk drivers based on supervisory publications. Then, using this as a foundation, we conducted a materiality assessment for the material risk types, analogous to the traditional risk inventory. Up until now, this has been a separate process, but looking forward, our aim is to integrate it into the existing risk inventory."* **(E1)**

The risk inventory serves as the foundation for the formulation of the risk appetite framework, which is further discussed in Section 4.4. As such, it plays a crucial role in shaping the institution's overall risk strategy, as well as the strategies for specific sub-risks. One key implication of the risk inventory is that risks identified as material have to be managed through appropriate governance, monitoring and reporting mechanisms, as highlighted by two respondents (D1, K2):

> *"It becomes part of the overall risk strategy. If climate risk is material for credit risk, then the corresponding risk strategies, such as for credit risk, must address this issue. The next step is to operationalize the credit risk strategy through concrete guidelines, processes and documents that also explicitly address climate risk."* **(D1)**

> *"The central question is what are the implications of such a materiality assessment and risk inventory? This leads to two main considerations: Do we need to allocate capital and is our existing risk management approach adequate? In other words, are our risk frameworks, e.g., guidelines, exclusion lists, or other processes sufficient? It might also involve establishing new types of limits. All of these questions are related to risk management, with the primary concern being whether we are effectively managing these key risk drivers."* **(K2)**

4.3.3 Risk quantification approaches

We now turn to the second key element of the ICAAP: risk quantification. This section outlines the core aspects of the risk quantification process (irrespective of climate risks), followed by a more detailed discussion on the integration of climate risks into this element in the sections that follow.

As part of the ICAAP, institutions use different risk quantification methodologies tailored to their specific characteristics, such as their business model, risk profile and size (ECB 2018). Unlike Pillar 1, which, for example, specifies rules for the calculation of RWA, Pillar 2 does not prescribe specific risk quantification methodologies for the ICAAP, provided that such methodologies ensure an adequate quantification of material risks (ECB 2018). In a report on ICAAP practices, the ECB noted that institutions typically use a variety of approaches to quantify their risks, including amended Pillar 1 approaches, scenario analysis and stress testing as well as internal statistical models, such as credit portfolio models and other models based on value at risk methods (ECB 2020*a*).[40]

One respondent (F1) described the risk quantification models under Pillar 2 as "adjustment models", explaining that they build on the outputs of Pillar 1 models. For example, as described in Section 4.2, some institutions use internal models under Pillar 1 to calculate credit risk parameters such as PD and LGD for every credit risk position. These outputs serve as the basis for forward-looking or hypothetical analyses under Pillar 2, such as scenario analysis and stress testing. For example, in the context of their stress tests, institutions assess the impact of adverse scenarios on key performance indicators of their credit portfolios (e.g., value at risk, risk-weighted assets and provisions). In this process, the potential effects of scenarios are translated into negative changes in existing key credit risk parameters in the relevant portfolios. Rather than competing with Pillar 1 approaches, the risk quantification models under Pillar 2 therefore refine and adapt the outputs to specific contexts, as one respondent (K1) pointed out:

> *"Pillar 1 serves as a foundation for the credit portfolio models in Pillar 2. The ratings provide a starting point, but in Pillar 2, we have the opportunity to take a much more forward-looking approach, rather than relying solely on retrospective analysis."* **(K1)**

While Pillar 1 focuses on the amount of "regulatory" capital that institutions are required to hold in relation to RWA, Pillar 2 comprises assessments of capital adequacy not only in terms of regulatory capital, but also in terms of "economic capital". Economic capital is a key metric for internal risk measurement and management. It is the amount of capital that should be set aside in order to mitigate potential unexpected losses from all material

[40] A value at risk measure represents the maximum level of potential loss over a specified time horizon and associated with a given confidence level (e.g., 99.9%). Credit portfolio models are typically used to quantify the credit value at risk, taking into account losses from credit defaults and rating migrations at the portfolio level. Such models provide a measure of the magnitude of potential credit risk losses above expected levels and therefore help quantify capital requirements in the context of the ICAAP.

risk types identified in the course of the risk inventory process (e.g., including business and reputation risks). Internal risk models, such as value at risk models, are used to calculate the economic capital within a given confidence level and time horizon.

These risk quantification estimates are subsequently used in daily risk management processes, including assessing the institution's risk-bearing capacity, refining its risk appetite, setting key risk indicators and limits (see Section 4.4.3), and allocating capital. Another important aspect of ICAAP risk quantification methodologies is independent validation. In particular, these methodologies are expected to be reviewed on a regular basis and the results of such review are expected to be reported to senior management (ECB 2018).

4.3.3.1 Credit rating simulations and credit portfolio models

Scenario analysis and stress testing are among the most widely used and essential risk quantification methodologies in the context of climate risks. A detailed examination of these methodologies is provided in Section 4.3.4. Some respondents (I1, G1, O1), however, noted an emerging trend within their institutions. On the one hand, there is a growing use of forward-looking simulation techniques to project and evaluate corporate credit ratings in response to climate-related risk drivers derived from climate scenarios. On the other hand, efforts are underway to enhance existing credit portfolio models to better capture climate-related risk factors. Both approaches are therefore addressed in this section.

Given that climate risks have the potential to alter future credit conditions, projecting credit risk parameters is crucial for improving risk quantification. For example, one respondent (G1) mentioned that their institution had developed an in-house risk quantification methodology based on a "forward-looking adjustment of internal ratings". This solution allows the institution to simulate changes in credit ratings and rating migration parameters in line with climate scenarios:

> *"There are two ways to influence PDs. One way is to use historical data on macroeconomic and sectoral activity variables and run them through our regression models. We are familiar with this approach. Unfortunately, this approach doesn't allow to fully take into account all climate-related issues because there are many transformation aspects that don't necessarily have a significant macroeconomic impact (...). Therefore, we also incorporate more direct climate-related effects linked to the fact that, for example, certain companies may have to invest more, that the cost structure of companies may change, that the price of raw materials may be higher and so on. This approach is more complex because we lack clear historical data to draw from. As a result, we*

> *use our credit scoring models. We know that, for example, the more debt a client has, the higher their credit risk, all else being equal. So, what we do is almost a classic customer-by-customer financial analysis. We take their financial ratios, their whole balance sheet and income structure, and we change them according to specific climate scenarios. We change their financial ratios and recalculate their credit rating."* **(G1)**

Another respondent (I1) also noted a growing trend toward simulating future credit ratings by incorporating climate-related risk drivers. While these simulations provide valuable forward-looking insights, the expert stressed the challenges associated with communicating the results to management and supervisors. Unlike ratings based on historical data, simulated ratings are less reliable because their accuracy can be quickly affected by new information or changing conditions:

> *"I believe we're beginning to see a shift toward simulating credit ratings. For example, if the portfolio contains a property with a poor energy classification, what will happen to its market value? What will the credit rating be in five or ten years from now? There's a growing trend in using simulation techniques for internal ratings (...). The challenge with these simulations is that their results are difficult to communicate to management and supervisors. While we can make predictions, the actual outcomes may not align with our forecasts. Unlike ratings based on historical data, which are more precise, these simulations are not an exact science, making the results harder to convey (...). A rating is essentially a statistical measure calibrated with historical default data, but simulating future ratings is much harder to calibrate. One reason is that within a year, we could have new information, or the environment could have shifted dramatically. So the predictive power of the simulated rating may, in retrospect, be very limited. This creates challenges in the communication, particularly with supervisors."* **(I1)**

One respondent (P1) described a different approach that focuses on assessing the impact of carbon pricing at the client level. By incorporating a carbon price sensitivity analysis into financial models, this method allows the institution to evaluate how shifts in CO2-related costs may affect a company's financial position. These financials, in turn, directly feed into internal models, as discussed in Section 4.2.3. Finally, one respondent (O1) elaborated on the use of credit portfolio models and current efforts to better integrate climate risks into such models, for example by using correlation factors:

> *"For companies, we take a carbon price sensitivity into account and incorporate it into our financial models. These financials are also ultimately an important input factor in our internal models."* **(P1)**

> *"In the credit portfolio model, one option is to adjust PDs. Another approach is to work with correlation factors. For example, it could be assumed that certain sectors are collectively impacted by the climate crisis, leading to stronger correlation effects, which can be integrated into the model. This is something we are currently exploring."* **(O1)**

4.3.3.2 Climate-related scoring methodologies

The ECB expects institutions to quantify the climate-related and environmental risks to which they are exposed (see expectation 7.3 of the ECB Guide, ECB 2020*b*). In addition, the EBA requires institutions to assess a "borrower's exposure to ESG factors, in particular environmental factors and the impact on climate change, and the appropriateness of the mitigating strategies, as set out by the borrower" (p.39, EBA 2020). The EBA further specifies that this assessment should be carried out on an individual borrower basis (EBA 2020). In this section, we explore client-level approaches for quantifying climate-related risks and discuss key challenges identified by our respondents.

All institutions in our sample have developed and implemented internal approaches for quantifying climate risks using dedicated scoring systems at the individual client level. Climate risks are typically considered a subset of ESG risks, with both transition and physical risks evaluated under the environmental pillar. As discussed in Section 4.2.3, these climate-related scores generally complement internal credit rating assessments and systematically incorporate an evaluation of climate-related risk factors into a distinct score. The exact climate-related criteria and methodologies are generally not disclosed by institutions, with the exception of one institution (J), which provides a table outlining the main question categories and their weighting.

Another observation is that despite the existence of ESG ratings (e.g., MSCI ESG ratings, Sustainalytics ratings), our respondents expressed a preference not to rely on such external ratings for risk quantification purposes. For example, one respondent (I1) stressed the importance of conducting individual assessments using institution-specific criteria or more tailored solutions. Several institutions developed their own climate-related scoring methodology, while others rely on specialized tool providers (e.g., CredaRate). In addition, two respondents (D1, H2) explained that internal scoring systems allow for a more tailored analysis of climate risks and encourage risk analysts to pay more attention to these issues. For example:

> *"We looked at external ESG ratings. In the end, we decided to develop our own score to do justice to our portfolios and our clients. External ratings are very dependent on the questions asked. External ratings also rely heavily on industry averages. We are trying to work more closely with our clients. We have risk managers and loan originators who know the clients well and try to assess them on a more individualized basis."* **(I1)**

> *"Why do we need the climate score? It has an important training effect for analysts. As an analyst, I need to understand how climate risk affects sector risk, sector by sector. Climate is not that simple because the challenges in the automotive sector are very different from those in steel or cement, for example. Is the technology I need to switch to already available? When will the technology be cost competitive? When can I use it efficiently? When is the right time to invest? This is very complex. My personal view is that a tool like the climate score is the right thing to have at the moment because it helps the analysts and also our corporate client advisors to think about these questions."* **(D1)**

As a result of these individual scoring frameworks, the climate-related criteria and methodologies used to quantify climate risks at the client level differ between institutions. Furthermore, even within the same institution, these methodologies often differ depending on the type of portfolio or segment (e.g., corporate, real estate etc.), as explained by two respondents (I1, K2):

> *"We have different scores depending on the segment. For example, we have a lot of corporates in our portfolio, but also real estate. The climate challenges are very different depending on the segment. Thus, we have decided to build this score differently. But, basically, we always have two main building blocks. One focuses on the physical risks and the other on the transition risks."* **(I1)**

> *"The questions of the scorecard are segment-specific. These questions are also guided by data availability. For each segment, we have a set of different questions that need to be answered, with predefined ranges."* **(K2)**

Transition risks:

We provide five examples of scoring approaches to quantify transition risks at the individual client level. One respondent (H1) reported having developed an internal "ESG credit risk score" for the corporate portfolio. This expert explained that the transition score is primarily based on two factors: the client's greenhouse gas emissions and its transformation efforts.

> *"How do we measure the transition score? Basically we have two components in this sub-score. One is an emissions score. This is based on the company's most recently reported emissions data and assesses the current exposure to changes in CO2 pricing and allowance allocation. This allows us to assess how exposed a client is based on current emissions. We look at all three scopes of emissions and consider emissions in relation to the company's sales. This emissions score represents the status quo. We calculate it for all of our clients (...). The second component is a transformation score. It is based on qualitative questions that assess how far-reaching and ambitious the company's transformation plan is, for example how fast and by how much a company plans to reduce its emissions over the next 5 to 10 years, and how binding it is, for example how much investment has already been made. Another important aspect of the transformation score is the extent to which a company plans to change its product mix in the future, i.e. the extent to which it wants to adapt its product portfolio towards less CO2-intensive products. Finally, we have a question on water consumption and a question on waste generation to assess the efforts made in these areas (...). This score is calculated for large clients in focus industries, i.e. industries with high CO2 emissions, where the bank has a larger portfolio volume (...). We have some very small clients that are not handled manually by our market and credit departments. For these clients, we do not calculate a transformation score, so the transition dimension is equal to the emissions score (...). The emissions score and the transformation score are equally weighted, so that each accounts for 50% of the transition dimension. The main reason for this is the lack of a real target figure. This is an entirely expert-based model. We have no historical data on which to train the model. This is why we have started with a very simple equal weighting."* **(H1)**

One respondent (J) described another climate-related scoring approach. The score consists of 18 questions related to climate and environmental issues, which account for 50% of the overall ESG score. The score components include five questions on greenhouse gas emissions, energy consumption and energy efficiency; four questions on climate-related issues such as technology risk; and nine questions on specific environmental areas such as water and marine resource protection. The final result is an overall ESG score ranging from 1 to 6, with 1 being the highest score:

> *"For transition risks, the analyst needs to assess the technological risks faced by the client. For example, is the client's production technology at risk? Have the necessary investments been made to stay technologically up-to-date and avoid being impacted by future regulations? In addition, we have a bonus-malus system for specific climate-related topics. For example, there are positive incentives for certain certifications in the real estate sector, while we apply penalties within this score, for example for unsustainable land use (...). In the environmental category, we assess factors such as the carbon footprint, reporting on emission reduction targets, energy consumption, energy efficiency, share of renewable energy, sustainable use and protection of water and marine resources and the transition to a circular economy. We also examine efforts to reduce pollution. There is a set of questions that are identical for everyone. However, there are also sector-specific questions, such as those for the shipping industry. The main questions remain the same, but the sub-questions and responses vary based on the sector."* **(J2)**

An additional respondent (O1) elaborated on the use of a scoring system provided by the external provider RSU, where the environmental dimension constitutes 60% of the total ESG score. This dimension focuses primarily on transition risks, including greenhouse gas emissions, waste and water-related factors:

> *"Strictly speaking, we use the tools from RSU and S Rating, depending on whether we are operating in the wholesale or retail sector. With RSU, the environmental dimension currently accounts for 60% of the total score, with 20% allocated to both the social and governance dimensions. Within the environmental dimension, the score is split between physical risks and transition risks, with a somewhat greater weight given to transition risks. Within transition risks, the assessment focuses mainly on Scope 1, 2 and 3 CO2 emissions. Waste generation and water consumption are also considered, with equal weight given to each."* **(O1)**

One respondent (D1) explained that their institution uses a "climate risk score", which incorporates both sector analysis and client-specific qualitative questions. Finally, another expert (P1) described a similar approach that assesses clients based on their alignment with sector transition pathways, the robustness of their transition plans, and the potential financial impact of the transition:

> *"We use the results of an external tool that we use for economic / risk analysis to create a climate risk score. This score is based on a sector analysis and is supplemented by qualitative questions asked in the individual credit analysis. With the tool, for example, we get a climate risk indication that is sector-specific. This tells us whether the client is active in a sector where climate risks do not play a role, or vice versa. In the individual analysis, we then use qualitative questions to gain a more detailed understanding of whether the specific client is more or less affected by these risks. The results are aggregated into a climate risk score."* **(D1)**

> *"We evaluate clients on an individual basis, with the aim of assigning a score to all of them. For transition risks, we consider a range of criteria, with a key focus on a company's emission intensity, specifically physical emissions rather than economic ones. For example, in the automotive sector, we assess the CO2 intensity of the vehicle fleet. This data is then compared to climate pathways, which we derive from the IEA transition pathways. We analyze whether these emission intensities are above or below the transition pathways, considering both the current status and a five-year outlook. Based on this analysis, we assign clients a risk grade of high, medium, or low. We also evaluate the quality of the client's transition plan, though this assessment is more qualitative. We examine whether the plan is credible, includes a detailed action plan. In addition, we apply a set of ten questions to assess factors like scope 1, 2, and 3 emissions, whether the client has a net-zero target and whether management is actively engaged. We also consider financial resilience. To do so, we use a model-based approach to apply transition risk pathways from integrated climate models. This allows us to estimate potential changes in CapEx and OpEx, helping us gauge the impact on cost structures and other financial metrics."* **(P1)**

Physical risks:

Next, we provide three examples of scoring approaches to quantify physical risks. Overall, we observe that the scoring methodologies developed by the institutions in our sample have a stronger focus on transition risks than on physical risks at the client level. One possible explanation for this could be that quantifying physical risks heavily depends on the location and nature of assets. Such an assessment may not be systematically relevant or feasible at the client level. In addition, some climate-related factors may already be reflected in collateral values. For example, one respondent (K2) highlighted that their institution currently sees a potential risk of double counting in this respect (e.g., environmental factors already influence the valuation of real estate collateral, see EBA 2023). The respondent (K2) explained:

> *"Currently, physical risks are still being assessed in a fairly general manner. The focus is primarily on overall vulnerability to physical risks. However, these risks are not yet factored into our internal scorecard to avoid the possibility of double counting. Physical risks are already accounted for in the collateral valuation, and including them in the scorecard as well could lead to the same factors being considered twice."* **(K2)**

One of the respondents (H1) described how their institution calculates a physical risk score by analyzing company locations using geolocation data and hazard maps. The model assesses physical damage and business interruption risks, considering factors such as asset type and diversification, and is fully automated:

> *"To calculate the physical risk score, we examine the company's locations. We convert addresses into geolocation data and estimate the risk for each location using hazard maps from the World Bank and other leading organizations, aggregating a score based on various natural hazards. In practice, we often have only one location per client in our database, usually the headquarters. So far, we haven't gathered data on other sites. However, to accurately assess physical risk, looking only at the main location is often insufficient. As a result, we now purchase data from an external provider, though this mainly covers large corporates. For small clients with only two or three other sites, we don't currently have a way of recording them manually, and we don't buy the data either (...). At the moment, we treat all of a company's locations as equally important. We attempted to gather information on the share of sales for each site to determine which are most critical, but the external provider couldn't deliver this. However, we do know the type of asset, such as whether it's a factory, office building, or power station (...). When assessing physical risks, we consider two impact channels: the first is physical damage, assessing how severely buildings could be affected by river floods, droughts, and similar events. The second is business interruption, where we examine the climate hazards that could disrupt operations. In the case of business interruption, the sector of the client and the type of asset also play a role. We also assess asset diversification, such as whether all factories are in the same location (...). Our model aggregates data from hazard maps and runs fully automatically."* **(H1)**

Another respondent (I1) described their institution's tool, which focuses on analyzing physical hazards, particularly flood risk and makes a distinction between regional and international corporate clients. Lastly, a third respondent (O1) explained using a scoring system developed by RSU, which includes criteria for assessing physical risks, such as floods and heat waves, at the client level:

> *"We have a physical risk tool application (...). We distinguish between regional and international companies. For regional companies, we look at the extent to which a region is exposed to physical hazards. For example, we look at a city and say that if more than 10% of it is at risk of flooding, then the entire city is flagged as being at risk. In turn, we mark companies that operate regionally in that city as potentially exposed to flooding. For international companies, we simply look at the sector. This is because large companies are generally able to replace certain assets. A flood may cause damage, but it may not lead to credit defaults of these companies. Therefore, we tend to perform a sectoral analysis and flag sectors that are particularly exposed to physical risks. There are certain sectors that are significantly more affected by physical risks, agriculture or tourism for example, and we take that into account."* **(I1)**

> *"With RSU, the E dimension accounts for 60% of the total score, with 20% allocated to both the S and G dimensions. Within the E dimension, 30% relates to physical risks and 70% to transition risks (...). For physical risks, the focus is on extreme weather events, such as coastal flooding, river flooding and heat waves (...). When financing a corporate client in a region prone to flooding, for example, we have to consider the potential impacts if the client's premises are flooded or if employees cannot reach work due to flood conditions. These are physical risks that cannot be fully addressed through collateral alone."* **(O1)**

Challenges:

While these scoring approaches are valuable for quantifying risk and collecting client-level data, several respondents (B1, H1, I1, J2) highlighted challenges posed by modeling uncertainties and data quality issues. For example, one respondent (H1) highlighted the difficulty of tailoring questions to specific industries and acknowledged the potential subjectivity in some scoring climate-related criteria:

> *"One question asks how fast and by how much a company plans to reduce its emissions over the next 5 to 10 years. Based on this, we created percentage buckets on a three-tier scale. Anything below 10% is considered 'unambitious', up to 20% is considered 'average' and anything above that is considered 'above average'. We recognize that there is a high degree of subjectivity in these aspects (...). We have also created 25 industry clusters and then, for so-called 'focus industries', we have discussed again with experts from the credit and loan origination departments how the questions need to be adjusted for specific industries. So far, we only did this for two sectors: automotive and energy. In the automotive sector, for example, the question is along the lines of 'How much does the company rely on the classic combustion engine?'. But, in essence, what we have done is to build an overarching model and then make only a few selective adjustments in individual sectors."* **(H1)**

Consequently, and as discussed in Section 4.2.3, climate-related scores are typically not quantitatively integrated into rating systems but remain a separate assessment considered alongside credit ratings. To illustrate, the respondent (H1) considered the integration of climate-related scores into PD models to be premature:

> *"For now, the PD remains unaffected by our ESG score. If we included it directly in our PD models, then it would be included everywhere. We don't want that. In our view, the ESG score is nowhere near the level of the Pillar 1 models due to modeling uncertainty and lack of data quality. Therefore, it is appropriate to assess such scores separately and not integrate them into PDs. I think it will happen eventually. But it makes sense that it hasn't happened yet because the ESG score is not that advanced in terms of data and also in terms of modeling."* **(H1)**

4.3.3.3 Climate-related data and data collection

In order to quantify climate risks, the ECB expects institutions to be able to generate aggregated and up-to-date climate-related data in a timely manner. Furthermore, it requires institutions to develop a holistic approach to data governance and to collect the necessary data to assess their exposures to climate risks (see expectations 6.1, 6.2 and 6.3 of the ECB Guide, ECB 2020*b*). This section provides examples of key data-related considerations and discusses the challenges involved.

In addition to the climate-related scoring methodologies discussed in Section 4.3.3.2, the institutions in our sample have implemented processes to overhaul their credit process and collect climate-related data in a more systematic way, including during due diligence and loan origination. For example, one respondent (H5) reported that their institution conducted a comprehensive review of the credit process and made adjustments to internal IT systems to aggregate climate-related data into relevant metrics:

> *"The entire credit process has been reviewed, from data collection to the systems in which we store data to the metrics we calculate around credit risk. We have also set up a new internal reporting on this topic."* **(H5)**

Corporate Sustainability Reporting Directive (CSRD):

Several respondents (D2, I1, L1, Q1) highlighted the challenges their institutions face in quantifying climate risks due to important data gaps. In this context, some noted the crucial role of the Corporate Sustainability Reporting Directive (CSRD) in facilitating data collection, despite some limitations.[41] For example, one respondent (I1) explained that beyond improving data quality, the CSRD is expected to simplify data collection for institutions in several ways, including by putting a greater focus on material issues. The involvement of auditors, who will have to audit the reported data and validate the analytical processes used, was also seen as a positive development. Another respondent (L1) echoed the relevance of the CSRD, but pointed out that important data gaps are likely to remain, in particular for small and medium-sized companies as well as companies headquartered outside the EU, to which the CSRD will apply at a later stage (reporting years 2026-2028):

> *"In addition to standard balance sheet reporting, we will integrate data from the CSRD. We expect our clients to report on material aspects, which we will then process internally. If a company reports that physical risks are not material, we will accept this information (...). If you compare this process with the way we process balance sheet data, we also do not question every single piece of information. We would need extreme insider knowledge. Instead, there are auditors who certify the reported data and verify the analytical process. Therefore, relying on audited and certified reports is the best approach going forward, and we will continue to do so with the CSRD."* **(I1)**

[41]See Directive (EU) 2022/2464. Large companies will have to implement the CSRD for the first time with the publication of reports in 2025 for the financial year 2024.

> *"In terms of data, everyone is waiting for the CSRD. However, we should keep in mind that this is only for the EU and, at least in the first step, mostly for large companies. It will be broken down further over the next few years (...)."* **(L1)**

Geolocation of financed assets, including corporate assets, facilities and sites:

Several respondents (I2, G2, L1, O1) highlighted the challenge of obtaining comprehensive data on the geolocation of company assets, facilities and sites, particularly in order to assess corporate exposures to physical risks. For example, one respondent (L1) highlighted the need for more detailed information on production and logistics sites, especially regarding their strategic importance and resilience to physical risks. Another respondent (O1) mentioned that their institution uses geolocation data from an external provider to evaluate exposure to physical risks. However, this data mainly covers real estate collateral and the headquarters of corporate clients, leaving out production sites. Finally, one expert (P1) explained that their institution currently has precise address-level data, including on critical company sites, for approximately 15% to 20% of the portfolio. For the remaining sites, the locations are approximated:

> *"We need more location data, not just about the headquarters, but also about where the main production or logistics facilities are located. For example, if a company relies on a few large logistics centres, it would be important to know whether they could be affected by physical risks (...). We also need to look at the impact of potential production downtime, e.g., because the surrounding infrastructure is broken or the company's infrastructure is broken. What is the impact of one month, two months, three months of production downtime on the company's turnover? It is important to analyze these second-round effects. This should not be limited to the damage caused. The analysis should also look at how the company will be able to resume full production, when it will be back to normal and how much revenue it will have lost by then."* **(L1)**

> *"We acquire data from Munich Re to quantitatively evaluate the exposure to various physical risks. This data helps us assess the risk levels for specific properties, such as the likelihood of flooding, storms, and other hazards. In addition, we take into account protective measures, such as whether a location is "defended" or "undefended", for instance, whether it has dike protection. We map this data onto the locations within our portfolio, particularly for real estate used as collateral. In general, we have*

extensive data for real estate collateral and agricultural land. We also use this approach for corporate clients, at least for certain business locations that we can already assess. However, we currently do not have data on production sites. For example, we can obtain the address of Volkswagen's headquarters in Wolfsburg, but this doesn't cover all relevant locations. The issue of production sites, particularly for large multinational companies, is complex, and we currently lack the necessary data to analyze them comprehensively." **(O1)**

"We analyze what percentage of a company's locations could potentially be affected. Based on this, we can then make a physical risk assessment. Typically, we know how many locations a company has, but we don't always have the exact details of where they are. For about 15% to 20% of the portfolio, we have clean data, but for the rest, the information is insufficient. Where we do have the exact locations, we use them. Internally, we also have a definition for 'business-critical' assets. Take, for example, FedEx, not every postal distribution center worldwide is considered a material asset. However, with cement plants, it is a completely different situation. There are sector-specific differences. When we don't know the exact location of the assets, because we don't have the addresses, we typically approximate based on the country, state or postal code, depending on the data we have." **(P1)**

As noted above, corporate portfolios present specific challenges, particularly as transaction documentation often only includes information on company headquarters, with data on other sites and assets varying based on the nature of the transaction. Some institutions are now expanding their data collection to address this data gap. For example, one respondent (G) explained that their institution is increasingly turning to commercial data providers to obtain more detailed information on corporate assets, particularly in sectors like power. This expert highlighted that specialized data providers offer granular data on company assets, including asset types, locations and capacities. This information is then used internally and aggregated at the company level:

"For our residential and commercial real estate portfolios, we already have most of the necessary data in our databases. We have geocoded addresses, which allow us to analyze physical risks. Corporate portfolios are different. The CSRD will bring more transparency to these assets, but for now, we rely on commercial data providers for information on company assets, such as asset types, latitudes and longitudes. We work

> *with data providers that are specialized in a particular sector, e.g., power. For example, in the power sector they can give us a list of a company's assets, the types of assets, their locations and the capacity of those assets. We use these latitudes and longitudes to run our climate models and then aggregate the results at the company level. Currently, we have a major internal project underway to expand our coverage to include more companies."* **(G2)**

A distinction needs to be made between the physical assets of residential and commercial real estate portfolios (e.g., immovable property used as loan collateral) and those of corporates (e.g., production facilities). In the case of real estate, several risk experts (G2, B1, J1, J2, P1) noted that much of the necessary data is already available in their institutions' databases, as its collection is generally mandatory, particularly for collateral valuation purposes (EBA 2023). For example, one respondent (J2) explained that their institution systematically collects data on energy performance (EPC) certificates to assess the energy efficiency levels of real estate assets:

> *"We collect data on energy performance certificates and energy labels ourselves and have been doing so for several years, intensifying the process again starting one year ago. For new business, it is mandatory to obtain the energy certificate, and for existing business, we have gradually gathered this information. In this area, we don't see any value in purchasing additional data. If we need to fill gaps, we rely on the information we already have, such as the type of use and the building's age, and then generate a proxy ourselves."* **(J2)**

Data on insurance coverage for corporate portfolios:

While most institutions already collect insurance data for real estate portfolios, this practice does not systematically extend to corporate portfolios, as one respondent (J2) observed. Overall, several respondents (L1, F1, G2, H5) highlighted the importance of having comprehensive data on insurance coverage, particularly for the purpose of quantifying physical risk exposure.

> *"We collect insurance data. Our process involves matching real estate properties with this insurance information. Insurance and reinsurance providers often have the capability to pinpoint a property's location and overlay various risk maps to assess potential risks associated with a specific address. Reinsurers can offer detailed information for*

> *almost any location globally. For example, by entering a property's address, we can determine the level of earthquake or flood risk on a specific scale. If a property shows high flood risk, we conduct a deeper analysis to check for mitigation measures. If none exist, we might withdraw from the transaction. If mitigation measures are in place, we need to verify their effectiveness, including whether the insurance policy sufficiently covers the risk. This approach is primarily used for our real estate portfolio and our renewable energy portfolio, as well as selectively for other transactions."* **(J2)**

One respondent (G2) explained that their institution has been working on improving the quality and coverage of internal data on insurance coverage, stressing that such information is crucial to gain a "net" view of risk. This expert also stressed the challenges posed by the global scope of their institution's portfolio, where insurance policies often differ from one country to another. Other respondents (H5, L1) also underscored the importance of data on insurance coverage and assessing the extent to which companies are insured against physical risks. One respondent (H5) pointed out that insurance coverage is sometimes overlooked in current models and mainly accounted for through overrides.

> *"Insurance is one of our major projects. Some insurance policies are systematically required, for example for certain assets. But, admittedly, for a global bank like ours, there are still procedures that can differ from one country to another. When it comes to insurance, national regulations apply. One of our key initiatives this year is to consolidate this insurance data to better understand our risk exposure. At the moment, however, we do not systematically monitor this risk on a global scale."* **(G2)**

> *"Insurance cover is an aspect that we would like to include in our model in the future through qualitative questions, but as of today it is not in the models and can only be taken into account today through an override."* **(H5)**

4.3.4 Risk quantification with climate stress testing

Another key component of the ICAAP and an essential tool for quantifying risks, including climate risks, is stress testing. A stress test is a "what if" exercise allowing institutions to examine the potential impact of certain risks under altered macroeconomic and financial conditions based on predefined scenarios (Baudino et al. 2018, Wilkens & Leister 2023). In this section, we outline key considerations, followed by a more detailed examination of how climate risks are integrated into stress testing practices in the next sections.

All institutions in our sample are required to conduct stress tests on a regular basis as part of their ICAAP (ECB 2018). Stress testing can be performed at multiple levels, from assessing the entire balance sheet and income statement to focusing on individual portfolios or specific exposures. In addition, stress testing can target specific risk types such as credit, market, liquidity and operational risk.[42] While comprehensive stress tests are generally conducted on a quarterly basis, other tests are conducted on an ad hoc basis for specific sub-portfolios (ECB 2018). These exercises help institutions track changes in profitability, capital and liquidity; set and monitor their risk appetite limits and targets; and inform their business and capital planning (ECB 2018). Stress tests are expected to cover both the normative and economic perspectives, providing insights into the impact of risks on regulatory capital ratios (e.g., CET1 ratio) and economic capital. In most cases, ICAAP stress tests are based on scenarios developed internally, which are updated at least annually to allow for reassessment and revision of the underlying assumptions, if necessary. From a governance perspective, ICAAP stress tests are typically subject to multiple governance layers, often involving a scenario and stress testing committee and a board risk committee (ECB 2018).

In addition, institutions regularly participate in supervisory stress tests conducted by the ECB and the EBA. Under EU law, the ECB is required to perform stress tests on supervised institutions at least annually (see Art. 100 of the CRD). The ECB also conducts thematic stress tests, such as the 2022 climate stress test, while the EBA carries out EU-wide stress tests every two years (ECB 2024*g*). These assessments typically focus on a short-term horizon of three years. In supervisory stress tests, institutions are presented with specific scenarios that impact their regulatory capital ratios and key performance indicators (e.g., large exposures), requiring them to evaluate how their capital positions would be affected by severe but plausible adverse economic conditions outlined in the scenarios.

The ECB expects institutions to perform stress tests in order to quantify the impact of climate risks on their exposures (see expectations 10 & 11 of the ECB Guide, ECB 2022*c*). In our sample, institutions tend to use climate stress tests and scenario analysis for three distinct but interrelated purposes (see Figure 9). First, climate stress testing is used for risk identification and quantification purposes, where specific climate-related risk drivers are closely examined across one or more risk types using sensitivity and scenario analysis. Second, scenario analysis, in particular, helps analyze how climate risks may evolve under different scenarios and time horizons, and translates these impacts into stressed risk parameters and capital measures. These analyses inform the materiality assessments and risk

[42] In essence, ICAAP stress tests can be broken down into different types of stress tests, including institution-wide stress tests with adverse scenarios, reverse stress tests, risk-type-specific stress tests and ad hoc stress tests.

inventories discussed in Section 4.3.2.2. Third, climate stress testing can also play a role in assessing capital adequacy, determining the need for capital buffers, supporting capital allocation decisions, and refining risk appetite (see Sections 4.3.5 and 4.4). These aspects are discussed in the following sections.

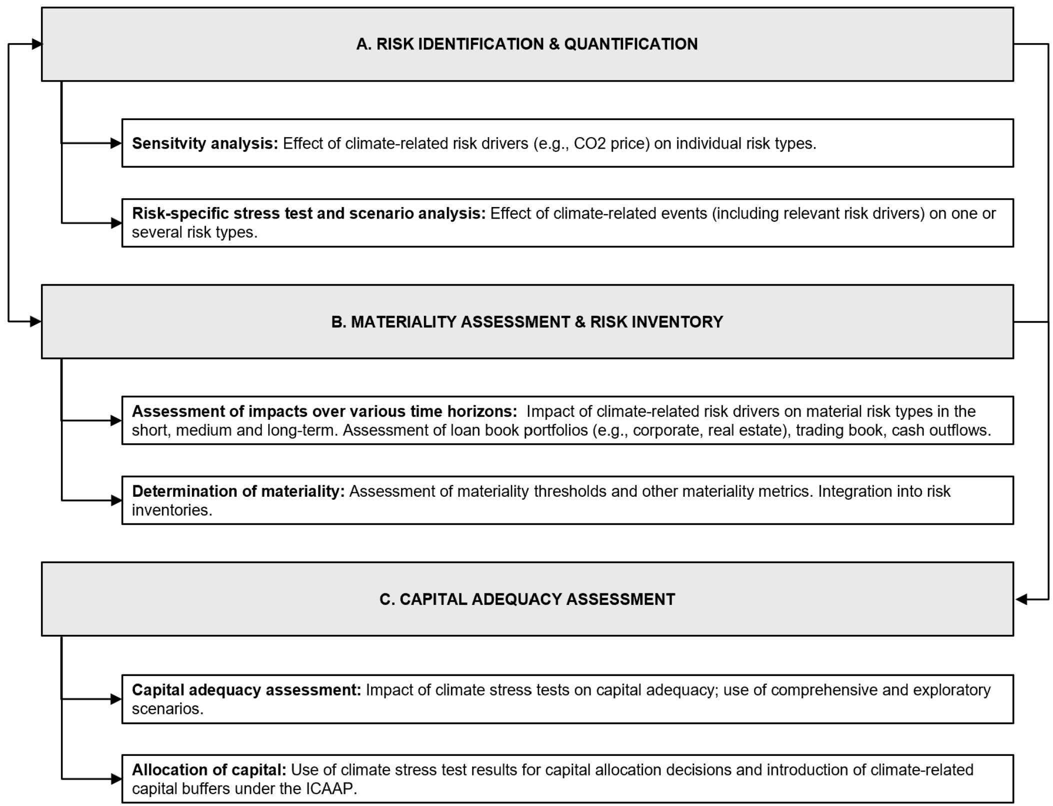

Figure 9: Key functions of climate stress testing. Based on ECB (2018), and ECB (2022*c*).

4.3.4.1 Integration of climate stress testing into stress testing framework

As part of the ICAAP, institutions perform a range of stress tests to quantitatively evaluate their risk profile, inform their capital planning and fulfill regulatory requirements. In particular, institutions are expected to perform tailored and in-depth reviews of their vulnerabilities, capturing "all material risks on an institution-wide basis" (p.35, ECB 2018).

To achieve this, institutions typically maintain a set of individual scenarios that are regularly updated and tailored to meet specific risk quantification objectives as part of their internal stress testing frameworks. The stress testing framework defines the internal scenarios, their objectives, key assumptions and methodologies and the roles involved in the stress testing process (BIS 2018). ICAAP stress tests are typically subject to multiple governance layers, often involving a scenario and stress testing committee and a board risk committee (ECB 2018). These governance bodies are expected to ensure the plausibility of the scenarios and the robustness of the underlying assumptions. Such responsibilities are usually also outlined in the stress testing framework.

As illustrated in Figure 10, institutions run adverse scenarios on a quarterly basis, taking a comprehensive approach by assessing the entire balance sheet and income statement and incorporating multiple risk types at once ("combined stress test"). Such combined stress tests provide information on whether capital levels are sufficient to cover different types of moderate to severe macroeconomic scenarios.[43] In addition, institutions also conduct exploratory stress tests that focus on specific risk types and targeted portfolios or sub-portfolios. Such exercises help to improve risk quantification.

Key risk quantification outcomes from these assessments may include metrics such as regulatory capital ratios (e.g., CET1 capital), leverage ratio, utilization of risk-bearing capacity, profitability and liquidity (Baudino et al. 2018). These outcomes are then compared against the quantitative objectives anchored in the risk appetite framework, as discussed in Section 4.4.2.

[43] We also refer to these stress tests as "macroeconomic stress tests".

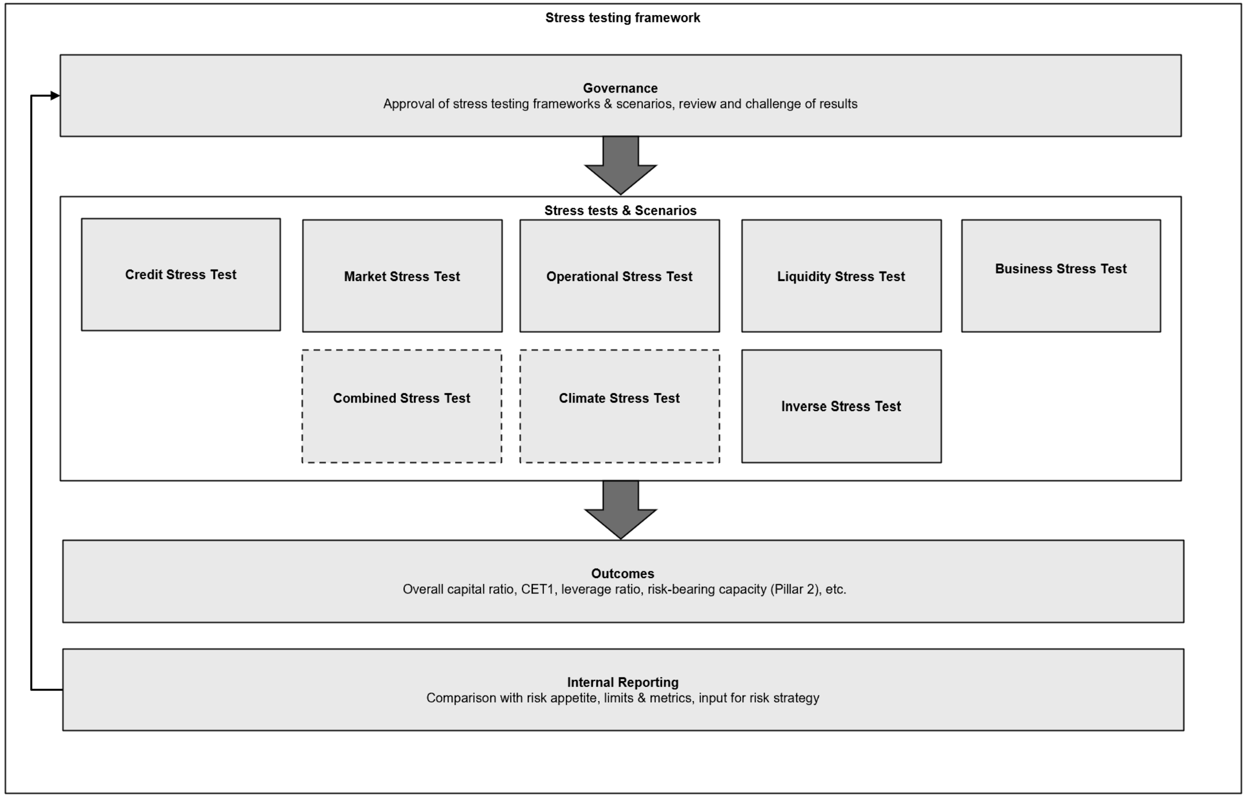

Figure 10: Stress testing framework. Based on EBA (2018) and ECB (2022*c*).

The ECB requires institutions with material climate risks to evaluate the appropriateness of their stress testing program, with a view to incorporating climate risks into their baseline and adverse scenarios (see expectation 11 of the ECB Guide, ECB 2020*b*). In response, several institutions have already integrated or are in the process of integrating climate stress tests into their internal stress testing frameworks, as noted by two respondents (N1, H5):

> *"Climate stress tests are now an integral part of the regular stress testing program."* **(N1)**

> *"Currently, climate and environmental stress tests still hold a certain special status and have their own reporting. However, the objective is to integrate them into the general stress testing framework in the future. The idea is that in future they will be treated like all other stress tests, so that we can assess potential impacts on capital and other factors, for example."* **(H5)**

The incorporation of climate stress tests into the internal stress testing framework is approached in a variety of ways. A few institutions (O, J) have added climate-related components to their quarterly institution-wide ICAAP stress tests (i.e., the "combined stress test" in Figure 10). In addition to this, the majority of institutions have expanded their internal stress testing frameworks to add climate stress tests as a distinct stress test and scenario category. For example, two respondents (J1, O1) described how climate risks are integrated as specific climate-related scenarios and how climate risk factors are embedded into other internal stress tests:

> *"As part of our stress test framework, we conduct various types of stress tests. This includes so-called 'adverse' scenarios, which we update on a quarterly basis. These scenarios incorporate climate-related components. For example, we have already started to include the CO2 price as a macro variable. In the future, we plan to integrate additional climate-related elements. We also perform 'exploratory' stress tests. For this, we create an annual stress test calendar in which we select 4 to 5 scenarios each year for in-depth analysis. For example, one year we might focus on a real estate market stress or interest rate risk scenario. Geopolitical scenarios, such as crises in the Middle East or Ukraine, may also be considered. In this context, we have now integrated an internal stress testing exercise for climate and environmental risks, which we aim to conduct every two years."* **(O1)**

"We currently have a set of 7 to 8 scenarios, including two that are explicitly focused on ESG and climate-related risks. Specifically, these are a short-term transition risk scenario and an ESG-related reputation risk scenario. In addition, several other scenarios have been enhanced to incorporate climate-related aspects. This means that climate considerations are not limited to our two specific ESG scenarios but are also embedded in others as well. This is particularly true for our shipping portfolio, where we use long-term forecasts for charter rates and market values that extend beyond the planning horizon. For example, we model the trend towards eco-efficient ships, as well as the expectation that non-efficient ships will experience greater losses in market value." **(J1)**

There are other examples of institutions incorporating climate scenarios into their internal stress testing framework. For example, one institution (E) mentions in its Pillar 3 report that it has incorporated climate risks into its internal stress testing framework, including in the form of "separate stress scenarios" for climate risks. Similarly, another institution (I) notes that ESG scenarios constitute a "separate scenario class" within its conceptual framework for stress tests and scenarios. Integrating climate stress tests into the broader stress testing framework also encourages institutions to conduct such stress tests on a regular basis (e.g., annually), while also ensuring that climate stress tests are subject to the same governance and reporting structures as conventional stress tests (e.g., stress testing committee, risk and credit committee, board of directors).

However, we find variation in the frequency with which these tests are conducted. For example, several respondents (E1, D1, H3, K2) indicated that their respective institutions conduct climate stress tests on an annual basis. Another respondent (O1) reported that explorative climate stress tests are performed every two years. In contrast, one respondent (J1) explained that climate-related scenarios are now treated as "regular scenarios" and are run on a quarterly basis as part of the institution's overall planning and forecasting process. These differences in frequency are also evident in the Pillar 3 report of one institution (K) in our sample, which states that macroeconomic stress test results are typically generated on a quarterly basis, while climate scenarios are conducted annually. However, a respondent (K2) from this institution indicated that a transition from the current annual approach to a semi-annual frequency is currently under consideration:

"We have a set of scenarios that we use for stress testing, which has been in place for several years. Each year, we review this list to determine if it remains relevant, if any

adjustments are needed, or if other issues with potentially greater impact should replace existing scenarios. Although the climate scenarios we have used over the past two years are important, they do not have the same severity as our top stress scenarios, and therefore are not included in that category. However, we still calculate them annually to ensure we stay alert to any developments that might justify their inclusion among our top scenarios. Unlike other stress tests, the time horizon for climate scenarios is much longer, projecting portfolio developments in business areas up to 2050. Currently, we run climate scenarios annually, while other stress tests are conducted quarterly. However, we are also evaluating whether annual assessments of climate scenarios are too infrequent and whether running them twice a year would be more suitable." **(K2)**

"We have now established a regular internal stress testing exercise for climate and environmental risks, which we aim to conduct every two years. We have just completed the most recent iteration of this process." **(O1)**

4.3.4.2 Climate scenario choices, assumptions and related challenges

Integrating climate stress tests into the broader stress testing framework requires the development and selection of appropriate scenarios. In addition, the availability of multiple climate scenarios raises the question of which ones are best suited for risk quantification and stress testing purposes. This section examines key considerations related to climate scenarios and discusses challenges highlighted by our respondents.

A stress test typically begins with scenario development, where the first step is to define a narrative based on a set of high-level qualitative and quantitative assumptions. These assumptions are typically presented in the form of a coherent and plausible scenario outline. The second step requires the definition of shocks to some key macroeconomic variables (e.g., interest rates, unemployment, house price index) that are representative of an economic downturn or a recession (Baudino et al. 2018). The design of these shocks, including their intensity and transmission channels, has to be grounded in historical and/or scientific evidence and take into account current economic and market conditions (Baudino et al. 2018). In addition, the scenario narrative needs to address relevant risk factors to which an institution is exposed and cover a time horizon consistent with the overall objective of the stress test exercise and the characteristics (e.g., maturity) of the institution's stressed portfolio (EBA 2018).

While some institutions incorporate climate-related risk factors (such as CO2 prices) into their internally developed macroeconomic stress tests, most institutions rely primarily on publicly available external climate scenarios to conduct their climate stress tests, as indicated by our respondents (D1, E1, F1, G1, H4, I2, K2, N1, O1, P1). These scenarios are developed by external organizations, including scientific bodies and supervisory institutions such as the NGFS, the IEA and the Intergovernmental Panel on Climate Change (IPCC) (Acharya et al. 2023, Bank of England 2024). Of these, the NGFS scenarios ("NGFS scenarios") were the most frequently referenced by our respondents.

Several respondents reported that European supervisors, in particular the ECB, typically select NGFS scenarios for their own stress testing exercises, which in turn influences the scenario choices of the respective institutions. In addition, the respondents cited additional reasons for preferring external scenarios, including better comparability of results, reduced reputational risk and the notion that climate scenarios are "common good" resources that institutions should both contribute to and use. For example:

> *"It is true that there are certain types of risk to which institutions are more or less vulnerable or sensitive. In such cases, it is useful to have your own scenarios. For example, if a bank only finances the automotive industry, it would be useful to explore certain aspects in more depth by developing specific in-house scenarios. But it is also important to remember that climate scenarios are a kind of scenario that describes how the world works. I don't think it would necessarily be useful or desirable for every bank to have its own vision of how the transition could work. For scenarios that describe the world, such as climate scenarios, I think it is important that they are developed by somewhat external authorities, such as regulators or scientists; there is no reason why they should be specific to a bank. Also, for reasons of communication, comparison and application, I think it is questionable whether certain scenarios should be constructed by the banks themselves."* **(G1)**

> *"We initially considered creating our own scenarios, but ultimately decided against it for a number of reasons. Firstly, some scenarios are mandated by regulatory stress tests. For example, when the ECB conducts a climate stress test, the parameters provided must be used as specified. Adopting these external scenarios aligns with current best practices and with the regulator's approach. In addition, using standardized scenarios ensures comparability and consistency. In all these scenarios, there is a very high degree of dependence on model inputs and assumptions. This risk does not diminish if we tweak them ourselves. Lastly, there is a reputation risk involved. We want to avoid*

a discussion where we have to justify ourselves for having set certain parameters in one way or another (...). Recently, we have been using NGFS scenarios a lot because they are also repeatedly picked out by the regulator." **(D1)**

"The NGFS provides a widely accepted foundation. As soon as you develop something of your own, questions arise, such as why it is parameterized this way or how does it align with specific aspects. By using an industry standard, you can to some extent avoid these types of discussions." **(K2)**

"In 2023, an internal climate stress test was conducted for the first time as part of the ICAAP stress testing program, encompassing multiple risk types. This test was partially based on the ECB's 2022 climate stress test. Given our bank's broad and diversified structure, it makes sense to primarily align with the ECB climate stress test. However, for more specialized banks, it would be more appropriate to have stress tests that are more specifically tailored to their portfolios (...)." **(N1)**

The institutions included in our sample use a variety of external climate scenarios. Figure 11 provides a stylized illustration of an institution's scenario mix. These scenarios can be broadly classified into two categories: short-term and long-term scenarios. Some scenarios examine transition risks, while others place greater focus on physical risks. Furthermore, they also use baseline scenarios, which we discuss in Section 4.3.4.3. We begin by discussing the use of short-term climate scenarios.

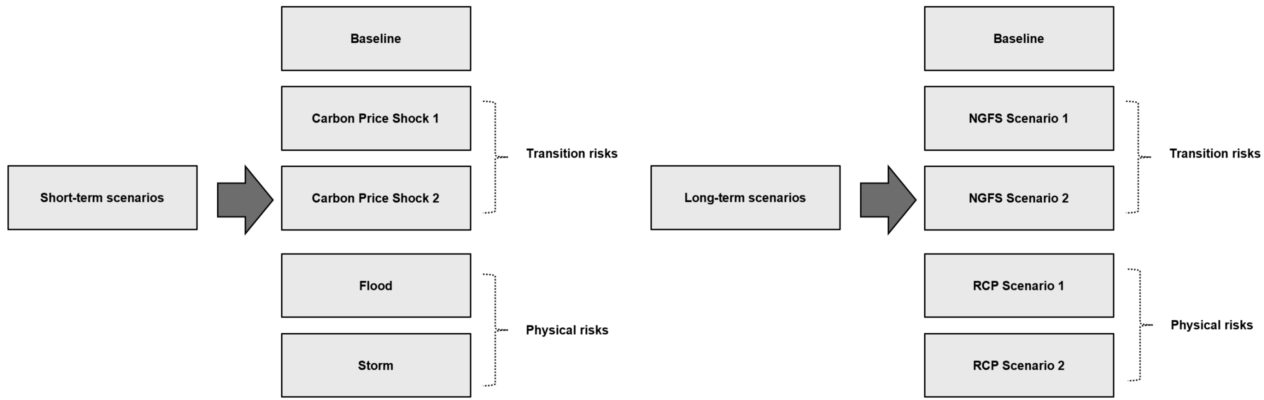

Figure 11: Simplified example of an institution's scenario mix. Own illustration.

Short-term scenarios:

A key motivation for using short-term scenarios is that the time horizon of such scenarios (e.g., 1 to 5 years) aligns with other key risk management and capital planning processes, which typically span 3 to 5 years. For example, one respondent (J1) noted that their institution uses a short-term scenario similar to the NGFS "sudden wake-up call" scenario. This scenario describes an abrupt and unanticipated transition in which an event (e.g., a severe natural disaster) triggers a sudden change in policy stance (NGFS 2023*a*). Similarly, another respondent (C1) described developing a short-term scenario centered on a severe carbon price shock. This scenario incorporates global forecasts for carbon prices and condenses their effects into a short-term framework. Finally, one respondent (O1) noted that their institution uses two short-term scenarios, each based on different levels of CO2 price shocks.

> *"Our standard stress tests typically cover a time horizon of 3 to 5 years, so we need scenarios that align with this timeframe. We have developed two specific ESG scenarios with internal parameters. One of these is a transition risk scenario, which goes in the direction of the NGFS's wake-up call scenario. It is a short-term scenario that models both a policy and confidence shock, including a rapid increase in carbon pricing."* **(J1)**

> *"We have developed an internal scenario, as the long-term NGFS scenarios are not well-suited for our internal assessments. Our short-term scenario is very conservative. We take research forecasts for 2030 and bring them down to today. We look at what research is forecasting in the more severe scenarios in terms of carbon prices around the globe, all at the same time, and we use those assumptions in our scenario as if they were occurring today (...). We have another transition risk scenario that assumes a sudden acceleration of green technology and analyzes what happens in different sectors (...). For the long-term scenarios, e.g., 30 years, we use NGFS as a base, but NGFS doesn't cover all the variables that we need for our portfolio, so we expand NGFS scenarios. Our models always start with a set of core variables that are linked to the scenario in question. Based on historical behaviors and certain characteristics of the scenario, we expand this to a set of 700-800 variables that help us to implement the scenario on the entire portfolio."* **(C1)**

> *"For the short-term scenarios, we consider different forms of a carbon price shock. We translate this into sector-specific PD shifts and apply them to our portfolio."* **(O1)**

A few respondents (E1, N1) also reported using modified versions of the scenarios employed in the supervisory climate stress test conducted by the ECB in 2022. For this exercise, the ECB provided several scenario projections, covering different time horizons, as shown in Figure 17. One of the scenarios was a short-term horizon of three years, modeling a disorderly transition. The calibration of this scenario was primarily based on NGFS estimates, with adjustments introduced by the ECB (ECB 2022*a*). Notably, the scenario entails a carbon price increase, which was frontloaded to 2022, 2023 and 2024 in the ECB's climate stress test (ECB 2022*a*). One respondent (E1) noted that the short-term disorderly transition scenario provided by the ECB served within their institution as a basis for further internal short-term climate stress testing exercises:

> *"In the previous stress test, the ECB provided a short-term disorderly transition scenario as a guideline. This scenario focused on the crisis years. We used this as a starting point and foundation for our internal stress scenarios."* **(E1)**

In terms of short-term physical risk scenarios, one respondent (O1) noted that their institution conducts stress tests focused on storm and flood risks using data from Munich Re's NATHAN database (Natural Hazard Assessment Network):

> *"In the short-term, we also look at scenarios for storm and flood risk. We use the NATHAN database, which contains data provided by Munich Re. Flood risk is a very relevant topic for us."* **(O1)**

Furthermore, several respondents (E1, I2, G2, O1) reported that their institutions' approaches to physical risk analysis were largely based on the ECB's methodology (see Figure 17). The 2022 ECB climate stress test covered a short-term horizon of one year and encompassed both a drought and heat scenario, as well as a flood risk scenario (ECB 2022*a*). The drought and heat scenario modeled the economic effects of a severe drought and heatwave in Europe, in particular a decline in sectoral gross value added growth as a result of a productivity shock to GDP. At the same time, the flood scenario modelled the risk of severe flooding in Europe. Both scenarios were designed by the ECB as instantaneous shocks, resulting in a much shorter time horizon compared to the transition risk scenarios (ECB 2022*a*).

Long-term scenarios:

We turn to the use of long-term scenarios. The scenarios used are typically from the NGFS or adapted versions of the climate scenarios introduced by the ECB in 2022 for the purpose of its supervisory climate stress test exercise (see Figure 17).

In terms of NGFS scenarios, one commonly used scenario is the "current policies" scenario, which falls under the "hot house world" scenario category (NGFS 2023*b*). This scenario assumes that existing policies remain unchanged, leading to approximately 3°C of global warming. The 3°C threshold is projected to be reached around 2090s, with important physical risks, such as floods and cyclones, expected to emerge by 2040 (NGFS 2023*b*). As a result, the associated transition risks are relatively mild. Another commonly used scenario is the "delayed transition" scenario, which assumes that emissions will not decline until after 2030, necessitating more stringent and disruptive policies to limit global warming to below 2°C. This scenario is classified as "disorderly" and presents higher transition risks due to the delayed policy response (NGFS 2023*b*). Lastly, the "net zero 2050" scenario assumes the EU will achieve net zero emissions by 2050, and that global warming is limited to 1.5°C through ambitious climate policies and innovations (NGFS 2023*b*). In terms of ECB scenarios, the respondents frequently referred to the "hot house world" scenario and the long-term "disorderly transition" scenarios. These long-term scenarios, employed in the 2022 ECB climate stress test, are largely based on NGFS projections, but include various adjustments (ECB 2022*a*). The main features of these scenarios are summarized in Table 8 in the appendix.

As shown in Figure 11, institutions tend to assess multiple long-term climate scenarios. The mix of scenarios is highly heterogeneous across institutions. By way of illustration, we provide in Table 3 three examples of climate-related "scenario mixes", including baseline and adverse scenarios observed in our sample. We discuss these different approaches further below.

Table 3: Examples of scenario mixes for long-term climate-related scenarios observed in the sample.

	Scenario mix A	**Scenario mix B**	**Scenario mix C**
Baseline	below 2°C	net zero 2050	macroeconomic scenario
Adverse	1) delayed transition 2) current policies	1) delayed transition 2) current policies	1) net zero 2050 2) delayed transition

For example, one respondent (G1) explained that their institution commonly uses three NGFS scenarios: the below 2°C scenario as a baseline, and the delayed transition and current policies scenarios as adverse scenarios. Similarly, another respondent (K2) reported that their institution also uses three NGFS scenarios: the net zero 2050 scenario as the baseline, and the delayed transition and current policies scenarios as stress scenarios. Finally, one respondent (I2) described the use of three long-term climate scenarios: the delayed transition, disorderly transition and hot house world scenarios. To illustrate:

> *"We use a below 2°C scenario, which represents an orderly transition, as well as a delayed transition scenario, which is a disorderly one, along with a current policies scenario. The goal is to have a baseline scenario and an adverse scenario that reflects a stressed projection compared to the baseline, allowing us to clearly identify the transition-related shock. The delayed transition scenario serves as the stressed version. We also consider the current policies scenario, known as a hothouse scenario, but intend to discontinue its use as we think it is highly unlikely to materialize."* **(G1)**

> *"We use the net zero 2050 scenario as our baseline, with two additional stress scenarios: delayed transition and current policies, all with a time horizon extending to 2050. This approach enables us to specifically capture the different dimensions, focusing on both transition and physical risks."* **(K2)**

Some institutions also make internal adjustments to these long-term scenarios. For example, one respondent (I2) pointed out that their institution incorporated a CO2 price pass-through:

> *"We base our analyses on the NGFS scenarios: hot house world, delayed, and disorderly transition. These scenarios are adjusted internally to better model sector-specific countermeasures. For each scenario and sector, we calculate the CO2 price pass-through rate to customers. Take, for example, the cement industry. If we were to apply a Disorderly Transition scenario without adjustments, it would lead to the collapse of the entire cement industry within approximately three years. The burden from CO2 prices would be so severe that companies would become unprofitable and lose creditworthiness, resulting in widespread defaults. However, Germany aims to construct many new homes annually until 2040, a goal that seems unattainable to us without cement. Therefore, we have developed a pass-through rate to model how much of the CO2 price can be passed on to the end customer across different sectors (...). The time horizon of these scenarios is 2050 (...)."* **(I2)**

Several respondents (D1, O1, P1) noted that their respective institutions use the net zero 2050 scenario as an adverse scenario in climate stress tests. For example, one respondent

(D1) reported using both the net zero 2050 and current policies scenarios, explaining that the net zero 2050 scenario aligns with their institution's net zero commitment, thus motivating its selection alongside the current policies scenario. Another respondent (O1) described using both the delayed transition and net zero 2050 scenarios as long-term transition scenarios. Similarly, respondent (P1) reported combining both a net zero and a delayed transition scenario in their approach:

> *"We combine several scenarios. For transition risk, we use a net zero scenario. This is simply because, as a bank, we also have a net zero commitment. It is part of our strategy. For physical risk, we use a relatively warm scenario that triggers physical risk events. We have not chosen a scenario because we think it is inherently more likely to occur. We don't think that it is possible to make such an assumption. We deliberately combine a net zero scenario with a relatively warm physical risk scenario. They are unlikely to happen at the same time, but we combine them anyway to get a more conservative view."* **(D1)**

> *"We believe that the net zero 2050 scenario is certainly a challenging scenario, and hopefully one that is not entirely unrealistic. That is what led us to choose it. We also included a delayed transition scenario, which captures the effects of a disorderly transition, alongside it on purpose."* **(O1)**

> *"We conduct a climate risk stress test with an exploratory focus, using NGFS scenarios and focusing on two key ones: delayed transition and net zero. We chose these scenarios because they have the most substantial impact and because our strategy is strongly aligned with the 1.5°C target. In addition, we also consider the delayed transition scenario to ensure a more comprehensive analysis. We view the net zero scenario as a stress test scenario, though its risk depends on the comparison. If we assume the world is on a current policies pathway, then the net zero scenario introduces substantial transition risks."* **(P1)**

For long-term physical risks, the institutions in our sample tend to use Representative Concentration Pathways (RCPs), which are scenarios developed by the IPCC.[44] For example, one of the respondents (O1) elaborated on the use of two RCP scenarios:

[44] For a more detailed discussion of physical risk analysis, see Section 4.3.4.7.

“We also incorporate very long-term scenarios in our analysis. For example, we use the RCP 8.5 scenario to assess severe flood risks with a time horizon extending to 2050. Similarly, we apply the RCP 8.5 scenario with a time horizon up to 2100 to evaluate the impact of sea level rise. While we can’t predict the exact composition of our credit portfolio that far into the future, we can apply these scenarios to our current portfolio to analyze what the potential implications would be for us.” **(O1)**

The use of climate scenarios and their underlying assumptions is not without its challenges. Some of these challenges have been widely discussed in the literature (see e.g., BIS (2023, 2024), Reinders et al. (2023). We complement this literature by documenting several important aspects raised by our respondents:

Time horizon:

A commonly cited challenge is the time horizon of climate scenarios, which often extends well beyond the typical timeframes considered by institutions in stress testing, risk management processes and capital planning. This presents both conceptual and technical difficulties, including issues related to IT infrastructure and data handling:

“In a standard EBA stress test or ICAAP stress test, the time horizon is usually three years. However, for the ECB climate stress test, we have to consider time horizons extending up to 30 years, which makes a big difference (...). Even from an IT infrastructure standpoint, a three-year time horizon is much easier to conceptualize than a 30-year one.” **(A2)**

“The temporal dimension poses a major challenge. Transition risks with time horizons of 30, 50, or even 100 years are fundamentally different from the models currently used in stress testing. This creates a high degree of uncertainty when trying to assess the potential impact of climate risks on capital ratios over such long periods. Quantifying these impacts, as in other stress scenarios, involves a large number of assumptions, which in turn raises concerns about the accuracy of the results. One of the main challenges is reconciling our traditional five-year management horizon with analyses that stretch over 50 to 100 years.” **(E1)**

Overall scenario design and lack of severity:

In addition to the time horizon, the design of climate scenarios also poses a significant challenge. Typically, institutions use scenarios that assume an economic downturn with significant macroeconomic shocks, such as a sharp decline in GDP. However, respondents frequently noted that several climate scenarios project only "mild" impacts on GDP. One challenge highlighted is therefore that NGFS scenarios do not provide the shocks "needed" for stress testing exercises. In addition, while internal ICAAP scenarios are typically updated quarterly to reflect changes in macroeconomic conditions, climate-related scenarios are rather reviewed only once a year. Institutions are therefore to some extent dependent on updates from the NGFS for any necessary adjustments:

> *"There is a difference in scenario narrative or scenario design. In a typical stress test, there is more of a narrative based on the macroeconomic downturn. There are assumptions about GDP or unemployment rates. A climate stress test is more about climate risk drivers. These could be carbon price shocks or something like that. As I see it, the focus is not so much on saying that there is an economic downturn. Instead, GDP is almost more of an additional piece of information here or perhaps even more of an output variable from my point of view. In other stress tests, you sometimes start with an assumption of an economic downturn and then analyze what would happen. Here it's more the case that you start with, let's say, a carbon price shock or physical risks and then at some point GDP and other economic factors come in later on."* **(A1)**

While acknowledging the serious threats posed by climate change, several respondents (B1, C1, F1, H4, I2, K2) also explained that most climate scenarios cannot be considered truly "adverse" and therefore have little impact on capital ratios. For example, one expert (A3) pointed out that traditional stress tests are designed to evaluate the effects of rather sudden, large-scale macroeconomic events that can rapidly undermine an institution's financial stability. In contrast, climate risks develop gradually over extended time periods, making them difficult to incorporate into stress testing frameworks. In addition, these experts compared NGFS scenarios with their internal macroeconomic scenarios, noting that the NGFS scenarios generally present less severe effects from a macroeconomic perspective:

> *"The macroeconomic shocks from these scenarios are very mild. The scenarios are milder than any of the other scenarios that we run."* **(C1)**

"In ICAAP or inverse stress tests, we look at adverse macroeconomic events. Some of these events could happen overnight. For example, if a country in the European Union were to default, the impact would be felt overnight. It would have a direct negative impact on the bank's balance sheet. In the case of climate events, it is more likely to happen over the next years, but certainly not overnight. In that sense, it is a long-term and slow process. Much slower than the macroeconomic events that we typically look at." **(A3)**

"In several NGFS scenarios there are significant CO2 price shocks and substantial changes in CO2 emissions, but the resulting change in GDP remains almost identical regardless of the magnitude of the CO2 price fluctuations. The impact on GDP often appears to be minimal." **(H4)**

"In traditional stress tests, we can define a specific shift in the yield curve by a certain number of basis points, outline how FX curves behave, and make certain growth assumptions. This enables us to predict the impact on the bank's portfolio with reasonable accuracy. When it comes to transmission mechanisms, such as a two-percentage-point increase in interest rates, the bank can arrive at a clear understanding of the resulting effects. In contrast, with climate change, a two-degree temperature rise requires many assumptions before we can gauge any impact on a loan portfolio. Moreover, this impact does not occur immediately. While interest rates respond quickly, FX even faster, the effects of CO2 accumulate gradually over time." **(D2)**

Several respondents (B1, E1, G1, J1) also point to some weaknesses in the scenarios used in the ECB's 2022 climate risk stress test. They noted that the scenarios did not lead to significant stress effects:

"Some of the forecasts were not really what you would call stress from a purely macroeconomic point of view (...). The growth rates under the various scenarios were far removed from any recession scenarios. In other words, on that basis alone, we did not find a stress effect at all. And I think that describes the challenge (...). Translating a specific climate stress scenario into a macroeconomic stress scenario is complex. We are talking about very long-term developments. What happens if, for example, long-term growth falls by an average of 0.3 percentage points and how that translates into credit risk is difficult to say. In general, stress test models react more to what happens if

> *there is an extreme recession next year with -3% GDP growth. We are not interested in 0.3 percentage points up and down. Even if you had very granular data and very good regression models, at the end of the day, there would probably be very little difference."* **(B1)**

> *"I find the transition scenarios especially challenging because, in my opinion, the ECB's parametrization of the climate stress test didn't yield entirely plausible figures. For instance, when examining the macroeconomic parameters, such as the GDP data provided in the 2022 climate stress test, we faced difficulties in modeling an internal stress scenario based on that data. As a result, we made additional assumptions about an economic downturn to model PD shifts with the scenarios."* **(E1)**

Lastly, another respondent (G1) argued that current climate stress scenarios do not qualify as true stress tests because they are based on overly optimistic mathematical models. These models assume ideal conditions, such as perfect agent behavior, unlimited resources, and rapid technological advancement. Although some improvements have been made, such as considering imperfect international cooperation, this expert explained that the scenarios still fall short by not accounting for real-world non-optimal conditions:

> *"It seems to us that there is currently no climate stress scenario as such. As far as we are concerned, the scenarios that are proposed are scenarios that are more or less favourable, but none of them are stress scenarios because they are all based on mathematical models that assume optimal behavior. The scenarios are all based on models that assume that everything is extremely fluid. Agents are all optimal. Resources are unlimited. Investments are immediately reflected in technological change. The NGFS and many others are currently working on this. For example, they have started to work on the fact that there is not necessarily perfect international cooperation. But so far we haven't managed to take into account all the dimensions that wouldn't be optimal. For example, even in a scenario with very high CO2 prices, we continue to assume that everything else works perfectly. This is also one of the reasons why we systematically end up with much lower impacts than in traditional stress tests."* **(G1)**

Low sectoral and spatial granularity:

Several experts (A1, F1, I2, J1) highlighted the difficulty of isolating the effects of climate scenarios and accurately attributing them to particular sectors or specific geographic areas.

They explained that a key limitation of these scenarios is their insufficient granularity, which makes it challenging to effectively capture the risks tied to an institution's specific business model and portfolio:

> *"In terms of GDP assumptions, some of them are given by the NGFS scenarios (...) but what is not always provided is, for example, what this means for the individual sectors. Part of it is given and part of it is based on additional assumptions that we make internally to differentiate the effects across sectors. But if we make additional assumptions for, say, the automotive and transportation industries, then we have to make sure that everything fits in with the overall GDP assumptions (...). We have a team of economists that perform this variable expansion. Some of it is based on qualitative assumptions (...)."* **(A1)**

Probabilities of climate scenarios:

Several respondents (G1, H5, K2) underscored that a discussion on the probabilities of different climate scenarios would be valuable. For example, one respondent (G1) explained that the current challenge is not the lack of scenarios, but rather the lack of probabilities associated with them. While many scenarios are used, each is typically analyzed in isolation. This expert made a case for analyzing scenario outcomes in a more conditional way, i.e. conditional on the probability of each scenario. Another expert (O1) argued that while institutions are faced with an increasing number of climate scenarios, the goal should be to focus on a more limited number of scenarios that are both highly probable and most useful for decision making. One respondent (K2) provided an example of how their institution has already begun to assign internal probabilities to climate scenarios based on expert judgement. These probabilities are taken into account in the ICAAP. By doing so, the institution prioritizes scenarios that it expects are likely to occur, thereby improving risk management and planning. Similarly, another respondent (H5) highlighted that their institution is actively working to assess what might be considered a likely scenario used for loan pricing:[45]

> *"A current challenge is that there are no probabilities associated with climate scenarios. Each time, we focus on one scenario and analyze its outcomes. What could be interesting is if there were probabilities assigned to each scenario. This way, we could*

[45]Probabilities may be assigned to scenarios in the context of expected credit loss calculations. For example, scenarios may be incorporated into the expected credit loss calculation and risk stage determination in a probability-weighted manner.

not only perform analyses for different scenarios, as is currently done, but also produce results that are conditional on the likelihood of each scenario. This would allow us to assess the overall risk by associating each scenario with its probability of occurring. I think this could be valuable to track how these probabilities evolve over time." **(G1)**

"Our macro stress scenarios do not have an assigned probability. These are narratives that focus on potential impacts, without consideration of how likely the scenario is to occur. The situation is somewhat different with climate scenarios. In this case, we collaborate with economists, as there are specific estimates regarding the probability of occurrence for scenarios such as our baseline, the hot house world, and the delayed transition. While these probabilities are not directly factored into the calculations, they are considered in the overall assessment. For example, knowing that the current policies scenario has a 10% probability is quite different from it having a 70% probability. This also plays a role in determining the climate-related buffer." **(K2)**

"A little further in the ECB Guide, we are asked to include climate and environmental risks into loan pricing. So we need to choose a scenario that we can use for our monitoring and that we can also use to set loan conditions for our customers (...). This scenario should be as realistic and close to expected developments as possible (...). For pricing, we try to focus on one scenario for the time being. We may at some point use a weighted average of several scenarios." **(H5)**

4.3.4.3 Choice of baseline scenario

The degree of severity of the scenario outcomes is typically determined by comparing them to a baseline scenario. A baseline scenario is defined as a "non-stressed, central projection that serves as a basis of comparison for the other analyzed scenarios" (p. 10, BIS 2024). Thus, the baseline is usually the most likely scenario. The stress effect is then quantified by comparing the impact of an adverse scenario against the baseline (EBA 2018). As with conventional stress tests, climate stress tests require the selection of one (or more) adverse scenarios and a baseline scenario. In this section, we outline the approaches taken by several institutions in our sample to incorporate climate risks into their baseline projections and highlight key challenges.

A baseline scenario that completely ignores climate impacts would be counterfactual and unrealistic (BIS 2024). Therefore, to provide a realistic path, climate risks should be accounted for in the baseline projection (BIS 2024). Selecting an appropriate baseline scenario for climate stress testing presents significant challenges, however. One difficulty is assessing what constitutes a likely scenario. Another is to incorporate climate-related impacts from both transition and physical risks into the central projection. Incorporating climate risks into the baseline also adds complexity. Specifically, if the baseline already reflects a certain level of stress, the perceived severity of the adverse scenario may be reduced, blurring the distinction between the two. As a result, the adverse scenario may seem only marginally worse and could therefore fail to highlight the full range of potential risks. Ideally, the baseline scenario should strike a balance between accounting for climate risks and maintaining enough contrast with the adverse scenario.

Overall, we observe two main approaches among the institutions in our sample. One is to integrate climate risks into the institution-wide macroeconomic forecast, which serves as the baseline scenario for various purposes, including business and capital planning. The other is to use a dedicated climate scenario as a baseline. We provide an overview of the scenarios mentioned by our respondents in Table 4 and discuss them below. As a first illustration, and as shown in Figure 17, institutions were provided with baseline projections in the supervisory climate stress test conducted by the ECB in 2022. For the long-term transition risk scenario, the baseline represented an orderly transition characterized by minimal transition and physical risks. For the short-term transition scenario, the baseline was based on the Eurosystem's December 2021 Broad Macroeconomic Projections Exercise (BMPE) ECB (2022*a*).

Table 4: Non-exhaustive list of examples of baseline scenarios.

Baseline scenario name	**Organization**	**Challenge**
Below 2°C	NGFS	Overly optimistic
Fragmented World	NGFS	Contains transition and physical risks
Net Zero by 2050	NGFS/IEA	Contains transition risks
Orderly transition	NGFS/ECB	Overly optimistic
Other macroeconomic scenario	Internal	May ignore climate risks

Due to the complexities involved, our respondents expressed varying views on the integration of climate risks into baseline scenarios. For example, one respondent (C1) argued that their institution had not incorporated climate risks into the standard baseline scenario and did not plan on doing so. This expert also noted a lack of clarity from regulators on this issue, as reflected in the following statement:

"The net-zero scenario can serve as a kind of baseline scenario and might actually work as a baseline for other climate scenarios. However, we have not included climate risks in our own baseline and have no plans to do so (...). I think there are a lot of different approaches being used at the moment. For example, in the Bank of England's climate stress test, the counterfactual did not include climate risks. The ECB provided a baseline, but in the results they publish, they never take the baseline into account - they always compare between scenarios. As a result, the baseline didn't have much impact on the overall climate stress test. If you look at the results published by the ECB, they never compare anything to the baseline. Meanwhile, the Federal Reserve used the current policies scenario as the baseline, which is problematic because it includes a lot of physical risks in the baseline, yet they asked us to benchmark against that for transition risks. So, overall, I think we have quite a bit of freedom to decide what the baseline is and how to use it because the regulators are not clear (...) For the short term, we take into account the whole loss resulting from the adverse scenario." **(C1)**

Other respondents explained that their institutions already use, or plan to use in the near future, specific baseline scenarios incorporating climate risks for their internal climate stress tests. For example, two respondents (I2, P1) explained that their respective institutions use an internal scenario used for capital planning (so-called "economic plan scenario" or "rolling forecast") as a baseline. Such scenarios are not specifically designed as climate scenarios like the NGFS scenarios, but institutions do incorporate climate-related elements, for example related to CO2 prices. Such baseline scenarios are based on macroeconomic forecasts developed by the institutions' economic research departments. They cover shorter time horizons than the NGFS scenarios. The forecasts are updated at least quarterly. Consequently, more immediate macroeconomic effects of climate risks are likely to be naturally incorporated and covered by the forecasts, while longer-term climate-related effects may be limited or even overlooked.

"For the short term, we use our internal scenario. We have an internal rolling forecast, which serves as the baseline scenario. Building on this, we then apply climate scenarios, such as the delayed transition, and break it down over a three-year horizon." **(P1)**

"We have developed a scenario that reflects our expectations for upcoming macroeconomic developments. This scenario, referred to as our Economic Plan Scenario, is independently developed by our research department. As the risk control function, we

> *independently adjust it in collaboration with the risk management units. Climate risk factors are included in the scenario, but their impact isn't felt until 2028 or 2029, so they are not highly relevant at this stage (...). Our expectation is that the first significant climate-related impacts won't occur immediately, but rather will begin around 2028-2029. This is reflected in our expected scenario (...). This scenario is reviewed quarterly. It is an iterative process and we are increasingly including climate-related aspects into our planning process."* **(I2)**

Similarly, another respondent (O1) provided further insight into the use of a baseline scenario based on medium-term macroeconomic assumptions, including a gradual increase in CO2 prices:

> *"In the baseline scenario, we primarily base our assumptions on our own medium-term planning and factor in an expected increase in CO2 prices, rising from 84 to 108 between 2023 and 2028. This baseline particularly plays a role for our short-term carbon price shock scenarios."* **(01)**

For the second approach, which uses dedicated climate scenarios as baselines, various NGFS scenarios are applied. For example, one respondent (G1) noted that their institution initially used the NGFS below 2°C (orderly transition) scenario as its baseline. This scenario belongs to the category of "orderly" scenarios and assumes that gradually more stringent policies provide a 67% chance of limiting global warming to below 2°C (NGFS 2023*b*). However, the expert noted that this scenario is becoming increasingly unlikely, prompting their institution to adopt the NGFS Fragmented World scenario as the new potential baseline. This scenario assumes delayed and inconsistent climate policy actions, resulting in high transition risks in some countries and significant physical risks globally due to the overall ineffectiveness of the transition (NGFS 2024*b*). A challenge with this baseline is its relatively high levels of both transition and physical risks, which could lead to an underestimation of the overall impact:

> *"We use a baseline and an adverse scenario to really identify a shock associated with the transition. At the moment, we still consider the orderly transition scenario to be the baseline in the sense that it is the least risky scenario. But we are in the process of evolving on this point as well, because unfortunately this scenario itself is not at all likely. It should be understood as a favorable or optimistic scenario rather than a baseline scenario. In its new set of scenarios, the NGFS has a scenario called fragmented*

> *world. This will be our baseline scenario from now on (....). One of the limitations of all the work done on climate is that there is really no very robust, consensual baseline scenario."* **(G1)**

Another expert (K2) explained that their institution uses the NGFS net zero by 2050 scenario as its baseline. This scenario is considered orderly, as it assumes global warming is limited to 1.5°C by 2050 through the smooth and immediate implementation of climate policies (NGFS 2023*b*). As a result, transition risks are moderate and physical risks are low (see Table 8 in the appendix). Similarly, one respondent (L1) noted that institutions also typically use the IEA's net zero by 2050 scenario. This expert argued that such a scenario may be particularly appropriate for institutions with a large portfolio of European companies, given the EU's commitment to a net zero target by 2050. However, such choice of baseline would also be based on the assumption that clients within the institution's portfolio follow this commitment path. Thus, understanding the behavior and trajectories of the institution's clients is an essential aspect of selecting the appropriate baseline scenario.

> *"We use the net zero 2050 scenario as our baseline, with two additional stress scenarios: delayed transition and current policies, all with a time horizon extending to 2050."* **(K2)**

> *"What can we use as a guide? A classic approach would be to use the IEA net zero 2050 scenario (...). This gives sectoral pathways with interim targets for 2030, 40, 50. Sometimes the only option we have is to say that our borrowers will follow the path that the IEA has set out in this scenario. Whether they do, or whether they go faster or slower [with the transition], is very hard to say. But you have to look at it and collect data."* **(L1)**

> *"If you take an optimistic baseline scenario like net zero 2050 and compare it to the less optimistic scenarios, such as current policies and hot house world, the impact becomes even more pronounced. In that case, the assessment would be rather conservative. But it is true that net zero 2050 is becoming increasingly unlikely."* **(K2)**

In terms of incorporating physical risks into baseline scenarios, one expert (G1) highlighted the particular difficulty of incorporating long-term physical risks, noting that institutions still struggle to fully understand and model these effects. On the other hand, another respondent (O1) mentioned that short-term physical risks are more likely to be reflected and factored into the medium-term macroeconomic assumptions used in baseline scenarios:

> *"When it comes to physical risks, we generally assume that these are initially reflected in our credit risk parameters and medium-term planning. If flood scenarios or similar events actually occur, we would likely face increased provision needs and higher risk-weighted assets. We can then compare these events to the baseline, but always in the context of the assumptions and goals set in our medium-term planning."* **(O1)**

4.3.4.4 Top-down modeling approaches

As outlined in Section 4.3.4, the institutions in our sample frequently conduct stress tests using a "top-down" approach as part of their ICAAP. These exercises typically consist of three key components: scenarios, models and outcomes (Acharya et al. 2023). In this section, we briefly examine some of the main steps of this approach and discuss the challenges that institutions face in this regard, as described by the respondents.

In their ICAAP, institutions typically use macroeconomic ("top-down") stress testing approaches in which exogenous shocks are applied to key macroeconomic variables (e.g., interest rates, unemployment) to simulate an economic downturn or recession (Baudino et al. 2018). The shocks are realized through various transmission channels and processed by satellite models that translate the macroeconomic indicators into financial risk parameters for different types of risk (e.g., credit risk, market risk) (Schult et al. 2023, Reinders et al. 2023). The results of such scenarios can generally be expressed in terms of stressed capital ratios and used to highlight potential capital shortfalls under severe but plausible conditions (Acharya et al. 2023). Figure 12 shows the main steps of this top-down approach.

In the context of climate risks, the institutions in our sample also apply such approaches using climate scenarios and climate-related stress events. An important first step in top-down modeling approaches is scenario specification, which involves defining the specific conditions or events that the stress test will simulate. This step involves selecting the types of shocks or events (such as economic recessions, market crashes, climate-related disasters) and defining their magnitude, duration, and other parameters. This step is typically performed by the institution's economic research department in collaboration with the specific risk control teams responsible for stress testing.

> *"Our colleagues in the economics department develop the macroeconomic scenarios. Key parameters include GDP, unemployment rates, interest rate trends, and so on. We provide some guidance on how adverse the scenario should be. They then apply their economic models, and we receive the parameters back, which we need to translate*

> *to the different risk types within our portfolio."* **(O1)**

Scenario expansion:

As discussed in Section 4.3.4.2, institutions typically rely on external long-term scenarios, such as those developed by the NGFS, for their climate stress tests. Although the NGFS develops the scenario narratives and provides a corresponding set of key variables, institutions typically have to perform a "scenario expansion", which involves refining and extending the scenarios to meet their specific needs. Such climate-related scenario expansion process was described as particularly challenging by our respondents (A1, C1, F1, H4, J1, J2). While the institutions' economic research departments are typically tasked with the scenario expansion, one institution (J) noted that several departments, including not only economic research and the chief economist, but also finance and risk management, contribute to scenario expansion, with risk management leading the process in this case.

In terms of scenario expansion, and by way of illustration, three respondents (A1, C1, H4) noted that while the NGFS scenarios provide GDP estimates at the country level, they lack detailed information at the sector level. This requires institutions to make assumptions about the macroeconomic impacts of climate change on specific sectors, including in terms of sector growth, but also price shifts (e.g., due to structural changes and shocks). Other issues such as changes in productivity (due to extreme weather) and socio-economic changes (such as changes in consumer behavior) may also require careful consideration at the sector level. For example:

> *"We have a research department that parameterizes the scenarios in the internal stress tests and derives GDP, inflation and other parameters from the storyline. There are also qualitative parameters (...). Even if we take the NGFS scenario as a basis, we have to do what we call 'scenario expansion'. For example, NGFS gives us GDP estimates at country level, but we need such estimates at both country and sector level, so we need to break such scenarios further down internally. That is something that, for example, we do ourselves internally. As a next step, we use these estimates in our satellite models."* **(H4)**

> *"In terms of GDP assumptions, some of them are given by the NGFS scenarios (...) but what is not always provided is, for example, what this means for the individual sectors. Part of it is given and part of it is based on additional assumptions that we*

make internally to differentiate the effects across sectors. We have a team of economists that perform this variable expansion." **(A1)**

"For the long-term scenarios, e.g., 30 years, we use NGFS as a base, but NGFS doesn't cover all the variables that we need for our portfolio, so we expand NGFS scenarios. Our models always start with a set of core variables that are linked to the scenario in question. Based on historical behaviors and certain characteristics of the scenario, we expand this to a set of 700-800 variables that help us to implement the scenario on the entire portfolio." **(C1)**

"We have to analyze how, for example, climate policy may affect GDP, but what the effect may be for different sectors and companies. And that is a really big challenge that our economic research department is also facing. It is very difficult to quantify this effect. The NGFS models provide data, this data is now quite good and we can of course use it as a first step." **(L1)**

In expanding scenarios at the sector level, some institutions incorporate additional assumptions, such as the pass-through rate of CO2 prices. For example, one respondent (I2) indicated that their institution estimates the capacity of specific sectors to transfer increases in CO2 costs to their consumers, a factor that is otherwise absent from the NGFS scenarios:

"We take a top-down approach at the sector level, using data on CO2 prices and sector GDP data as outlined in the scenarios. Based on the changes in sector GDP, we further estimate the impact on the sectors by incorporating additional assumptions about their ability to pass on CO2 costs to consumers. These sector-level pass-through rate estimates are then applied to our clients' actual CO2 intensity. In essence, we assess each client's CO2 emissions and analyze their balance sheets to determine how future CO2 prices may affect their profitability. If a client can pass on the full cost of CO2 to consumers, their profitability will remain unchanged. However, if they can only pass on 50% of these costs, they will see a reduction in profitability. This allows us to calculate changes in PDs for individual clients based on their CO2 intensity. Our ability to make accurate assessments at a sector level is already very good. However, when it comes to individual clients, particularly their ability to pass on costs, we recognize that there is room for improvement. This will improve as we collect more data, allowing us to

better reflect the specific intensities of individual clients. In 2021, we started calculating sector intensities using data from MACS and applied these calculations to individual clients. For our largest clients, we have already collected detailed data and are now iteratively building a database based on real data." **(I2)**

Satellite models and related challenges:

Once institutions have translated climate scenarios into macroeconomic impacts, including at the sector level, they typically use "satellite models" that translate the macroeconomic variables into financial risk parameters (Reinders et al. 2023). For example, one respondent (H4) explained that their institution's top-down approach currently allows them to derive credit risk parameters and impairments[46] from climate scenarios. However, the respondent also noted that this top-down approach does not currently extend to the entire balance sheet and therefore does not consider the potential impact on all risk types. Several respondents (A1, G1) highlighted the limitations of satellite models when assessing climate risks. One issue is the reliance of such models on historical data for model calibration. Furthermore, these models may not effectively capture granular effects at the sector or even intra-sector level. As a result, institutions combine the top-down approach with microeconomic, or bottom-up, stress testing approach, which we discuss in Section 4.3.4.5.

"What we do is we stress PD, LGD and collateral for credit risk and then translate that into risk-weighted assets and impairments. To be fair, what we don't do is actually stress the whole balance sheet." **(H4)**

"We don't like to work with these top-down portfolio models. If I have two companies, two energy producers for example, both in the same country and both with the same rating, our normal portfolio models would treat them the same. If the GDP is the same, everything is the same, the result will be the same. But maybe one has 100% renewable energy and no emissions at all. If the CO2 price goes up, nothing changes in terms of profitability. The rating might stay the same. And then there is the other energy producer that might have their whole business based on, let's say, oil or coal, so they have a lot of emissions. If the price of carbon goes up, you can see that the company would have a lot of additional high costs and there would be a negative impact

[46] Under IFRS 9, impairments refer to the recognition of potential credit losses on financial assets, such as loans, based on expected credit loss models.

on profitability or leverage. So we think it is better to do very granular modeling in order to quantify climate risks, so that we can then look at those differences and really process them." **(A1)**

"The issue is that we don't have the capacity to produce mass statistics about things we have never observed. On the one hand, we can invent a climate z-factor, a climate sensitivity. We can write equations that feed into top-down models. There are lots of attempts to do that, and it is possible. On the other hand, we can't calibrate them because we don't have enough statistical observations. Fundamentally, we don't know what the difference is in the default rate of a portfolio between a baseline level and a level where there would be a greater climate impact. So, we can write equations, but I don't think we can calibrate them. And as we can't calibrate them, we have to make assumptions about the future. So it seems to me that the only way to have an impact on portfolios is to simulate something that is a little theoretical and bottom up. Our conclusion to date is that to see any impact, as we do not observe anything at portfolio level, we have to go down to client level and try to build a microeconomic stress-test logic. That is why we are now working with a bottom-up approach." **(G1)**

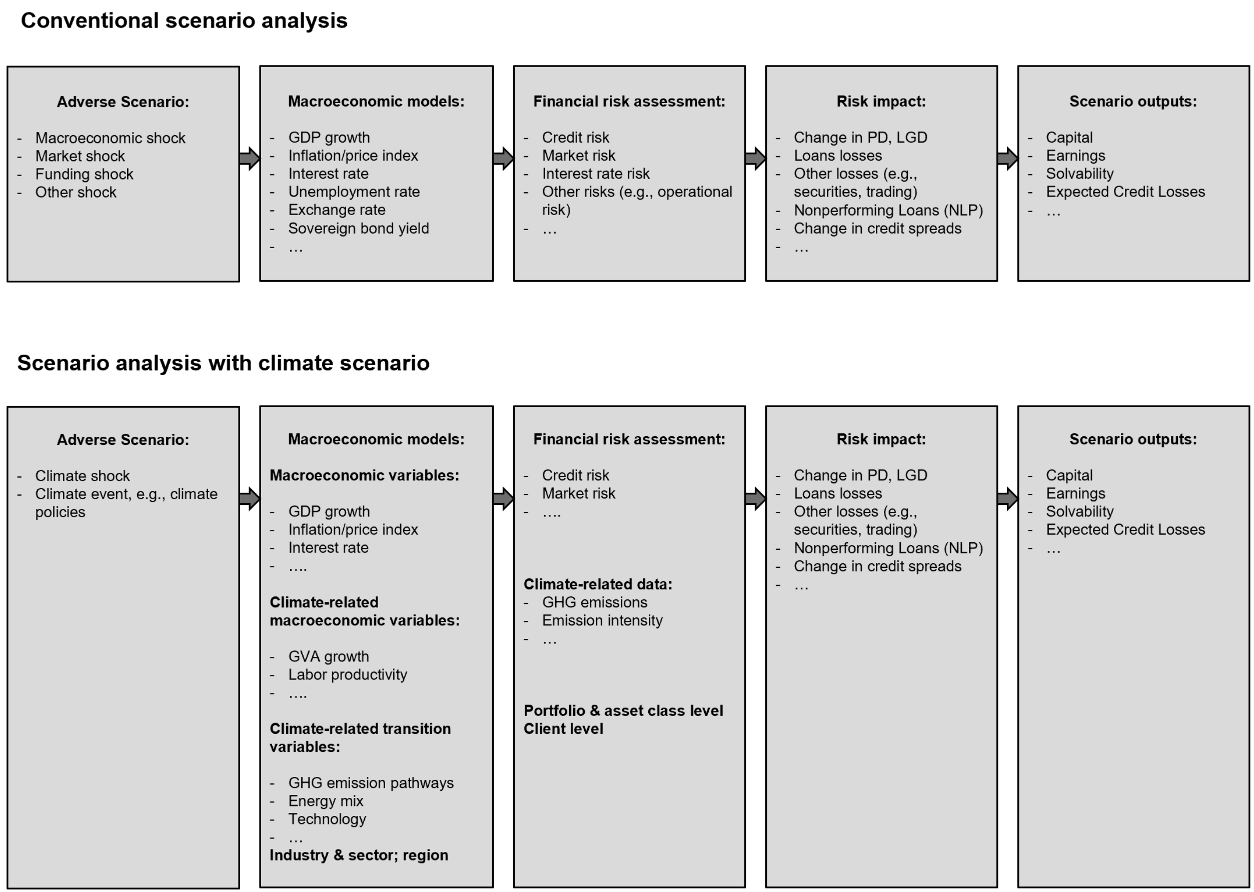

Figure 12: Top-down approach for scenario analysis without and with climate risk integration. Based on ECB (2022*c*) and Reinders et al. (2023).

4.3.4.5 Bottom-up modeling approaches

In light of the challenges described in Section 4.3.4.4, the majority of institutions in our sample have adopted a "bottom-up" modeling approach to complement their climate stress tests. In this section, we discuss this approach in greater detail.

Several respondents (C1, B1, H4, F1, K2, G1, N1) noted that their respective institutions are increasingly combining both top-down and bottom-up approaches, or even prioritizing bottom-up analysis for stress testing and risk quantification purposes. They described the bottom-up approach as particularly useful as it allows institutions to assess risks at a more granular level, enabling them to capture specific climate-related impacts that may be overlooked in a broader, macro-level analysis.

Bottom-up analysis often focuses on transition risks and involves adjusting clients' financial metrics to reflect the impact of climate-related risk drivers (e.g., incremental costs from carbon price increases) according to specific scenarios and recalculating credit risk parameters at a granular level. This approach therefore allows for the assessment of changes in credit ratings under different scenarios.[47] For example, one respondent (C1) described their institution's two-step process, which begins with assessing climate-related impacts from a macroeconomic perspective, followed by a detailed, client-specific analysis of carbon price impacts. Similarly, another respondent (G1) highlighted the importance of combining both approaches, noting that relying solely on a top-down analysis may lead to an incomplete risk assessment:

> *"We have a two-steps process. Through the macroeconomic and market shocks, we capture the macro impact or systemic impact of the scenario. Let's say the impact on GDP, inflation and interest rates. We capture those through our well-established macroeconomic models and satellite models. But on top of that, we follow the advice from the ECB to also use a bottom up approach. Therefore, at the counterparty-level, we apply shocks. For example, we look at the emissions on a name by name basis and we apply the prices that are assumed in the scenarios. By combining the bottom-up approach with the top-down analysis, we obtain a comprehensive picture of the overall losses."* **(C1)**

> *"One way is to use historical data on macroeconomic and sectoral activity variables and run them through our regression models. We know how to do that. Unfortunately,*

[47]For a more detailed discussion of such simulation exercises, see Section 4.3.3.1.

> *it doesn't allow us to take into account all climate issues, because there are many transformation aspects that don't necessarily have a significant macroeconomic impact (...). For example, we could produce electric cars instead of cars with internal combustion engines. This may not drastically alter GDP figures, as the overall economic activity — producing cars — remains constant. However, the technological risks and the required investments for certain companies to achieve this transition may be significant and must therefore be accounted for. The challenge is to integrate such aspects into our models. Thus, in addition to the macroeconomic variables, we also integrate more direct effects related to the fact that certain companies will have to invest more and that the cost structure of companies may change. This is more difficult because these elements do not always have clear historical data to draw from, making it challenging to establish clear statistical links. As a result, we have to use our credit scoring models. We know that, for example, the more debt a customer has, the higher their credit risk, all else being equal. So what we do in our stress test is almost a classic client-by-client financial analysis. We take their financial ratios, their whole balance sheet and income structure, and we change them according to a specific scenario. We change their financial ratios and recalculate their credit rating."* **(G1)**

The respondent (G1) also elaborated on the methodology, explaining that while the traditional regression models employed in macroeconomic stress tests are useful, they may not fully capture the broader transformation risks associated with the transition to a low-carbon economy. For example, a shift to electric vehicle production may not have a direct and immediate impact on GDP figures, but it could involve significant technological risks and investment requirements for specific companies. While such changes need to be taken into account in the models, a challenge is the lack of historical data to draw clear statistical conclusions. The bottom-up approach is therefore particularly useful as it allows credit risk parameters to be formulated according to specific scenarios. The scenarios simulate macroeconomic conditions that may not have existed in the past, but can be fed into risk models to simulate financial ratios, and hence credit risk parameters, conditional on such scenarios:

> *"We use both approaches. The reality is that both the macro and micro view are important. If you only look at one, you may miss something important. On the micro side, it is important to simulate credit ratings in a bottom-up approach. These ratings are probabilities of default, which, in line with regulatory requirements, are 'through the cycle' PDs. What is certain, therefore, is that the PDs associated with the ratings fluctuate*

over the cycle. In other words, these PDs tend to be higher when the macro-economy is bad and lower when the macro-economy is good. For us, this is where the articulation comes in. A bottom-up approach gives us versions of the credit ratings that would theoretically be obtained assuming a certain scenario. A top-down approach gives us a vision of the defaults associated with a particular macroeconomic environment (...). It is possible that sometimes the two overlap a little bit, but there is still this dual reality (...). Having only a top-down approach is clearly not enough. We can ask ourselves whether we can only do a bottom-up approach, because in reality the macroeconomic effects are not very strong, so in theory it might not make much difference to only do the bottom-up approach. We do both in order to have a more complete approach and to cover all dimensions." **(G1)**

Another respondent (H4) also mentioned the use of both approaches, highlighting the importance of linking traditional macroeconomic analysis with the direct assessment of climate-related risks, such as changes in carbon prices. In addition, this expert explained that the approach involves deriving shift factors for key credit risk parameters from the top-down and bottom-up analyses. These shift factors are then weighted using expert judgement:

"We approach this in two ways. First, through traditional macroeconomic analysis using our satellite models. Second, by directly assessing climate-related changes in CO2 prices and emissions at the level of individual clients. The challenge lies in linking these two perspectives. While this is still under review, our current method involves simply weighting these two effects or perspectives. We have what we call shift factors for PDs and LGDs, as well as shift factors derived from scenario paths. These shift factors are weighted based on expert judgement to produce final shift factors. This is still work in progress." **(H4)**

One respondent (B1) highlighted the use of a bottom-up approach, particularly for valuing property portfolios and assessing potential market value changes. This method is especially effective in capturing factors not reflected in broader economic indicators, such as renovation costs and their financial implications. Another respondent (N1) shared a similar view:

"We tend to take a bottom-up approach to stress testing. We analyze how individual factors that do not necessarily depend on GDP could affect market value [of real estate properties] in different scenarios. For example, what happens if the price of CO2 rises and, in particular, how does this affect market value if the owner has to bear most of

the CO_2 price? We also look at what happens if, for certain reasons, a property needs to be renovated. These are the two factors we take into account in the transition stress test (...).” **(B1)**

“The economic transmission channels of transition and physical climate and environmental risks to our risk types operate at both the micro and macro levels. When it comes to stress testing, I believe the bottom-up, micro-level approach is the most valuable. It allows us to closely examine how changing conditions impact specific sub-portfolios. For instance, what would an increase in CO_2 prices mean for real estate costs and, consequently, property values? This approach yields a much more nuanced understanding than simply projecting a general GDP decline, for example.” **(N1)**

An key challenge highlighted by the respondents is that the bottom-up approach requires highly granular data (e.g., client-level CO_2 emissions) at the client level. One respondent (G1) mentioned that their institution is already able to cover all corporate clients and industries using this approach. For institutions without access to comprehensive data, the expert recommended using representative samples and clients to conduct this analysis:

“We cover all clients and all industries in our bottom up approach. However, if we want to make savings, or if we don’t have a lot of data or a lot of computing power, we are able to do something hybrid, which means that we can be deceptively granular by creating representative companies, for example. In theory, we don’t have to take all the companies in your portfolio and analyze them one by one. There are a lot of things you can do with samples (...). If we assume that our credit risk models are reliable and that the relationship between profitability, leverage and credit risk remains stable, then we can derive very useful information.” **(G1)**

4.3.4.6 Balance sheet assumptions

The approach to balance sheet projections, whether static or dynamic, significantly influences the quantification of climate risks in the context of climate stress tests. A static projection assumes that the size, composition and risk profile of an institution’s balance sheet remain unchanged throughout the stress testing period. In contrast, a dynamic projection allows for variations in the size, composition or risk profile of the institution’s balance sheet over the testing horizon (ECB 2022*c*). This section explores key considerations associated with dynamic balance sheet assumptions and the challenges highlighted by our respondents.

As most climate scenarios span 30 years or more (see Table 8 in the appendix), the ECB considers dynamic projections to be more appropriate for assessing the impact of strategic decisions over long time horizons (ECB 2022*c*). The 2022 ECB climate stress test used both static and dynamic balance sheet assumptions, providing institutions with initial methodological guidance. For the short-term (three-year) delayed transition scenario, institutions were allowed to apply a static balance sheet, thus replacing maturing loans with loans of similar credit quality and maturity (ECB 2021*a*, 2022*a*). In contrast, for the long-term scenarios extending to 2050, institutions were required to project changes to their balance sheets (ECB 2022*a*).

Traditional stress tests, including those conducted by the EBA, typically have a time horizon of 3 to 5 years. The introduction of dynamic balance sheet modeling for time horizons of up to 30 years poses significant challenges. The ECB also underlined the innovative nature of this approach and recommended a focus on collecting data on clients' transition plans to facilitate further progress in this area (ECB 2021*a*, 2022*c*,*a*). In this context, several respondents identified dynamic assumptions as a particularly challenging aspect that is likely to receive increased attention in the future. For example, one respondent (A2) acknowledged the need to account for more distant realizations of climate risks through dynamic assumptions, but cautioned that such models may produce unrealistic and unreliable results:

> *"From a climate risk perspective, it makes sense to look at a 30-year horizon. But from a calculation point of view, this leads to completely different challenges. Simplified assumptions that may work for a three-year period are unlikely to hold over 30 years. Standard stress tests often assume that the balance sheet remains unchanged over a three-year period. While this may not be entirely accurate, it simplifies calculations and generally yields plausible results. Currently, the EBA stress test methodology explicitly requires the assumption of a constant balance sheet. This means that the modeling must assume that a maturing loan is replaced by an identical loan, or that a maturing bond is replaced by a new bond with the same characteristics. In contrast, projecting 30 years into the future under the assumption of a constant balance sheet implies that the business remains static. This significantly reduces the plausibility of the results."* **(A2)**

Several experts (G1, I2, K2) indicated that their institutions have started to implement dynamic balance sheet approaches. However, they acknowledged that this implementation is still at an early stage and that estimates are subject to large uncertainties. For example:

> *"We use static balance sheets for certain analyses and dynamic ones for others, which always involves a great deal of uncertainty. This is partly because we typically only plan for up to three years, then extend that plan further, making assumptions about how things will evolve. With dynamic balance sheets, you also need to make assumptions about factors like how technologies will develop and how the greenhouse gas intensities of these financings will change. This leads to very large uncertainty. We use dynamic balance sheet assumptions because we are required to, but whether we fully stand behind it — I'm not sure."* **(K2)**

Several respondents highlighted the importance of aligning dynamic balance sheet assumptions with an institution's strategic objectives, particularly in relation to supporting clients' transition efforts and/or reducing specific exposures. For example, many institutions have committed to phasing out lending to the coal sector, a shift that should be reflected in balance sheet assumptions (Acharya et al. 2023). For example, one respondent (L1) explained that the dynamic balance sheet approach needs to be consistent with an institution's strategic decisions and their underlying assumptions. Similarly, another respondent (G1) stated that their institution's focus on supporting clients in their transition to a low-carbon economy will likely result in greater exposure to sectors vulnerable to transition risks. The institution developed dynamic assumptions that reflect the expectation that exposure risk will become more concentrated in sectors requiring significant investment for the transition:

> *"As a bank, you have to somehow translate your business strategy into a dynamic balance sheet. This also means that you need to know what your borrowers are going to do. In other words, you also need to understand how they are going to decarbonize by 2030, 40, 50 and by what percentage. Some of this information is already available, but it is far from being comprehensive."* **(L1)**

> *"The dynamic balance sheet is a key issue. We believe that if we are looking at a 30-year horizon, we need a dynamic balance sheet perspective, otherwise we end up with something that is not very realistic or even internally contradictory, because if there is a transition, it is legitimate to expect our portfolio to evolve. We know that the tricky thing about dynamic balance sheets is that they can have a very significant impact on stress test results. Nevertheless, our view is that our bank will seek to finance the transition. It is a very important source of income for our institution, and by funding the transition, our bank will actually be taking on more risk because the portfolio will grow*

in the exposure categories that are most exposed to transition risk (...). Our guiding assumption is that we are supporting our customers, so we have estimated our customers' needs in our dynamic balance sheet modeling. We expect our exposures to grow in line with our clients' investment needs. As a result, we see a kind of concentration in those sectors that require massive investments. In other words, we expect to be much more exposed to certain sectors. We assume that there are no sector limits. So the structure of our portfolio will be very similar to the structure of the financing needs for the transition." **(G1)**

One respondent (I2) provided further insight into the methodology behind their institution's dynamic balance sheet approach, outlining how it is aligned with internal strategic guidelines. The method involves adjusting future portfolio weights in line with the institution's strategic objectives and anticipated economic growth. Similarly, several respondents (C1, N1) highlighted the importance of aligning balance sheet assumptions with institutional strategy and considering macroeconomic data when developing the assumptions underlying the dynamic assumptions:

"We developed a dynamic balance sheet approach by first analyzing potential changes in our portfolio weights. Starting with the current portfolio distribution, we evaluated whether there are areas, according to our strategic guidelines, that we intend or are likely to exit. From this analysis, we determined future portfolio weights while also factoring in expected balance sheet growth. Using the GDP forecast for Germany, we projected the increase in our total balance sheet. We then adjusted the portfolio weights accordingly, discussed these adjustments with the board, and used this foundation to calibrate a dynamic balance sheet extending to 2050." **(I2)**

"We expect our balance sheet to move with the economy. Whatever the economy does in the scenario, it is reflected in our balance sheet. We have had a lot of discussion internally about how to do that. It is a point that risk analytics teams can spend a lot of time on." **(C1)**

"In the ECB's climate stress test of 2022, specific guidelines were already provided. If I were to design such a test myself, I would base it on long-term studies from organizations like the United Nations, focusing on factors such as population development and GDP growth. Using these indicators, it would be possible to estimate whether a bank

> *will grow or shrink in the future."* **(N1)**

4.3.4.7 Physical risk scenario analysis

Physical risk scenario analysis holds a distinct status, with institutions employing individual approaches and scenarios to quantify the potential impact of specific climate-related physical events over different time horizons. In this section, we provide a brief overview of different approaches to physical risk scenario analysis and highlight challenges identified by respondents.

The institutions in our sample regularly conduct physical risk scenario analyses, with methodologies differing depending on the time horizon. In the case of short-term analysis, several respondents indicated that their institutions rely primarily on the methodology set out by the ECB in the 2022 supervisory climate stress test. For example, one respondent (E1) indicated that their institution's flood-related scenario analysis was based primarily on the parameters provided by the ECB:

> *"So far, we have taken a pragmatic approach, relying on the scenario guidelines from the 2022 ECB stress test. They provide a parametrization that we have used internally. For example, we have based our internal scenario on the flood risk scenario provided by the ECB, rather than developing our own flood risk scenario with our own flood maps. We took this pragmatic approach because we don't have in-house experts who are deeply involved in climate modeling or have significant experience in this area."* **(E1)**

In the 2022 ECB climate stress test, two specific scenarios were introduced: one addressing flood risk and the other covering drought and heat risk (see Figure 17). The objective of both scenarios was to assess the impact of these physical events on credit risk. The flood scenario focused on institutions' mortgage exposures and other real estate-backed loans. This scenario modeled the risk of severe flooding in Europe. To this end, the ECB divided geographical regions (NUTS-3) into several risk categories (low, medium, high) and provided data on projected declines in residential and commercial real estate prices (ECB 2022*a*). The drought and heat scenario, on the other hand, examined the economic effects of a severe drought and heatwave in Europe, specifically a reduction in sectoral gross value added (GVA) growth caused by a productivity shock to GDP (ECB 2022*a*). In this case, institutions were asked to evaluate how these events would affect the credit risk of their corporate loans. Both scenarios were designed with a one-year time horizon (ECB 2022*a*).

Several respondents (I2, J1) noted challenges with the ECB's flood scenario, citing the lack of spatial granularity due to the use of broad NUTS-3 regions. As a result, one respondent (I2) explained that their institution decided to build on the ECB's approach by integrating address-level data sourced from Google Maps:

> *"In the ECB stress test, NUTS codes were used, which essentially correspond to postal codes. This means that every building within a postal code area was treated the same. What did we do? We built a tool that, using Google Maps, retrieves the precise geographical location of an address. This allows us to take into account elevation profiles — whether the property is in a low-lying area or on a hill. Based on this information, we are able to assess the level of flood risk for each property according to its elevation."* **(I2)**

In addition, this institution (I) has developed an internal physical risk tool that allows for three different assessment levels: a location-based assessment of real estate collateral, a regional assessment of regionally focused companies and a sector-based assessment of geographically diversified companies. For the location-based assessment of collateral, the exact address of the collateral is used and evaluated through access to hazard maps. To this end, the institution uses publicly available hazard maps from the World Bank and the European Joint Research Centre, which depict potential catastrophic events for each selected risk type (e.g., a 100-year flood event). The institution then translates the obtained hazard values into a qualitative assessment of exposures.

With regard to the assessment of regionally focused companies, the institution (I) classifies corporate clients based on their regional dependency. This is done using information from rating systems. If such data is unavailable, company size is used as an approximation. For clients classified as regionally focused, the institution assumes that their production facilities, supply chains, and customer bases are primarily located in a single region. As a result, the physical risk for these clients is assessed based on that region. To do this, clients are first assigned to the appropriate NUTS-3 region based on their headquarters. In a second step, the exposure to physical risks for these regions is assessed. A region is classified as highly exposed if at least 10% of its area is identified as highly affected based on precise queries. Finally, companies with a geographically diversified presence are assumed to have minimal regional dependencies and thus generally not significantly affected by acute climate risks, which are more localized in nature. As a result, an assessment of the sector is performed. One respondent (I1) from this institution described the tool as follows:

"We have a physical risk tool application (...). We distinguish between regional and international companies. For regional companies, we look at the extent to which a region is exposed to physical hazards. For example, we look at a city and say that if more than 10% of it is at risk of flooding, then the entire city is flagged as being at risk. In turn, we mark companies that operate regionally in that city as potentially exposed to flooding. For international companies, we simply look at the sector. This is because large companies are generally able to replace certain assets. A flood may cause damage, but it may not lead to credit defaults of these companies. Therefore, we tend to perform a sectoral analysis and flag sectors that are particularly exposed to physical risks. There are certain sectors that are significantly more affected by physical risks, agriculture or tourism for example, and we take that into account." **(I1)**

Similarly, one institution (G) reports collecting detailed location data, allowing it to apply more granular price shocks at the property-level than in the 2022 ECB climate stress test. The approach takes into account the fact that all properties are not hit at the same time during a realistic flood event. Furthermore, one respondent (O1) explained that their institution refined the ECB's methodology by incorporating data from Munich Re's NATHAN database (Natural Hazard Assessment Network) for flood risk. Furthermore, the institution assesses storm risk, in addition to flood risk, in the short term:

"In the short-term, we also look at scenarios for storm and flood risk. We use the NATHAN database, which contains data provided by Munich Re. Flood risk is a very relevant topic for us." **(O1)**

In order to conduct long-term physical risk analysis, institutions implement a variety of strategies. Several respondents mentioned using the RCPs from the IPCC, though the choice of RCP varies across institutions.[48] For example, one respondent (O1) mentioned that their institution applies the RCP 8.5 with a time horizon extending until 2050 for river flood risk and the RCP 8.5 with a time horizon until 2100 for assessments related to sea level rise:

"We also incorporate very long-term scenarios in our analysis. For example, we use the RCP 8.5 scenario to assess severe flood risks with a time horizon extending to 2050. Similarly, we apply the RCP 8.5 scenario with a time horizon up to 2100 to evaluate

[48] RCPs represent various scenarios of future greenhouse gas concentrations and other radiative forcings, ranging from lower to higher levels (Acharya et al. 2023). Four pathways are used for climate modeling and research: RCP 2.6, 4.5, 6.0 and 8.5, named after a possible range of radiative forcing values in watts per square meter in the year 2100 (Acharya et al. 2023).

the impact of sea level rise. While we can't predict the exact composition of our credit portfolio that far into the future, we can apply these scenarios to our current portfolio to analyze what the potential implications would be for us." **(O1)**

One institution (G) reports having assessed its residential real estate portfolio against riverine and pluvial flood risks under RCP 8.5 2085 conditions. In addition, one of the respondents from this institution (G2) elaborated on the institution's approach, stating that it has constructed multiple models based on scenario projections to conduct a range of physical risk assessments at the portfolio level and consider the spatial correlation between assets within the portfolio:

"For portfolio analysis, we use various in-house models that allow us to project climate risks over different time horizons and according to different climate scenarios for specific asset locations. These locations are identified either by an address or based on latitude and longitude coordinates, since we can geocode the assets. We can assess the exposure of specific assets to risks such as flooding, heat, drought, and other physical risks. Each type of risk has its own model because the data required varies. For example, when analyzing flood risk, we use the probabilities and depths of flooding at a particular location. Ultimately, we can aggregate the results of these different risk assessments. In addition, our stress test approach considers the spatial correlation between assets and simulates risk events to evaluate their impact on the entire portfolio." **(G2)**

Another institution (F) explains in its Pillar 3 report using exposure scores provided by Standard & Poor's. These exposure scores forecast climate event probabilities for different hazards (e.g., tropical cyclone, extreme heat, extreme cold, fluvial floods, coastal floods, wildfire and drought) and different climate scenarios. The exposure scores represent the likelihood of each climate hazard and scenario over several decades. In conducting physical risk analysis, this institution uses the exposure scores corresponding to the RCP6 (2.0° – 3.7°) scenario projection for the decade 2020-2030. An exposure is deemed to be impacted by acute climate risk if the exposure scores exceed the 98% confidence level for any one of the analyzed hazards.

An additional institution (K) indicates in its Pillar 3 report that it applies the SSP2-4.5 scenario, which represents a moderate socioeconomic pathway.[49]The institution uses this

[49]Shared Socioeconomic Pathways (SSPs) complement the RCPs and explore five potential pathways for global development, considering factors such as population growth, economic trends, education, urbanization, and technological advancements (Acharya et al. 2023). These pathways illustrate how varying levels of climate change mitigation can be achieved when combined with RCP scenarios (Acharya et al. 2023).

scenario to assess the sensitivity of exposures to physical risks over different time horizons, such as 2030 and 2050. Finally, one respondent (P1) outlined an approach for assessing flood risk based on different scenarios and RCPs. The respondent stated that their institution acquired data from a third-party provider to integrate so-called "damage functions" into the analyses. These functions help translate potential weather events into projections of economic damage (Diaz & Moore 2017).

> *"In cases where we have information about the locations of our clients, we use the precise geographic data of our assets to determine whether they are situated in potential flood zones. To do this, we rely on scientifically recognized maps that depict various scenarios and RCPs. We evaluate these maps to assess the level of risk. In addition, we have acquired so-called 'damage functions' from insurance companies, which have decades of experience in damage assessment. These functions help us estimate the financial impact of flooding based on its severity, allowing us to quantify the potential damage in monetary terms. From this, we derive a probability assessment and the corresponding potential damage, leading to an overall risk evaluation."* **(P1)**

4.3.4.8 Data for climate stress testing

Having comprehensive and granular data is crucial not only for risk quantification, but also for internal reporting purposes (see expectation 6 of the ECB Guide, ECB 2020*b*). This section discusses key data points that respondents highlighted as often missing and posing important challenges, particularly in the context of climate stress tests.

A particularly important data point relates to transition plans. Several respondents (A2, E1, L1, J1, J2) highlighted that transition plans are important because they provide a forward-looking perspective that allows for a more nuanced assessment of risk within sectors. They also provide a clearer picture of clients' strategic objectives and their alignment with long-term sustainability goals. For example, one of our respondents (A1) noted that a common current practice among institutions is to rely on scenario-based projections to estimate how clients might evolve over the coming decades. However, this approach has limitations, as it often assumes homogeneous behavior among clients within a sector and does not account for differences in individual strategies. Access to more granular data directly from clients would provide a more refined and accurate assessment of their transformation efforts. In addition, obtaining transition plans from clients would help institutions develop more robust transition plans for themselves. For example, one respondent (E1) highlighted that their institution is currently developing a transition plan based largely on proxies and assumptions, and that access to more client data would greatly enhance this process. To illustrate:

> *"It is crucial to have more forward-looking data. This is something that as bank we very much would like to use. If you don't have that, what can you use? The classic approach would be to use the net zero 2050 scenario. Many of us use it as a guide. The scenario provides sector pathways with interim targets in 2030, 2040 and 2050, which is sometimes the only way for us to model how our clients will behave in the future. In this case, we assume that they will follow the path that the scenario sets out. Whether this is true, or whether they move faster or slower, we don't know. Another challenge with this approach is there is no differentiation. According to this scenario, everyone within one sector is ticking in the same way. This is why it is so important to get granular, forward-looking data. It is also a really big pain point in risk management at the moment (...). Transition plans would be helpful here, i.e., defined targets by 2030, 40, 50 for how far you want to have reduced your greenhouse gas emissions. Against a clear benchmark, of course. For example, compared to 1990 or 2010."* **(L1)**

> *"Transition plans are valuable and contain information that we actively consider. We are particularly interested in detailed insights into specific strategic actions aimed at addressing climate risks. These plans improve our understanding of how clients are preparing for future climate-related challenges and offer a clearer view of the concrete measures being taken to mitigate these risks."* **(J1)**

In addition to transition plans, respondents identified several key data points that, while difficult to obtain or model, would greatly improve the accuracy of climate-related stress tests. One key data point mentioned by several experts (A2, I2, J1, L1) is the pass-through of CO2 costs, which indicates how effectively companies can pass these costs on to their consumers. According to our respondents, this factor is largely overlooked in current climate stress tests. As noted in Section 4.3.4.4, one of the respondents (I2) emphasized that considering the dynamics of price transmissions is particularly important in the context of climate stress testing. This respondent explained that their institution has developed and is implementing a model-based approach to estimate CO2 cost pass-through rates at both the sector and client level. Similarly, another respondent (L1) pointed out that companies with monopolistic positions are more likely to pass on rising CO2 costs to consumers, a factor that should be more accurately reflected in stress test models:

"What I think would be very important is an estimate or information on how well prices are being passed on. Sometimes there are monopolists in a sector who may be better able than others to pass on their costs to their consumers. In other words, the increased costs resulting from CO2 would not affect them as much as companies that are not able to do so." **(L1)**

"More data on sensitivities would be useful. For example, how sensitive are companies, especially their revenues, to changes in CO2 prices, and how are prices passed on?" **(A2)**

Other important data points include the level of future investment required and the depreciation potential of fixed assets, as outlined by one respondent (L1). This expert highlighted the importance of estimating the level of investment required by clients to transition to greener technologies and underlined the need to assess their risk of stranded assets. In particular, information on the depreciation potential of fixed assets is often lacking and would be useful:

"It would be helpful to know how much companies will have to invest in the future in order to transform themselves. Take the example of a steel producer that has not invested in green technologies such as hydrogen-powered plants: how much would it need to invest to reduce its emissions? This would make it possible to estimate how debt ratios, for example, will develop in the future (...). Furthermore, if we think in terms of stranded assets, it would be helpful to know how many brown assets a company has on its balance sheet. When we look at a company's balance sheet, one of the things we see is the fixed assets. Unfortunately, at the moment we cannot see what is brown and what is green. There is no such classification of assets. Nevertheless, it would be helpful if we could estimate the depreciation potential of these fixed assets because that has an impact on equity and then on the probability of default." **(L1)**

Further data points are discussed in Section 4.3.3.3. For example, most institutions do not systematically take insurance coverage into account in their stress tests. One of the reasons for this is the lack of such information. While most institutions already collect insurance data for real estate portfolios, this practice does not always extend to corporate portfolios. In addition, several respondents (I2, G2, L1, O1) highlighted the challenge of obtaining comprehensive data on the geolocation of corporate assets and their strategic or operational relevance, in particular to assess corporate exposure to physical risks.

4.3.4.9 Integration of climate stress test results into business and risk strategies

Stress test results are commonly used for a variety of risk management purposes, including refining the risk appetite framework, setting limits, determining capital adequacy and informing strategic planning (ECB 2021*a*, AFME 2023). In this section, we discuss the integration of climate stress testing results into the broader risk strategy framework and highlight challenges reported by respondents.

In line with prior studies (see e.g., AFME 2023, Dietz 2022), several respondents reported that their institutions primarily use climate stress test results for exploratory purposes, including assessing portfolio sensitivity. The incorporation of these results into risk management and business strategies is still in its early stages, with varying degrees of integration across institutions. In terms of challenges, one respondent (O1) highlighted the difficulty of deriving actionable insights from the multitude of climate scenarios currently being examined internally. This respondent explained that their institution conducts climate stress tests primarily in an exploratory manner, i.e., to assess portfolio sensitivities and identify potential vulnerabilities:

> *"We now have a wide range of tools and scenarios at our disposal. However, what remains challenging is translating these insights into concrete actions. The key question that many banks are currently grappling with is: What do we actually derive from these climate stress tests? In the future, we want to go deeper in analyzing the results, rather than continually expanding our set of climate scenarios. A key questions to ask are: What have we learned from this? Where are we most impacted? Which scenarios make the most sense for us? And based on the probabilities of occurrence we estimate, which scenarios are the most important to examine closely? What kind of feedback loop do we get from these scenarios, and do we see anything there that we don't in other analyses? Our goal is to dive deeper and focus on fewer but more relevant scenarios."* **(O1)**

Furthermore, several respondents (C1, D2, G1, H3, J1, N1) noted that climate scenarios often involve much longer time horizons than those used in capital planning processes, which typically span 3 to 5 years. For example, respondents (C1), (J1) and (D2) reiterated the challenge of reconciling the insights from long-term climate stress tests with the shorter time horizons used in risk management. They all emphasized that the use of the results is limited by the high degree of uncertainty and the numerous assumptions underlying the scenarios:

> *"I view long-term scenarios and stress tests as valuable for strategic considerations, particularly in assessing how counterparties may evolve during a transition. However, at present, these long-term scenarios are primarily used for informational purposes. In contrast, our ICAAP and other key risk frameworks focus on a three-year time horizon."* **(C1)**

> *"Presenting my management with stress test results for 2040 or 2050 is pointless. At best, this is a 'nice to have', but not practical for management decisions, as overall market conditions could change dramatically by then. Most of our planning is done based on a time horizon of 3 to 5 years."* **(J1)**

> *"We are expected to consider what might happen in 30 years through climate stress tests, but we don't even know what will happen in the next 3 to 5 years. In that sense, it is almost impossible to derive anything meaningful, especially with such long time horizons. Even for risk types where we have a lot of data and information, like yield curves, making predictions over 30 years is pure speculation (...). There is still some work ahead of us to use the results of the climate stress tests as a fully integrated management tool for a bank governance."* **(D2)**

The uncertainty associated with climate risks poses a challenge to the integration of climate stress test results into broader risk management and business strategies. Nevertheless, several institutions are increasingly taking this uncertainty into account in their capital adequacy assessments (see Section 4.3.5). Climate stress tests also yield insights that are incorporated by several institutions into their risk appetite frameworks and internal reporting structures (see Section 4.4). For example, several respondents (C1, K2) noted that their institutions have developed limits and key risk indicators (KRIs) derived from climate-related stress tests. These KRIs are included in the regular internal reporting shared with governance bodies, such as the executive board. Finally, a few respondents (G1, H5) indicated that climate scenario analysis plays an increasingly important role in credit provisioning and loan pricing. We discuss the integration of climate risks into loan pricing in greater detail in Section 4.5.

> *"We plan to incorporate these climate scenarios and their impact into the calculation of credit risk provisions by the end of this year. This will have a very rapid impact on pricing considerations because it means that as soon as we originate a transaction, and*

even for existing transactions in their internal billing, we will see the impact of these scenarios (...). This means that we will include default probabilities that are conditional on these scenarios." **(G1)**

4.3.5 Internal capital adequacy assessments and capital considerations

4.3.5.1 Integration of climate risks into scenarios for capital adequacy and capital planning

As outlined in the ECB guide to the ICAAP, institutions are required to develop comprehensive strategies and processes to ensure that their material risks are adequately covered by capital (ECB 2018). A key process in achieving this objective is stress testing. As discussed in Section 4.3.4, all institutions in our sample are required to conduct regular stress tests as part of their ICAAP (ECB 2018). In addition, in accordance with the ECB guide on climate risks, institutions are also expected to perform stress tests to quantify the impact of climate-related risks and appropriately incorporate these considerations into their ICAAP (see expectations 10 & 11 of the ECB Guide, ECB 2022*c*). In this section, we discuss key considerations regarding the integration of climate risks into ICAAP stress tests and highlight some of the main challenges raised by respondents.

In Section 4.3.4.1, we show that institutions generally maintain a diverse set of scenarios within their stress testing frameworks and as part of their ICAAP. These scenarios fall into two broad categories. The first category includes "comprehensive" scenarios, typically macroeconomic in nature, which are assessed on a quarterly basis. Within these comprehensive scenarios, there are further subcategories. Some scenarios serve as baseline estimates, providing a standard macroeconomic forecast (see Section 4.3.4.3), while others present variations with different levels of severity and shocks. These scenarios allow institutions to assess multiple risk types simultaneously, for example in the context of institution-wide adverse stress tests, and are also used for capital planning.[50] Second, there are also "exploratory" scenarios, which focus on specific risk drivers and, in some cases, target specific portfolios or sub-portfolios (see Figure 10). These exploratory scenarios are rather used for risk-type-specific stress tests and ad hoc stress tests. Such scenarios are used for exploratory stress tests that are conducted on a regular basis, e.g., annually or every two years. Some risk-type-specific stress tests are also conducted on a quarterly basis. Both categories of scenarios are complementary.

[50] For example, the ECB indicates that "although institutions may not 'plan' to enter into adverse conditions, the assessment of adverse scenarios is a key element of capital planning as it helps institutions to continue operating even in a prolonged period of stress." (p.39, ECB 2018).

Some institutions have started to integrate climate risks into their comprehensive scenarios. For example, one institution (O) included climate-related elements such as CO2 prices in its scenarios. Similarly, another institution (J) incorporated climate-related aspects into several scenarios, in particular for the analysis of its shipping portfolio, where long-term forecasts for market values and charter rates are made. These forecasts now take into account the transition to eco-efficient ships and the devaluation of non-efficient ships:

> *"Our colleagues in the economics department develop the macroeconomic scenarios. Key parameters include GDP, unemployment rates, interest rate trends, and so on. We provide some guidance on how adverse the scenario should be. They then apply their economic models, and we receive the parameters back, which we need to translate to the different risk types within our portfolio. Currently, we are working with the economists to incorporate the CO2 price as a fixed component in the scenarios. In the future, we may add additional factors, but this is still under discussion. These additions could, of course, be a result of the exploratory climate stress tests we are conducting."* **(O1)**

> *"Several other scenarios have been enhanced to incorporate climate-related aspects. This means that climate considerations are not limited to our two specific ESG scenarios but are also embedded in others as well. This is particularly true for our shipping portfolio, where we use long-term forecasts for charter rates and market values that extend beyond the planning horizon. For example, we model the trend towards eco-efficient ships, as well as the expectation that non-efficient ships will experience greater losses in market value."* **(J1)**

An institution (Q) uses three different scenarios of future economic development, which are also used to calculate expected credit losses: a baseline scenario, a negative scenario, and a positive scenario. The scenarios are designed to provide a sense of the range within which the economy, as well as interest rates, exchange rates, and other variables, are likely to move over the short to medium term. The scenarios describe a range of either negative or positive outcomes. The institution indicates that climate issues are now included in all three baseline, positive and negative macroeconomic scenarios. Regarding the negative scenario, for example, the climate issues include assumptions based on a disruptive transition that would affect the economy, as well as assumptions on the impact of nitrogen regulations in the Netherlands on GDP.

Finally, one institution (P) reported conducting an "internal combined climate risk stress test" in 2022, which included climate-related components. The stress test covered the full credit risk portfolio as well as other risk types such as interest rate risk in the banking book and operational risk. In terms of narrative, the scenario consisted of the following events: a prolonged war in Ukraine triggering full suspension of the Russian gas supply to Europe; extreme weather events (i.e., fires in Southern Europe and floods in Northern Europe) were assumed to create additional burdens on European economies and energy consumption patterns change; EU governments stepped up their efforts to meet the well-below 2°C Paris Agreement target by creating a New Green Deal which led to soaring carbon taxes; a disorderly transition followed, and the institution faced greenwashing claims.

In terms of exploratory scenarios, and as discussed in Section 4.3.4.1, institutions use a variety of short- and long-term climate scenarios that model transition and physical risks. To date, the stress tests conducted mainly focus on one risk type, in particular credit risk (Baudino et al. 2018). Even the 2022 ECB climate stress test predominantly targeted credit risk, with some attention given to market risk (see Figure 17). Although exploratory, these climate scenarios are becoming an important part of capital adequacy assessments and complement the comprehensive exercises described above.

For example, one institution (G) reports in its Pillar 3 disclosures that climate scenarios are now integrated in the ICAAP and documented in a dedicated section of the corresponding ICAAP report. The institution indicates conducting, on the one hand, an assessment in relation to credit risk, and on the other hand, an assessment of losses calculated from operational risk events for which climate risk has been identified as a material risk factor. The institution adds that climate risks are treated as risk drivers — in particular of credit and operational risks — rather than stand-alone risks. Furthermore, it notes that such scenarios are not used for capital planning purposes, but rather to assess the impact on its internal capital requirements of events that may be exacerbated by climate risks. Similarly, one of the respondents (I2) described their institution's current approach by stating that climate stress tests focus primarily on risk types for which climate risks are considered to be material drivers. Since climate risks are deemed to have a material impact on credit risk, this area forms the primary focus of their institution's exploratory stress tests:

> *"In line with the ICAAP guidelines, we consider both comprehensive ICAAP scenarios and risk-specific scenarios. Based on our risk inventory, climate risks currently primarily affect credit risk. However, if we were to assume that climate risks require a comprehensive risk assessment, we would need to ask ourselves: How does climate impact all other types of risk today? This means we would need to examine how climate*

risks impact not only credit risk, but also market risk, liquidity risk, and operational risk. So far, we do not find that an increase in CO2 prices leads to substantial changes in market volatility. In our current approach, climate is only material for credit risk. In the comprehensive ICAAP scenarios, the effects of the climate scenarios are included in a rudimentary form (...). There we have to consider all material types of risk or provide a well-founded justification for excluding them (...).” **(I2)**

Thus, institutions are starting to develop both exploratory and comprehensive scenarios that incorporate climate risks. These scenarios provide complementary insights and play an important role in integrating climate risks into capital adequacy assessments and capital planning.

4.3.5.2 Climate-related capital adequacy assessments

As outlined in the ECB guide to the ICAAP, institutions need to have in place comprehensive strategies and processes to assess and maintain on an ongoing basis the “amounts, types and distribution of internal capital” that they consider adequate to cover risks to which they are or may be exposed (p.41, ECB 2018). A key element of this process is the concept of capital adequacy, which refers to the degree to which risks are covered by capital (ECB 2018). This section discusses key considerations raised by the respondents regarding capital adequacy in relation to climate risks. The following section (see Section 4.3.5.3) explores how some institutions are introducing climate-related capital buffers and similar “add-on” approaches to setting aside capital to mitigate climate risks.

Institutions are required to assess the potential impact of climate risks on capital adequacy (see expectation 7.6 of the ECB Guide, ECB 2020*b*). The ECB expects institutions to “take into consideration the impact of climate-related and environmental risks when determining their capital adequacy in a way that enables the institution to sustainably follow its business model by ensuring economic and normative capital adequacy” (p.34, ECB 2020*b*). As a result, if climate risks were to result in important losses (e.g., exceeding a certain materiality threshold during a stress test), the institution in question may need to reserve additional capital. As a best practice, the ECB has already observed that some “institutions allocate economic capital specifically to the management of material transition and physical risk drivers. In such cases, economic capital is typically allocated to credit, market, or operational risk, based on scenario analysis outcomes“ (p.9, ECB 2022*d*).

Capital adequacy assessments typically rely on stress testing, which involves running one or more scenarios based on narratives that impact different risk types. The primary purpose of these stress tests is to evaluate an institution's capital adequacy by estimating potential capital stress losses, which then guide capital allocation decisions. Before delving into the integration of climate risks into these considerations, we first provide a simplified example of a capital adequacy assessment, illustrated in Figure 13. A similar methodology can be applied to climate scenarios and climate stress tests, where the potential capital loss resulting from such scenarios similarly informs capital allocation decisions.

In our simplified example, the remaining capital amount, after meeting the minimum capital requirements under Pillar 1 is 1 billion EUR. After applying the stress scenario,[51] this amount is reduced to 500 million EUR, resulting in a capital stress loss of 500 million EUR. This stress loss represents the capital that needs to be "buffered" to ensure capital adequacy. To calculate the capital surplus, we subtract the capital stress loss of 500 million EUR from the original capital of 1 billion EUR, leaving a surplus of 500 million EUR. This surplus is further reduced by additional buffers, such as a management buffer, which is detailed in Section 4.3.5.3 and amounts to 200 million EUR. After accounting for the management buffer, the final total capital surplus is 300 million EUR. This surplus serves as the foundation for further capital allocation decisions, including the amount available for dividend payouts. This example illustrates how capital buffers reduce the total available capital surplus for other business considerations and determine the amount to be set aside.

[51] It should be noted that if a loss is realized through the P&L and deducted from capital, the total RWA under Pillar 1 will decrease.

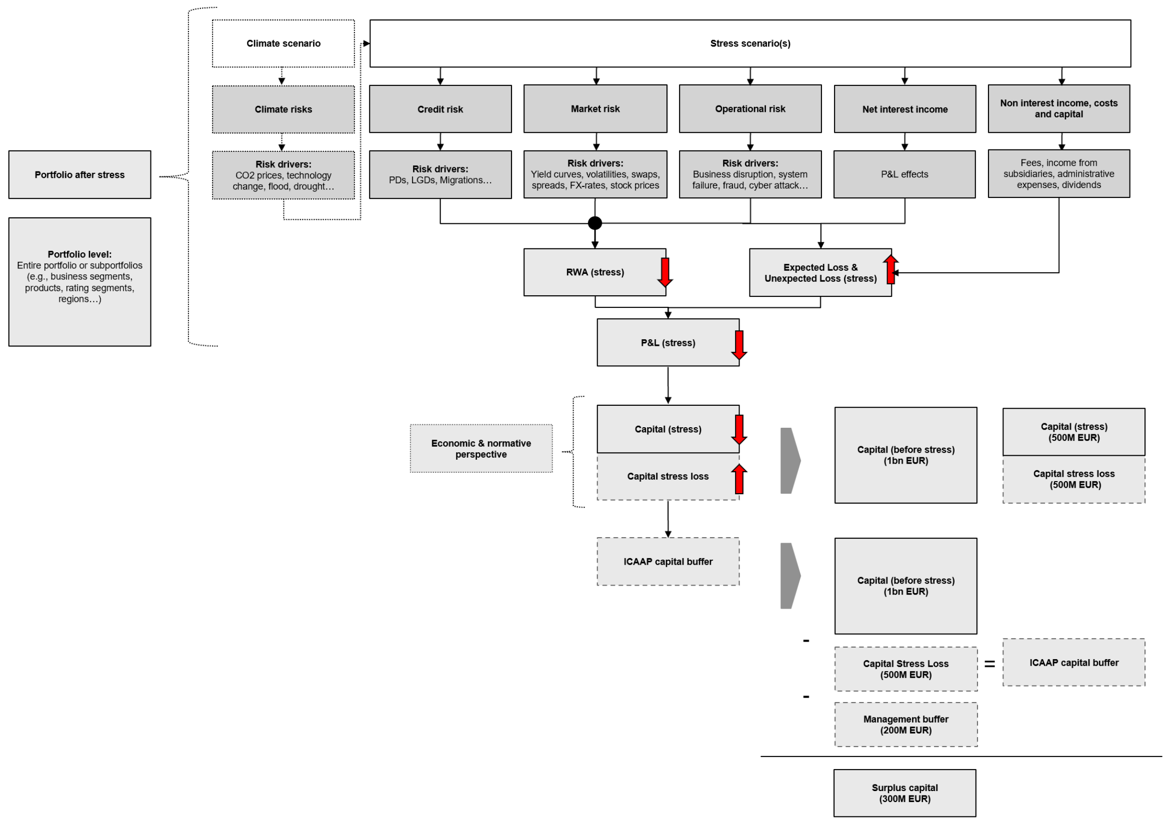

Figure 13: Simplified example of capital adequacy assessment. Own illustration. Note that if a loss is realized through the P&L and deducted from capital, the total RWA under Pillar 1 will decrease.

We begin by discussing the motivations of institutions that have decided not to implement specific capital measures for climate risks. For example, one institution (N) states in its Pillar 3 report that a separate, additional capital allocation for climate and environmental risks within the ICAAP is not considered necessary, mainly due to the very limited impact of climate risks identified in the 2023 internal climate stress test. In the same vein, another institution (G) explicitly reports that while it continuously monitors the contribution of climate-related events to its internal capital requirements, it does not currently calculate a capital charge specifically linked to climate-related risk. A respondent (G1) from this institution expressed reservations about implementing a climate-specific capital buffer, explaining:

> *"Buffers are almost a philosophical question. We are completely against the idea of seeing capital as the sum of buffers. We already have a lot of capital. This capital is designed to cover crises with very high levels of stress. We can therefore assume that our capital already covers a wide range of scenarios. It would not really make sense to add capital for each driver that could lead to an increased level of stress. The question is the maximum plausible level of stress, not the addition of all driving causes. We do not explicitly allocate capital to geopolitical risks or unemployment, for example. Our aim is to develop holistic scenarios that include climate. We aim to integrate climate considerations into all aspects of our risk management, but not in a way that is structurally different from other risk drivers."* **(G1)**

Similarly, several respondents (C1, J2, G1) noted that capital adequacy and the corresponding capital needs are primarily driven by the results of comprehensive ICAAP stress tests. They pointed out that capital needs are evaluated through multiple scenarios, with the most severe stress test typically guiding the required buffer size. At present, climate scenarios tend to be less severe than the economic downturn scenarios commonly used in these assessments. For example:

> *"We have integrated climate into our ICAAP for four years now. It is important to say that climate risk doesn't result in large losses in our scenarios. Overall, we don't see a large effect from climate risk. Now, to determine capital, we use more severe scenarios than the climate-related ones (...)."* **(C1)**

> *"Our approach is to always derive our risk appetite from the results of our stress tests. We have developed two specific ESG scenarios, both well-parameterized, though less*

> *severe than our usual downside scenario, even after frontloading some of the effects from NGFS scenarios. When it comes to planning and determining the amount of capital that needs to be allocated across different risk types — essentially the buffer that needs to be maintained — we always consider all scenarios. The worst-case scenario determines the amount of capital that needs to be allocated. We do not have a separate capital buffer specifically for climate risks. Instead, we incorporate climate risks into our stress test scenarios and use the results to decide how much capital should be allocated to each risk type. Such decisions are based on the outcomes of the stress tests."* **(J2)**

A few respondents (I2, J2, H5) expressed reservations about implementing climate-specific capital buffers, but also noted the possibility of allocating economic capital to specific risk types, such as credit, market or operational risk. They explained that this approach may be relevant if certain risks are perceived to be inadequately captured by existing models and risk management processes. For example, one respondent (H5) explained that their institution does not currently hold a capital buffer specifically for credit or market risk to account for climate-related risk factors. The reason for this is that stress tests have shown an insignificant financial impact in terms of economic capital, suggesting that no significant gap currently exists:

> *"An essential element of stress testing under Pillar 2 is the concept of risk-bearing capacity. For certain risk types, such as operational risk and reputational risk, climate is already integrated into capital adequacy considerations. For example, we have a large insurance subsidiary that insures against natural catastrophes, and we already allocate significant amounts of capital to this area, as well as to operational risks. However, there are other risk types, such as credit risk and market risk, where potential gaps may exist. For example, we have an ESG credit risk scorecard, but it is not yet factored into our capital requirements. Our focus has therefore been on identifying and addressing potential gaps for such risk types [credit risk and market risk]. We asked ourselves by how much the 99.9% quantile in our models would be affected if we incorporated climate and environmental risk parameters. In other words, while our portfolio models already include a high level of stress, we adjusted parameters such as PDs or spread movements to reflect an expected climate scenario. As of 2023, the resulting euro amounts were so minimal that we currently do not find a significant gap."* **(H5)**

> *"We do not think that our PDs and LGDs are inadequately measured or that our processes for climate risks are insufficient, necessitating an additional capital buffer for climate risks."* **(J2)**

One respondent (I2) argued that a climate-specific capital buffer may be necessary if an institution believes that current ratings do not adequately capture climate risks.[52] The objective of the buffer would therefore be to account for the uncertainty associated with climate risks. Furthermore, this expert pointed out that, in theory, such a buffer should diminish over time as climate-related defaults are increasingly reflected in the data and incorporated through the recalibration of PD models. Overall, this expert expressed doubts about the value of implementing such a buffer, highlighting the potential risk that institutions may consider themselves exempt from further refining their climate-related risk management strategies:

> *"If I apply a buffer today, it simply means that I believe my current ratings are not adequate. This buffer should typically decrease as actual defaults related to climate risks occur. As these defaults are integrated into my time series and subsequently factored into future PD calculations through recalibration, such risks will naturally be captured and reflected in my observations (...). Some institutions already allocate capital specifically for climate-related risks, which is a valid approach, but one I don't fully endorse. Why? Because I question whether this truly supports internal climate goals. For example, if a bank's objective is to achieve climate neutrality by 2035 or 2040, particularly in its lending activities, how does setting aside capital for climate risks contribute to that goal? In my view, it doesn't. Allocating risk capital today as a reserve for potential climate risks may signal preparedness in terms of planning, but it doesn't equate to actively addressing such risks through robust monitoring and management."* **(I2)**

4.3.5.3 Climate-related capital buffers

A few institutions (I, N) are either actively exploring the implementation of capital buffers (or similar instruments) for climate risks or have already done so (D, K, O, P). In this section, we examine their approaches and motivations, as well as the challenges identified by our respondents.

A central motivation for establishing such a buffer is the concern that traditional risk models

[52] For example, as discussed in Section 4.2, institutions are increasingly quantifying climate risks through climate-related scores but rarely integrate them quantitatively into their rating systems and PD models. Such integration, particularly for long-term climate risks, remains a major challenge.

may fail to adequately capture climate risks over the medium to long-term horizon. For example, one respondent (K2) explained that the primary rationale for implementing a climate risk buffer was precisely this concern. Although the institution's Pillar 3 report indicates that stress test outcomes indicated no significant capital or liquidity requirements stemming from climate risks in the scenarios considered,[53] this expert indicated that the institution very recently opted for a climate-related buffer to mitigate potential medium- to long-term risks that existing portfolio models may not account for:

> *"In terms of capital adequacy, we need to make a distinction. In the short term, we consider climate risks to be covered by our existing productive models, which have a one-year time horizon. However, in the medium term, they are not covered, which is why — this is a very recent development — we have recently introduced a buffer for climate and environmental risks. We are currently working on integrating this buffer into our overall risk-bearing capacity concept to safeguard against potential medium-term losses as a precautionary measure (...). At present, our risk-bearing capacity calculations have a one-year horizon, meaning that the risks we identify are those that, with a certain confidence level, will not be exceeded within the next 12 months. In other words, losses that may occur in the coming year are covered, but not beyond that period. All the parameters that we use are designed to reflect this short-term focus. Therefore, a CVaR covers a one-year risk horizon, but does not include risks beyond that horizon. This inevitably creates a gap, particularly for medium- and long-term climate and environmental risks, which are not accounted for within the existing risk limits."* **(K2)**

There are different approaches to designing such a buffer, and more generally to "reserving" capital for climate risks. This can be approached as an extension to existing risk types, as a "general" (or cross-risk) capital buffer addressing multiple risk types, or as an enhancement to an existing management buffer (see e.g., ECB 2022*d*).

General (cross-risk) buffer:

At least two institutions (K, O) in our sample have allocated capital in the form of a general buffer for climate-related risks. For example, one respondent (K2) explained that their institution opted for a comprehensive capital buffer. The main motivation was that capital requirements are based on risk models that have a one-year time horizon and thus do not

[53] The institution's Pillar 3 report indicates minimal impact on the Tier 1 capital ratio and only a modest rise in risk capacity utilization within the single-digit percentage range.

take longer-term climate risks into account. Although not derived from a precise quantitative formula, the size of the buffer was determined based on insights from internal climate stress tests (e.g., the cumulative impact of climate risks over several years):

> *"We asked ourselves whether this should be addressed as an "add-on" to the existing risk metrics — such as having an add-on for CVaR, market risk and operational risk. Or should we establish a comprehensive buffer specifically for climate and environmental risks. We opted for the latter. We decided to introduce this buffer right at the beginning of our risk-bearing capacity calculations, essentially subtracting it directly from our risk appetite and available capital. We are essentially setting this amount aside. There is no exact mathematical formula guiding this process. Instead, we carefully analyze the available results, particularly from climate scenarios, and then make qualitative judgements about the likelihood of these events. We use specific climate scenarios as part of our macroeconomic stress testing, assessing impacts over a longer time horizon, up to 2050. In reviewing the scenario outcomes, we consider both financial and risk-related indicators. By combining these insights with our medium-term planning — focused on a three-year horizon — we make management decisions about how large the buffer should be and how quickly it needs to be built up as a precautionary measure. With this buffer, we focus on a medium-term perspective. We only consider what is required in the near term and gradually adjust it. This means that the buffer builds up over time. We can already assume that it will continue to grow over the coming years. It may eventually decrease if the risks are sufficiently captured in the models. However, as long as this isn't the case, we will need this buffer."* **(K2)**

Similarly, one institution (O) explains in its Pillar 3 disclosures that an additional capital amount was allocated to the "reserve for other risks" at the end of the year 2023. This buffer is intended to cover potential climate-related risks that are not yet fully captured by risk models. The institution also adds that, while previous qualitative and quantitative analyses do not indicate an immediate need for adjustments to the risk models, further planned analyses may provide new insights, thus justifying the current buffer. One respondent (O1) from this institution elaborated on this approach:

> *"In the economic ICAAP, we look at the sum of individual risk types, such as credit risk, market risk, liquidity risk and operational risk. In addition, there is a reserve in the numerator for all other risks that are not explicitly captured. This reserve is then compared to the economic risk capital in the denominator. Last year, we added an extra*

amount to this reserve as a temporary buffer to account for climate-related risks. This buffer represents roughly a 6% add-on to our risk potential. The size, however, is not derived from extensive scientific analysis. For now, we have set aside a relatively large amount of capital, but the long-term goal is to incorporate these climate-related risks into the models, particularly our credit portfolio models. And the expectation would be that, once we have properly integrated it into the credit portfolio models, the surcharge generated by the model would be smaller than the current buffer. As our models become more sophisticated, the buffer will gradually be reduced, and we will be able to remove the additional allocation." **(O1)**

Management buffer:

Another institution (B) in our sample has incorporated climate-related considerations into its management buffer. Specifically, this institution states in its 2023 Pillar 3 report that its management buffer has been adjusted to account for potential climate-related risks. This approach is similar to the one described above, except that management buffers particularly play a role in the normative perspective of the ICAAP. Management buffers are defined by the ECB as "an amount of capital above the regulatory and supervisory minima and internal capital thresholds that the institution considers necessary in order to sustainably follow its business model and to remain flexible regarding possible business opportunities, without endangering its capital adequacy" (p.42, ECB 2018). In essence, the management buffer serves as an additional capital reserve, illustrated in Figure 13, designed to prevent capital (e.g., CET1) from falling below regulatory thresholds. The size of this buffer (and its climate-related adjustments) is typically established through a combination of stress testing and expert judgement.

Economic capital allocated to credit or market risk:

Another approach consists in implementing an economic capital add-on to an existing risk category. In other words, instead of setting aside a general buffer, a larger amount of capital could be allocated to credit or market risk in the ICAAP. For example, one institution (D) explains in its Pillar 3 report that, based on the scenario-specific volatilities associated with the climate scenario, it has concluded that transition risk is a material driver of market risk over the long term. The institution has an ICAAP capital buffer for this risk that explicitly takes climate risks into account. A respondent (D1) from this institution explained:

> *"We want to finance the transformation because we believe that we understand the business and the transition risks reasonably well. This is anchored in our business strategy. Accordingly, we have accounted for this in the ICAAP by incorporating a capital buffer for climate risks."* **(D1)**

Furthermore, another respondent (P1) explained that their institution considers climate risks to be a material driver of credit risk and thus considers this aspect in its add-on to credit risk:

> *"We apply a small add-on for credit risk as a precautionary measure. It is a single-digit percentage. We generally assume that we are currently underestimating the risks. That is why we introduced this small add-on proactively. If the risks were perfectly captured in our internal models, there would logically be no need for the add-on anymore. Essentially, the add-on exists because we haven't fully mastered the rest yet."* **(O1)**

Finally, one institution (Q) has adopted both an economic capital add-on for climate-related credit risk under the ICAAP and a management overlay for climate risks within IFRS 9 models. In its Pillar 3 disclosures, the institution highlights that incorporating climate risk into credit risk models remains challenging, primarily due to the lack of granular data and limited historical instances of climate risks impacting credit risk. As current models may not fully capture climate-related risk drivers, the institution considers future estimates of credit risk to be associated with uncertainty. As a result, the institution has introduced an economic capital add-on for climate risks under the ICAAP. Furthermore, it has established a EUR 25 million management overlay for climate transition risk, both of which were informed by a materiality assessment.

Challenges:

While recognizing the key motivations for implementing these buffers, such as addressing modeling uncertainty, several respondents (D2, N1, I2) observed that their current size remains modest and primarily precautionary. At present, these buffers are largely estimated using expert judgement and insights from materiality assessments and stress tests, which often suggest a moderate impact in the short to medium term. One expert (N1) added:

> *"I believe many institutions are currently implementing these measures to meet ECB requirements, and as a result, we will eventually introduce a buffer as well. However,*

> *the question remains whether a small buffer will have any significant impact. Institutions generally have very high risk-bearing capacity ratios. For example, with a 175% risk-bearing capacity, adding a 5% buffer for climate risks can easily be done to show action. But will it meaningfully affect portfolio steering? I don't think so. I haven't seen any institution with a buffer substantial enough to make a real difference in terms of steering effect, and I doubt any bank will set a buffer so high that it limits itself. Nonetheless, introducing a buffer can be justified by uncertainties in the models. If climate risks aren't adequately reflected in the models, having a buffer makes sense. That is why we plan to introduce one, though the risks are currently minimal within the bank's decision-making horizon (...). In my opinion, the most reasonable approach is to base such buffers on climate stress tests and related analyses."* **(N1)**

Another respondent (D2) noted that setting aside capital for climate risks may reduce dividend payouts, potentially making shareholder support relevant to the successful implementation of climate-related buffers in the future. Finally, one expert (I2) expressed concerns about the overall usefulness of climate-related capital buffers, arguing that instead of prioritizing the introduction of such instruments, a more effective strategy would be to define clear sector-specific targets and implement a limit system that restricts lending to high-risk sectors. In particular, this expert argued that simply allocating capital to climate risks does not actively support the achievement of long-term climate goals:

> *"The capital market also has to be on board with this approach. If the capital market accepts this, why not, we can build such a capital buffer. But if we allocate a substantial amount of capital to hypothetical risks, there is a chance that shareholders may become dissatisfied, as it would mean paying out less capital in the form of dividends."* **(D2)**

> *"Allocating risk capital today as a reserve for potential climate risks may signal preparedness in terms of planning, but it doesn't equate to actively addressing such risks through robust monitoring and management. I believe a more effective approach would be to establish sector-specific targets and a limit system as management tools and to ask: How should the proportion of green investments grow over time to achieve climate neutrality? Incorporating climate-related considerations into the management buffer is one thing, but it is crucial to operationalize them through a limit system and sector-specific targets."* **(I2)**

4.3.5.4 Economic and normative perspectives

The ECB requires an assessment of the impacts of climate risks on capital adequacy from both a normative and an economic perspective (see expectation 7.6 of the ECB Guide, ECB 2020*b*). As shown in Figure 13, both perspectives offer different views of an institution's internal capital adequacy. In this section, we briefly outline the key features of each ICAAP perspective and highlight some of the approaches and challenges identified by our respondents.

The normative perspective relies on accounting and prudential values (ECB 2018). Specifically, this perspective focuses on the impact of material risks on an institution's balance sheet, P&L structure, regulatory indicators, key performance indicators (KPIs) and limits (ECB 2018). The assessment of the normative perspective is typically based on stress tests with a minimum time horizon of three years. Moreover, the normative perspective is closely tied to the concept of capital planning, which requires institutions to assess their capital adequacy through a multi-year projection of their capital demand and supply, accounting for both baseline and adverse scenarios (p.43, ECB 2018). The overall objective of the normative perspective is to ensure that an institution remains sufficiently capitalized to pursue its planned business strategy on an ongoing basis, even under adverse conditions. In contrast, the economic perspective focuses on a shorter time horizon (one year) and is based on economic value considerations (ECB 2018). For example, while the normative perspective conceptually considers the accounting value of assets, the economic perspective focuses on a fair value / net present value perspective of such assets to derive risk and capital requirements (BaFin 2018). Therefore, the focus is less on regulatory capital ratios and more on value at risk quantification metrics as well as the identification of "hidden losses" (p.23, ECB 2018). In this sense, the economic perspective is also closely related to the concept of economic capital discussed in Section 4.3.3.

Regarding the normative perspective, several respondents (C1, E1, H5) described the integration of climate risks into their institutions' internal stress testing frameworks as a critical step towards embedding climate risk within this perspective. They indicated that their institutions had either already integrated climate risks into these frameworks or were in the process of doing so (see Section 4.3.4). However, one respondent (G1) reiterated the challenge of reconciling the longer time horizons of climate stress tests with the typical three-year time horizon used in the normative perspective, making it difficult to incorporate climate risks into capital planning. Another respondent (H5) described initiatives to include climate-related KPIs into capital planning and business environment analysis, both of which are essential elements of the normative perspective. In addition, one respondent (E1) further highlighted plans to incorporate climate-related factors into the institution's risk appetite and limit system:

> *"We have integrated climate into our stress test framework. The normative perspective is therefore well covered."* **(C1)**

> *"We currently address the normative perspective through stress tests. In our discussions with the supervisors, we have observed that this approach is well accepted. Of course, this expectation also involves the integration of climate-related considerations into our risk appetite. This is the next step. This means, for example, explicitly incorporating climate into our current limit system. Our bank-wide limit structure is derived from the Board's risk appetite, which is then broken down into different risk types and portfolios. So far, climate has not been an explicit criterion, so we are now in the process of incorporating it in a meaningful way."* **(E1)**

> *"The normative perspective has a very strong focus on information from stress tests. We plan to include climate and environmental risks into our internal stress testing framework. We are still working on this, but we expect this to be done by the end of the year. After that, we will have the normative perspective and the impact on RWA and own funds. Another important aspect of the normative perspective is capital planning. There we have expectations 1 and 2 of the ECB Guide, which require us to integrate climate and environmental risks into our business environment analyses. We have a large number of KPIs that we have included in the baseline scenario. We also now include KPIs such as the CO2 price or similar aspects in our strategic planning (...)."* **(H5)**

With respect to the economic perspective, one respondent (C1) noted that their institution integrates climate risks into internal ratings, so that climate risks feed into the economic ICAAP perspective. Two respondents (E1, N1) noted that sensitivity analysis and stress testing are also used in the economic perspective to assess the impact of climate risks:

> *"As far as the economic perspective is concerned, since we have integrated climate-related aspects into the credit ratings, it is now also part of the economic perspective because all these ratings feed into the economic perspective. Thus, I think that climate risk is well integrated in this area as well."* **(C1)**

> *"From an economic perspective, we perform ad hoc analyses of PD shifts. These analyses also go in the direction of stress testing."* **(E1)**

> *"We have rating models that we use under both Pillar 1 and Pillar 2. For Pillar 2, we also take portfolio effects into account, for example through our portfolio models. We apply specific scenarios to assess the impacts on our risk-bearing capacity. In practice, we have models that allow us to assess the economic perspective."* **(N1)**

4.4 Pillar II: Integrating climate risks into risk appetite, risk metrics and limit system

4.4.1 Linking risk appetite, risk strategy & business strategy

In 2021, the ECB observed that only "few institutions have put in place climate and environmental risk practices with a discernible impact on their strategy and risk profile" (p.2, ECB 2021*b*). One way for institutions to effectively align their risk practices with both their business strategy and risk profile is by clearly defining their risk appetite. This section discusses key considerations related to the risk appetite and its role in the broader risk strategy. Subsequent sections discuss specific approaches to integrating climate risks into the risk appetite framework, including KRIs and limits.

An institution's risk appetite is set at an aggregate level, outlining the types of risks it is exposed to and the actions it intends to take to manage those risks in line with its broader business strategy (ECB 2018). This is typically formalized through a "risk appetite framework" and a "risk appetite statement" (ECB 2018), both of which ensure that the institution's risk appetite is effectively communicated and consistently monitored at all levels. In the context of climate risks, institutions are expected to explicitly incorporate these risks into their risk appetite framework (see expectation 4 of the ECB Guide, ECB 2020*b*). The risk appetite framework ensures that risk-taking is aligned with the institution's strategic priorities, capital and liquidity plans (ECB 2020*b*), and is typically approved by the board of directors.

The risk appetite statement, as part of the risk appetite framework, is a comprehensive document that defines the types and levels of risk that the institution is willing to accept or wishes to avoid (ECB 2020*b*). It includes both qualitative statements and quantitative targets, together with specific limits and thresholds for managing these risks. In addition, the risk appetite statement outlines the governance structures and processes in place to address breaches of risk limits (ECB 2020*b*). Furthermore, the risk appetite framework and the corresponding risk appetite statement are typically segmented by risk type. For example, institutions generally have specific appetites for credit risk, market risk etc. This risk appetite may be further subdivided. Table 5 provides a stylized example of a risk appetite statement for credit risk.

Defining a clear risk appetite for climate risks requires integrating climate risks into the risk appetite framework and risk appetite statement for risk types that are considered to be materially impacted by such risks (see expectations 4.1 and 4.2 of the ECB Guide, ECB 2020*b*). This integration requires institutions to formulate qualitative risk appetite principles, while also establishing risk metrics, limits and responsibilities. We discuss some of these metrics and limits in Sections 4.4.2 and 4.4.3.

Table 5: Simplified example of risk appetite statement for credit risk.

Credit Risk		
Definition: Internal definition of credit risk. Owner: Internal control organs and product owners. Objective: Internal definition of overall objective, e.g., achieve the highest quality loan portfolio in line with profit and risk parameter targets.		
I. Qualitative Risk Appetite Statement (RAS)		
Description of key qualitative principles put in place to achieve overall credit risk objective.		
Inherent risk	**Unaccepted risk**	**Controls**
Description of inherent risk with respect to credit risk.	Description of unaccepted risk with respect to credit risk.	Description of controls and processes with respect to credit risk.
II. Level, Limits and Thresholds		
Description of key quantitative principles put in place to achieve overall credit risk objective.		
Level	**Description**	**Limit / Red Threshold**
E.g., board, head of department, etc.	Specific credit risk indicator	e.g., 10% ; >9,5%

Several respondents highlighted that their respective institutions were still in the early stages of integrating climate risks into their risk appetite frameworks. For example, one respondent (N1) explained that their institution was working on translating sector-specific targets and pathways into key risk metrics and limits that would eventually become part of the risk appetite framework. To illustrate:

> *"As a bank, we have committed to adhering to climate goals, including interim targets for 2030. This involves adhering to specific climate or CO2 reduction pathways for different industries, such as cement and aviation. We are currently translating these pathways into risk metrics, including limits. The objective is to monitor whether we are significantly deviating from the path we, as a bank, have committed to—approved by the board. In the next phase, we will integrate this into the risk appetite framework, using multiple indicators and limits to establish control mechanisms that trigger alerts if something falls off track."* **(N1)**

> *"Integrating ESG factors into our risk appetite is essential, particularly ensuring they are explicitly included in our risk appetite framework. This serves as the foundation for managing these risks effectively. At present, we are only measuring and observing these risks. Without a clear strategic goal on how we intend to address them, we cannot develop effective risk management measures. Limits can only be imposed once we have made a strategic decision that we do not want to take on these risks in the future. Defining our risk appetite must come first. From there, we can implement appropriate management tools, such as limits, exclusions, in a top-down approach."* **(E1)**

For some institutions, the integration of climate risks is more advanced. While institutions generally do not publish their risk appetite statements, some do disclose updates and additions to their frameworks in their Pillar 3 reports. For example, one institution (P) mentions that it has used the results of its climate-related risk heatmap exercise to integrate climate risks into its credit risk appetite. A key element of this integration involves limits for sectors that are particularly vulnerable to transition and physical risks. Furthermore, the institution notes that climate-related risk aspects were incorporated into the market risk banking book risk appetite through the introduction of climate-related sensitivity metrics. A few other institutions disclose key climate-related qualitative principles that have recently been added to their risk appetite framework. These principles, often presented as commitments, primarily focus on carbon neutrality, such as sector-specific targets or a net-zero plan. For example, one institution (I) discloses in its Pillar 3 report key qualitative principles, including achieving carbon-neutral banking operations (scopes 1 and 2) and a carbon-neutral portfolio (scope 3); setting sector-specific climate targets for 2030 for the highest emitting sectors in its portfolio; measuring the climate impact of its credit portfolio and aligning its management with national and international targets. Similarly, another institution (F) reports having incorporated key principles into its risk appetite framework, including aligning operations and business activities with a five-step net-zero plan; setting interim targets (2025, 2030 and 2035) based on a quantitative carbon budget at the sector level; reducing the carbon footprint of operations (scopes 1 and 2); supporting client transition by offering green products and engaging with clients to further develop methodologies.

Beyond incorporating climate risks into risk appetite, institutions often face the challenge of aligning their business strategy with their risk strategy. In this context, several respondents (D1, B2, L1) noted the importance of establishing a clear business strategy, which then serves as the foundation for the risk strategy. They also stressed the importance of having the right processes, policies and documentation in place to effectively implement and operationalize these strategies:

> *"I think it all starts with strategy. You have to be clear about the strategy you want to pursue and then align the other processes accordingly. In other words, the whole credit process and risk management can only contribute to what the strategy means — for example in terms of future deals, but also for future defaults or loss amounts."* **(B2)**

> *"It is a misconception to think that current loans are not relevant from a climate perspective just because they have a five-year maturity. In five years' time, new loans will have been taken out for another five years. Unless a bank's strategy has fundamentally changed, the profile of borrowers is likely to be the same. The strategy therefore plays a key role."* **(L1)**

4.4.2 Key risk indicators (KRIs)

Institutions typically monitor their risk appetite through a dedicated system that is organized around a set of key risk indicators (KRIs) (ECB 2022*d*). Such KRIs are usually included in the risk appetite statement and reported internally (e.g., quarterly) to the management and/or supervisory body as well as relevant committees (e.g., risk committee). Common KRIs include metrics such as internal and regulatory capital ratios (e.g., CET1 capital), leverage ratio, total RWA and breakdown of RWA by risk type and liquidity ratios (e.g., Liquidity Coverage Ratio, Net Stable Funding Ratio). In this section, we provide an overview of climate-related KRIs and highlight the approaches described by the respondents in establishing such indicators.

As part of the integration of climate risks into risk appetite frameworks, the ECB expects institutions to develop KRIs designed to manage climate risks (see expectation 4.2 of the ECB Guide, ECB 2020*b*). While KRIs primarily serve as tools for risk monitoring, they can also be used for observation purposes before formal limits are established. Several institutions included in our sample have already developed or are in the process of developing KRIs to incorporate climate-related risks into their regular risk monitoring and reporting. As with other risk management tools, the design of the climate-related KRIs varies across institutions. We provide an overview of these KRIs in Table 6 and discuss them below.

For example, one institution (G) monitors the share of coal in the electricity production mix of the power generation portfolio it finances. It also considers several KRIs derived from its net zero targets for the oil and gas, power and automotive sectors. Another institution (Q) monitors for its residential mortgages portfolio the assets with an increased physical risk exposure and checks the percentage of vulnerable collateral in areas of high physical risk. Furthermore, it tracks an indicators of data quality of financed emissions. Furthermore, one institution (K) uses a set of climate-related KRIs linked to its business strategy, climate scenario outcomes and credit and operational risk. A respondent (K2) from this institution described the approach as follows:

> *"We have several indicators that are directly tied to our business strategy. For example, we assess how much green business we are conducting and the volume of assets eligible for green bonds. In addition, we have cross-risk and risk-specific indicators. We focus on the outcomes of climate scenarios, using metrics like the utilization of our risk-bearing capacity and the CET1 capital ratio as key indicators. Furthermore, we have developed specific risk metrics, such as those based on the results from our internal ESG scorecard, which we apply to credit risk assessments. In the domain of operational risk, we track the number of service locations that are exposed to physical risks — particularly those that lack appropriate mitigation measures. Another operational risk metric, which is more aligned with legal risks, is the tracking of lawsuits and customer complaints linked to ESG issues."* **(K2)**

One institution (O) uses several KRIs linked to climate risks and specific risk types, including market, liquidity and operational risks:

> *"We have developed some indicators for market and liquidity risks. For liquidity risk, for example, we look at the Liquidity Coverage Ratio (LCR) buffer and assess how much of this securities buffer is associated with entities highly exposed to transition risks. In market risk, we examine the portion of credit spread risk. For operational risk, we track incidents related to climate and environmental issues."* **(O1)**

Another institution (H) has introduced two climate-related KRIs: one tracks the proportion of credit exposure to companies with the lowest transition score, and the other measures the total gross carrying amount exposed to physical climate events. This latter KRI is linked to the climate-related disclosures outlined in Template 5 of the Pillar 3 disclosures:

> *"We monitor the proportion of our lending volume to companies that fall into the lowest category according to our internal scoring system. This system assigns a transition score from 1 to 100, divided into five classes, each spanning 20 points. Specifically, we use a KRI to track our total credit exposure to companies in the fifth and lowest category. For physical risks, we apply a similar approach. In relation to our disclosure requirements, we use Template 5, which provides highly granular information on maturities, sectors and the gross carrying amounts exposed to physical risks. This data is disclosed both for our domestic market and for foreign markets. We aggregate this information into a single metric, which represents the total gross carrying amount of our portfolio exposed to physical risks, and use it as a KRI."* **(H1)**

One institution (E) has a comparable strategy, encompassing one KRI that monitors credit volumes based on the institution's internal ESG scoring system, and another KRI that tracks exposure to climate-related physical risks, with a particular emphasis on flood risks:

> *"We have implemented a set of KRIs, which are now part of our overall risk reporting system. Currently, these indicators follow traditional risk management methods. For example, we use our internal ESG scoring system to track how many clients fall into each scoring category, ranging from A to G. This helps us understand the distribution of credit volumes across these categories, especially for new business. Moreover, we place a strong emphasis on monitoring exposure to specific climate risks, with flooding being a key focus. In this regard, we assess our exposure across various flood risk categories."* **(E1)**

Another institution (J) in the sample tracks six climate-related KRIs, including the number of blacklist cases, a carbon intensity indicator for the shipping and real estate portfolios, and a KRI that monitors credit volumes highly exposed to physical risks. One expert (J2) elaborated:

> *"We ensure that we really do not have any blacklist cases and we also track the proportion of our portfolio with a poor ESG score. In addition, we analyze the distribution of energy efficiency classes, particularly in the shipping portfolio. We also examine the distribution of energy efficiency classes within the real estate portfolio. Furthermore, we monitor the portion of the credit portfolio that is exposed to high physical risk. We have also implemented a trigger based on changes in the ESG score which require discussion in the credit watchlist meeting. Here, we have integrated ESG criteria to monitor cases that deteriorate and are added to the watchlist."* **(J2)**

One respondent (I1) mentioned that their institution has developed a KRI to monitor progress toward decarbonization targets, focusing particularly on the emissions intensity of both the corporate portfolio and the real estate and project finance portfolio:

> *"We have set ourselves the goal of decarbonizing our portfolio. Each year, we assess the long-term decarbonization trend to determine the level of ambition and then track our progress to ensure we are meeting our targets. This process requires monitoring of the emissions intensity of our portfolio. Our KRI is specifically designed to track this intensity at the bank and segment level."* **(I1)**

Another respondent (P1) elaborated on the use of multiple KRIs to monitor decarbonization objectives, while also addressing potential greenwashing risks related to energy label downgrades in the real estate portfolio:

> *"We use various KRI, for example, to monitor our decarbonization goals. In the areas of construction financing and residential real estate, we look at how many renovation projects of existing properties are happening within our portfolio. We have also set a target that we need to meet in order to achieve a specific internal scenario we have outlined. In addition, we monitor greenwashing risks from a compliance perspective. For example, we offer a discount on loans for real estate properties with certain sustainability labels. We ensure that this incentive is not misused by verifying that the properties being built genuinely meet the initial criteria we set. It can happen that a property receives a lower label than expected once it is completed. We monitor these label downgrades as well."* **(P1)**

Table 6: Non-exhaustive list of examples of climate-related key risk indicators (KRIs).

KRI type	**KRI description**
Transition risk KRI	Based on an internal transition score. Tracks total credit exposure to companies with the lowest transition scores.
Physical risk KRI	Based on Template 5 of Pillar 3 disclosures. Monitors the total gross carrying amount exposed to physical risks.
Collateral KRI	Tracks the percentage of vulnerable collateral in areas of high physical risks.
Internal score KRI	Based on the overall internal score. Tracks credit volumes within each scoring class.
Emissions intensity KRI	Tracks emissions intensity across key portfolio segments.
Emissions data KRI	Tracks data quality of financed emissions.
Blacklist KRI	Tracks the number of blacklist cases.
Efficiency Classes KRI	Monitors the distribution of energy efficiency classes within real estate and shipping portfolios.
Green bond-eligible assets KRI	Monitors the volume of amount of assets within the portfolio that can be classified as eligible for green bonds.
Risk-bearing capacity KRI	Monitors the results of the climate scenarios in terms of risk-bearing capacity (ICAAP).
CET1 ratio KRI	Monitors the results of the climate scenarios in terms of common equity Tier 1 capital ratio.
Legal risk KRI	Monitors the number of lawsuits and customer complaints related to ESG topics.
Oprisk KRI	Focuses on operational risk by tracking the number of critical service locations that are exposed to physical risks without mitigation measures in place.
Oprisk KRI	Tracks the number of incidents related to climate and environmental issues.
Liquidity risk KRI	Based on the LCR buffer and tracks the proportion of entities that are highly exposed to transition risks.
Decarbonization KRI	Based on the net zero targets set in key sectors. Tracks alignment of emissions intensity of exposures to key sectors with the institution's sectoral targets or overall net zero target.
Coal KRI	Based on the share of coal in the capacity mix of the financed power generation portfolio.

4.4.3 Limits and exclusions

As part of their risk appetite framework, institutions typically implement a comprehensive limit system that sets specific quantitative thresholds for individual risk types and sub-risks identified in their ICAAP (ECB 2018). In addition, institutions often establish limits at an aggregate level, tied to capital metrics such as the CET1 ratio or overall economic capital adequacy ratios (ECB 2020*a*). These limits allow institutions to operationalize their risk appetite by defining maximum acceptable risk exposures. In this section, we briefly discuss the concept of limits and examine the approaches and challenges reported by respondents in integrating climate risks into their limit systems, along with exclusion strategies.

The ECB defines a limit system as follows: "A documented and hierarchical system of limits set in line with the overall strategy and risk appetite of the institution in order to ensure that risks and losses can be limited effectively in line with the capital adequacy concept. The limit system is expected to lay down effective boundaries for risk taking for, for example, different risk types, business areas, products and group entities" (p.41, ECB 2018). Limits are often linked to various triggers, which can lead to different actions such as hedging transactions to mitigate risks or even halting new transactions if certain thresholds are breached. Internal reports, usually generated monthly, provide governance bodies with information on the utilization of both individual and overall risk limits.

The form and scope of these limits can vary. For example, to avoid excessive credit risk concentration, institutions are subject to a regulatory limit, known as the "large exposure limit", which restricts total exposure to a single counterparty or a group of related clients to 25% of an institution's Tier 1 capital at any time (see Art. 395 of the CRR). Institutions may also apply limits for credit exposures to single names, industries and countries (ECB 2020*a*). In this context, ratings are often a key input parameter in determining credit risk limits. For example, sovereign ratings are important for establishing country limits, and a downgrade in a country's rating may lead to a reduction in its associated limit. For industries or sectors, institutions generally apply a risk-oriented sector key, which combines sector segments that have high economic dependencies along certain value chains (ECB 2020*a*).

In the context of climate risks, the ECB expects institutions to set "appropriate" limits to manage such risks (see expectation 4.2 of the ECB Guide, ECB 2020*b*). Institutions use different approaches to incorporate climate risks into their limit systems. In Table 7, we provide an overview of the climate-related limits observed in our sample and discuss these examples further below.

For example, one institution (C) uses a "climate stress loss limit" across credit and market risks. To monitor potential credit and market risk losses against this limit, this institution runs a short-term transition risk carbon repricing scenario assuming that a global effort to address carbon emissions leads to a sudden and sustained carbon repricing across all countries. The results of this scenario are assessed on a monthly basis against the limit. The limit itself is reviewed annually. As described by one respondent (C1), the climate stress loss limit operates as follows:

> *"The climate stress loss limit is expressed as a specific loss amount and reflects our appetite for climate risk. We tie this to the broader macroeconomic stress loss limit, which represents the firm's overall risk appetite. We run macroeconomic stress scenarios on a regular basis to measure market and credit risk loss potential and to monitor those against the macroeconomic stress loss limit. Given that transition risk is a material risk for us, we use carbon pricing as the key scenario for monitoring this risk, and we assess this limit specifically against potential losses from carbon repricing. The climate stress loss limit covers both credit and market risk. As our transition scenario includes market shocks, it has the potential to trigger market losses, which we also monitor. We use the same methodology as for any other shock and cover the entire portfolio. It think this approach sets us apart from other institutions, which often only focus on specific portfolio segments. In contrast, we run the scenario across the entire portfolio, including both lending and trading exposures (...). We've developed an internal scenario, as the NGFS scenarios are not well-suited for short-term evaluations. Our scenario is deliberately conservative. We take forecasts of carbon price scenarios for 2030 and apply them to the present day. We look at what research is forecasting in the more severe scenarios in terms of carbon prices around the globe, all at the same time, and we use those assumptions in our scenario as if they were occurring today."* **(C1)**

Several institutions apply limits to sectors or industries that are particularly exposed to transition and physical climate risks. Such limits are typically expressed in terms of aggregated credit risk net exposure, either risk-weighted or non risk-weighted (e.g., total amounts in EUR million). For example, one institution (C) has specific industry limits that complement the climate stress loss limit. These limits are based on a sub-industry segmentation approach and take into account expert credit assessments, greenhouse gas emission data and external physical risk scores:

> *"We have sector limits for industries highly exposed to transition or physical risks, using internal methodologies to assess these risks, based on industry scores and expert*

judgement (...). The limits are set at the industry level, tied to the industry of the company in the transaction. For instance, if a new transaction is originated in the energy industry, it has to fit into our limit (...). This approach allows us to manage new lending in sectors particularly vulnerable to these risks. Since our primary climate risk arises from credit risk, we implemented this credit exposure limit below the Climate Stress Loss Limit for more targeted monitoring." **(C1)**

Another respondent (O1) outlined a similar strategy, incorporating both sector limits and an additional limit tied to the portfolio's exposure to physical risks:

"In an initial step, we deliberately chose a simple approach. We didn't want to set limits based on CO2 intensities across the entire portfolio right away. Instead, we started with a relatively straightforward method. We developed industry-specific limits and thresholds. For example, we monitor a specific indicator that tracks the share of our portfolio in five high-risk sectors: agriculture, aviation, real estate, non-renewable energy and the food industry. This means we examine how much exposure we have in these sectors, and the overall exposure is capped. We also have a second indicator that measures the portion of the portfolio located in physically high-risk areas. This is further broken down into subcategories. For real estate, we assess the collateral, and for companies, we evaluate their physical locations. We consolidate this information into one indicator and map it using data from Munich Re. We've also incorporated 'defender' scores. For example, in the Netherlands, there is significant flood risk, but substantial investments have been made in dike systems, which we can factor into our scoring. We then evaluate what remains in the portfolio that falls into these high-risk areas, and this share of the portfolio is also capped. Looking ahead, the topics of CO2 emissions and emission intensities will play a more prominent role. However, for now, we are focusing on gaining more experience in this area, as there is still considerable uncertainty around data and modeling. Therefore, we haven't imposed limits in this regard yet. We continually review the sector-specific pathways as part of this process." **(O1)**

A more advanced and complex approach involves setting limits based on CO2 intensities for specific sectors, as well as carbon footprints in lending and investment portfolios. For example, one institution (F) has established quantitative thresholds for several carbon-intensive sectors (e.g., power generation, automotive, steel production). These thresholds have been incorporated into its risk appetite statement and are directly linked to the institution's net zero targets for each sector. In addition, any new transaction that has a significant impact on the institution's financed emissions has to be reviewed by a dedicated net zero forum. Similarly, another institution (P) uses a combination of instruments, including sector-specific limits for industries highly exposed to transition risks, limits tied to energy efficiency labels for the residential and commercial real estate portfolios, and a concentration limit aimed at managing physical risk exposures:

> *"In the area of residential and commercial real estate, we have set limits based on energy efficiency labels and energy efficiency classes. In addition, we have a concentration limit in relation to physical risks. The objective here is to limit our credit exposures to geographies subject to high physical risks. For wholesale banking, we have established so-called 'growth caps' for individual sectors, such as oil, gas and coal. These caps are aligned with the climate goals we are pursuing. For example, for oil and gas, we have a phase-out scenario and corresponding limits in place to support this reduction process."* **(P1)**

Similarly, another institution (N) is considering the introduction of a limit system on the basis of sectoral emission intensity:

> *"We are focusing on intensity-based climate pathways, such as CO2 emissions per ton of steel or per ton of cement produced in the case of cement manufacturers. The main challenge is aggregating these diverse metrics. However, we are currently exploring how to express this as a deviation from our climate pathway, for example, by determining how many months or years we are behind the target and what needs to be done to catch up. The aim is to consolidate this into a single figure for the bank, though it is still very much a work in progress at this stage."* **(N1)**

Table 7: Non-exhaustive list of examples of climate-related risk limits.

Limit type	**Limit description**
Climate stress loss limit	A limit on potential credit and market losses resulting from a transition risk scenario, such as sudden carbon repricing. This limit is assessed monthly and reviewed annually.
Sector limits for transition/physical risks	Limits on aggregated credit exposure to sectors particularly exposed to transition and physical risks (e.g., energy, real estate). These are based on industry scores, credit risk assessments, and physical risk scores.
Physical risk exposure limit	A cap on the share of the portfolio exposed to areas or industries with high physical risks (e.g., flood zones), often based on external data and risk assessments.
Energy efficiency label limit	A limit on credit exposures in residential and commercial real estate portfolios based on energy efficiency labels or classes.
CO2 intensity limits	Quantitative thresholds for carbon-intensive sectors (e.g., power generation, automotive), aligned with net zero targets. Transactions significantly affecting financed emissions are reviewed by a dedicated committee.
Concentration limits for physical risks	A limit on credit concentration in geographies or industries highly exposed to physical risks, such as natural disasters.
Growth caps for high-risk sectors	Limits set on the growth of exposure to high-risk sectors like oil, gas, and coal. These caps align with decarbonization goals, often tied to phase-out scenarios.

Rather than limiting exposure to climate risks as described above, institutions may also choose to exclude certain sectors or industries from their lending activities altogether. To facilitate the implementation of these exclusion policies, the institutions in our sample have developed checklists, blacklists or similar tools to systematically evaluate new loan applications based on specific criteria. These procedures are typically tailored to specific asset types (e.g., corporates, project finance, countries) and are subject to regular review, often overseen by an exclusion criteria committee. For example, a few institutions (G, F, I) have also introduced guidelines for sector-specific exclusions based on climate-related criteria. Typically, the sectors targeted are large CO2 emitters.

For example, one institution (I) no longer provides project finance to companies that build, expand and/or upgrade coal-fired power plants or coal mines. Similarly, this institution has set new thresholds for general purpose financing to energy utilities that derive a large part of their revenue from coal or operate one or more coal-fired power plants. Another sector to be subject to exclusion policies is the oil and gas sector. One institution (G) no longer grants financing for the development of new oil fields. Furthermore, it has introduced a phasing out of financing for non-diversified oil upstream companies and excludes financing dedicated to the development of new capacities for gas exploration and production. As noted by several respondents (B1, B2), these exclusions are often particularly driven by strategic decisions and reputation risk concerns:

> *"The ESG checklist is an expression of our bank's reputation risk."* **(B2)**

> *"These exclusions, which are designed to limit new business in certain sectors, are currently more the result of strategic and reputational considerations, rather than a consequence of stress test results."* **(B1)**

4.5 Pillar I & II: Integrating climate risks into loan pricing

4.5.1 Background and rationale

A key issue raised on multiple occasions by our respondents is the topic of loan pricing in the context of climate risk integration. This aligns with the ECB's expectation that loan pricing should reflect the "different costs" driven by climate risks (see expectation 8.6 of the ECB Guide, ECB 2020*b*). Meeting this expectation requires a conceptual understanding of how "traditional" cost parameters affect loan pricing, and how these may be adjusted to better account for climate risks. In this section, we briefly outline key considerations related to loan pricing, followed by a summary of the approaches and challenges highlighted by our respondents.

According to the EBA's guidelines on loan origination and monitoring (EBA 2020), institutions need to consider and reflect several types of costs in their loan pricing, including the cost of capital (both regulatory and economic capital), the cost of funding, operating and administrative costs, credit risk costs (based on historical losses and, where applicable, using expected loss models), other real costs associated with the loan, and parameters related to competition and prevailing market conditions (EBA 2020). Figure 14 provides a simplified illustration of such costs.

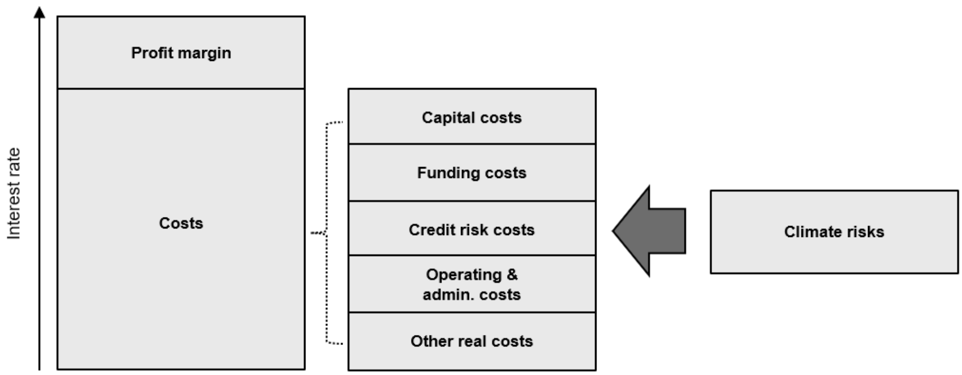

Figure 14: Costs affecting loan pricing. Based on EBA (2020) and KPMG (2023). Note that the relative size of the cost components is not to scale.

Climate risks can influence loan pricing in several ways. In particular, the ECB notes that the "impact of climate-related and environmental risks may play out through various cost drivers, such as the cost of capital, funding or credit risk" (p.38, ECB 2020*b*). As we show in the next sections, institutions have started to implement climate risk integration strategies across all three cost drivers — capital, credit and funding.

4.5.2 Pricing of climate risks through capital considerations

Cost drivers can arise from both Pillar 1 and Pillar 2 considerations. In particular, the EBA recommends incorporating the cost of capital (taking into account both regulatory and economic capital), resulting from the existing capital allocation, into loan pricing decisions (EBA 2020). This recommendation underscores the importance of aligning pricing with the institution's overall capital requirements. Building on this idea, Gruenewald et al. (2023)

argue that integrating climate risks into Pillar 1 capital requirements would ensure that these risks are adequately accounted for in internal business decisions, such as loan pricing.

In support of this, one respondent (C1) explained that their institution captures climate risks in loan pricing by incorporating such risks into internal ratings. Furthermore, as noted in Section 4.2, most respondents consider the short-term financial effects of climate risks are to be implicitly captured by the ratings, either by the quantitative rating criteria (e.g., financials) or by more qualitative factors (e.g., competitive positioning, industry risk). Institutions are also increasingly relying on tools such as climate-related scores and applying rating overrides to account for more longer-term effects of climate risks. Such tools have an impact on capital requirements and thus on loan pricing.

> *"Climate risk is integrated into our pricing because we have incorporated it into our internal ratings and it is part of the PDs."* **(C1)**

As shown in Section 4.3.5.3, several institutions allocate economic capital specifically for climate risks or set aside dedicated capital buffers. For example, one institution (K) has established a comprehensive climate risk buffer within its risk-bearing capacity calculations, effectively reducing the institution's available capital. This approach may also have an impact on loan pricing. In addition, one respondent (K1) explained that their institution's loan pricing framework is driven by economic capital considerations, with credit portfolio models under Pillar 2 playing a key role in shaping loan pricing decisions:

> *"For us, pricing is primarily driven by Pillar 2. We use a credit portfolio model, essentially a value at risk model, and from that, we derive profitability which then determines loan pricing. Once these climate-related risk drivers are incorporated into Pillar 2, where they are currently already much more prominent than in Pillar 1, they influence pricing (...)."* **(K1)**

Such approaches may nevertheless result in a more ad hoc and fragmented inclusion of climate risks into loan pricing. Although achieving a more systematic integration of climate risks is seen as particularly challenging, three respondents (H5, D1, P1) noted that integrating climate risks into internal risk models remains an important long-term goal for risk-based pricing:

> *"There are regulatory requirements that we have to take climate risks into account for loan pricing. Some institutions, who were perhaps more proactive, have already*

allocated capital for climate risks in some way, making it easier for them now because the cost of capital is factored into loan pricing. As a result, they have little else to do. We, on the other hand, did not take this approach. Based on our risk inventory and sensitivity analyses, we concluded that climate risk was not material and therefore did not allocate capital for it. As a result, climate risks are not systematically reflected in our pricing. Our credit risk scorecard is likely to play a role in the future for pricing, but this is still under development." **(H5)**

"Ideally, climate risks would be automatically incorporated into the PDs and consequently into risk-adjusted pricing. Of course, we can, and in certain cases we certainly will, set opportunistic price incentives independently of the PD. In a perfect scenario, these considerations would be embedded within the PD, ensuring automatic risk adjustment. Until we reach that point, we may need to intervene individually in certain sub-portfolios or with selected customers." **(D1)**

"Ideally, this would be managed through our internal models, allowing us to price the risks accordingly. However, this would require adjustments to our internal models, and we are not quite there yet in terms of progress. What we are doing at the moment are post-model adjustments, or overrides. For example, when we see that certain risks are not adequately reflected in the model, we can make adjustments, which results in the customer receiving a higher interest rate. Otherwise, the adjustments are more on the business side, in terms of economic calculations. For example, I have a target ROE [Return on Equity] for the entire portfolio that I want to maintain, say 10% ROE. I can offer discounts on certain loans, and for others with higher risk, I can apply a premium. This way, I can distribute the impact across the portfolio and still achieve my target." **(P1)**

In addition, one respondent (O1) noted that, although their institution does not view climate risks as being internally mispriced, loan origination teams may offer pricing incentives for transactions that support the institution's emissions reduction targets. This approach, however, is driven by strategic priorities rather than adjustments in cost of capital or risk modeling considerations:

"At the moment, we are not explicitly intervening by making green loans cheaper or brown loans more expensive. We have consciously chosen not to take that approach.

One reason is that we consider these risks to be already implicitly reflected in our ratings, through factors such as business model or collateral valuation. We do not feel that we are incorrectly measuring or pricing credit risk. As a result, we haven't seen the need to intervene from a risk management perspective by, for example, requiring higher margins for certain sectors. However, what is happening is that the loan origination divisions, within their decision-making authority, are offering incentives and may accept a few basis points less in terms of margin premium (...). This allows us to support transactions that contribute to our CO2 emissions reduction targets. But this is more of a business decision made by individual loan origination departments, rather than something risk management mandates because of concerns about incorrect pricing." **(O1)**

4.5.3 Pricing of climate risks through credit risk and funding considerations

In addition to capital considerations, the EBA recommends loan pricing to also account for the cost of funding and credit risk costs (EBA 2020). The credit risk costs may be determined based on historical losses or, where applicable, on expected loss models (EBA 2020).

One institution (K) applies a combination of strategies to incorporate climate risks into loan pricing, differentiating between short-term and long-term risks. Short-term climate risks are captured through credit risk costs and reflected in profit margin requirements, while long-term risks are addressed by leveraging potentially lower refinancing costs via a green refinancing curve and adding a margin premium based on the internal ESG scorecard, with particular attention to the environmental scores and loan maturities. A respondent (K2) from this institution explained:

"We consider our short-term climate-related risks to be included in our credit risk costs, which are ultimately reflected in our profit margin requirements. We have also factored in potentially lower refinancing costs through a green refinancing curve. While this curve does not significantly differ from the standard refinancing curve at the moment, we have structured it in a way that allows us to account for larger differences if they arise in the future. In addition, last year we introduced a margin premium in response to the ECB's requirements. This premium is determined based on the results of our internal ESG scorecard and loan maturity. You can think of it as a matrix: the longer the term of a loan and the worse the ESG score, particularly the environmental sub-score, the higher the premium. These aren't arbitrary numbers that would price us out

> *of the market. Instead, we have implemented a structural framework to address issues that are not otherwise captured by risk parameters such as probability of default and loss given default in the short term (...). Although a rating usually has a one-year time horizon, the additional profit margin requirement considers the entire loan duration. For example, a poor internal score on a two-year loan may not have a significant impact on the margin, but for a 20-year loan, the effect would likely be different."* **(K2)**

In terms of credit risk costs, two respondents (H5, G1) highlighted that their institutions are increasingly relying on scenario analysis to integrate climate risks into loan pricing considerations. In this context, individual scenarios are used to assess potential shifts in credit risk parameters and expected credit losses. For example, respondent (G1) explained that their institution developed a methodology for expected credit loss provisions (credit risk provisions)[54] that relies on default probabilities conditional on climate scenarios:

> *"By the end of this year, we plan to integrate the impact of climate scenarios into the calculation of credit risk provisions. This will have pricing implications, as the effects of these scenarios will be felt from the moment a transaction is originated, and even for existing transactions in their internal billing. To implement this, we are developing default probabilities that are conditional on these climate scenarios. Historically, provisions were based on three-year scenarios, but this year, we have developed a comprehensive methodology to incorporate the effects of longer-term scenarios into short-term projections. In this context, it is important to consider the concept of the term structure of default probabilities. In our stress tests, we assume a continuously renewed portfolio and typically focus on one-year default probabilities projected over longer time horizons, such as 30 years. For provisioning, we account for this by adjusting the marginal default probabilities. This means that, starting today, when we look at the term structure of default probabilities for a loan in the portfolio with a 30-year horizon, for example, the entire structure will shift to an extent that depends on the horizon in relation with a climate scenario."* **(G1)**

Finally, one institution (Q) uses a combination of economic capital buffer, provisioning for expected credit losses and incorporation of climate risks in macroeconomic scenarios used to estimate future expected credit losses. The institution notes that the incorporation of climate risks into such models is challenging due to a lack of data. Despite these challenges, the institution notes that it has implemented a strategy to partially integrate climate risks

[54] Expected credit losses under IFRS 9 are deducted from capital (Krüger et al. 2018).

by embedding them into macroeconomic forecasts commonly used to assess expected future losses. The institution adds that, as a result of the materiality assessment, a management overlay of EUR 25 million has been taken for expected credit losses.

4.6 Pillar II: Integrating climate risks into the Supervisory Review and Evaluation Process (SREP)

4.6.1 Background and rationale

Unlike regulators, supervisors cannot enact binding rules, but they can offer guidance on how they interpret specific regulatory requirements, thereby influencing institutions' expectations and behavior (Smoleńska & van 't Klooster 2022). Under the SSM, the ECB directly supervises significant institutions in euro area countries through the SREP. In recent years, the ECB has included climate risks as one of its new priorities in SREP assessments (Gruenewald et al. 2023). Although the SREP is a tool for supervisors rather than institutions, it can help shape institutions' risk management practices with respect to climate risks and therefore contribute to a greater integration of such risks. The SREP also influences individual capital requirements for institutions. This section outlines key aspects of the SREP, while the subsequent sections explore how this process may further enhance the integration of climate risks into risk management and capital requirements.

The SREP is an annual process in which supervisors evaluate, on a case-by-case basis, the risks faced by institutions and their ability to manage these risks in terms of risk controls, capital and liquidity (ECB 2023*g*). It is structured around four key thematic elements and results in three primary outcomes, as shown in Figure 15. The first element is a business model assessment, where supervisors evaluate both the viability and sustainability of an institution's business model (EBA 2022*a*). Specifically, they assess the viability of the institution's current business model based on its ability to generate sufficient returns over the next 12 months, and the sustainability of its strategy, considering its capacity to generate sufficient returns over a period of at least three years, considering strategic plans and financial forecasts (EBA 2022*a*). In addition, supervisors are required to develop a clear understanding of the "current and future business conditions in which an institution operates or is likely to operate based on its main or material geographic and business exposures"(p.42, EBA 2022*a*).

The second element of the SREP methodology focuses on governance and risk management. In this context, supervisors evaluate whether an institution's internal governance framework is appropriate for its risk profile and business model. They also assess whether the governance structures are properly aligned with sound risk management mechanisms and other corporate policies (EBA 2022*a*). The third element involves assessing and scoring the risks to capital deemed material for the institution. Supervisors conduct a detailed evaluation of risk types, such as credit and counterparty risk, market risk and operational risk (EBA 2022*a*). In addition, they review other risks identified in the institution's ICAAP (e.g., reputational risk) and assess the quality and effectiveness of the controls in place to manage these risks. Lastly, the fourth element addresses liquidity and funding risks, focusing on the institution's ability to meet short-term cash requirements (EBA 2022*a*).

As shown in Figure 16, the combined assessment of these four elements results in an overall SREP score, ranging from 1 (low risk) to 4 (high risk), reflecting the supervisors' comprehensive evaluation of the institution.[55] Institutions also receive a detailed report outlining the outcomes and identified shortcomings through a formal ECB SREP decision or "SREP feedback letter".

A key outcome of this process, and in particular of the SREP score, is the P2R. The P2R is a legally binding capital requirement that complements Pillar 1 minimum capital requirements (ECB 2023*f*). It is applied when the ECB comes to the conclusion, through the SREP assessment, that certain material risks are either underestimated or inadequately covered. For example, below average SREP scores (e.g., 3 or 4) may trigger higher P2R levels. P2Rs are typically expressed as an additional percentage of capital that must be held in relation to RWA, and both the ECB and supervised institutions have to publicly disclose current P2R levels (ECB 2023*f*, 2024*h*). This process allows the ECB to make tailored decisions regarding additional capital and liquidity requirements and to introduce qualitative supervisory measures.

[55] In 2023, the average overall SREP score in 2023 was 2.6, based on 106 SREP decisions(ECB 2023*a*).

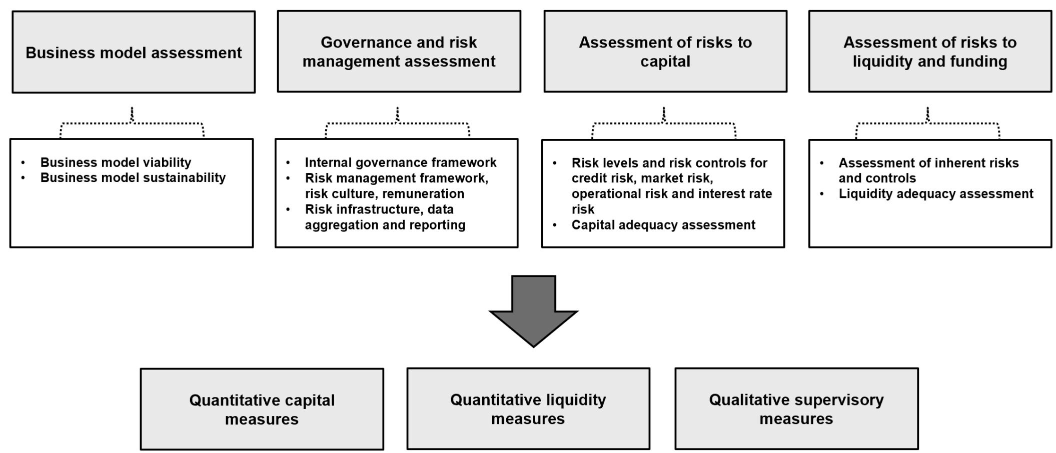

Figure 15: The key components and main outcomes of the Supervisory Review and Evaluation Process (SREP). Based on EBA (2022*a*) and ECB (2023*g*).

4.6.2 Business model, governance and risk management assessments

As described in Section 2.1, by the end of 2024 institutions are expected to comply with the ECB's supervisory expectations on climate risks established in 2020, including the full integration of these risks into their ICAAP and stress testing frameworks (ECB 2020*b*, 2023*a*). In addition, the ECB is increasingly integrating climate-related aspects into key supervisory assessments under the SREP, a development which is further explored in this section.

In both the 2022 and 2023 SREP cycles, the ECB conducted a thematic review of climate risks. In the 2022 cycle, the review focused on qualitative aspects, resulting in 40 binding qualitative measures for around 30% of supervised institutions (ECB 2022*b*). These measures mainly addressed governance, business model and credit risk-related issues (ECB 2022*b*).

The ECB noted that most of the measures from the 2022 review were focused on "strategic and operational plans", highlighting that supervisors view this area as a "key enabler" for effective climate risk management (ECB 2022*b*). In addition, some measures required institutions to improve materiality assessments across various risk types (e.g., credit, market), enhance internal climate stress tests and scenario analyses, and further integrate climate risks into risk appetite frameworks (ECB 2022*b*).

In the 2023 SREP thematic review, the ECB reported that around one-third of the 40 binding measures issued in 2022 had been resolved and completed. However, approximately 12% of significant institutions were issued additional binding measures to address ongoing deficiencies or newly identified shortcomings (ECB 2023*a*). These measures again focused primarily on climate-related issues, particularly in relation to governance and business models, and included the integration of climate-related considerations into strategic and operational plans. In addition, for institutions with "persisting severe weaknesses", the ECB issued ad hoc supervisory board decisions (ECB 2023*a*).

These recent developments, based on the 2022 and 2023 SREP cycles, suggest that climate risks now play a role in at least three key elements of the SREP: the business model assessment, the corporate governance and risk management assessment, and the risks to capital assessment. A recurring theme is the integration of climate risks into business models and strategies. For example, one respondent (A1) noted that climate risks are now being addressed in SREP feedback letters. This respondent pointed out that the ECB provided feedback on both areas of improvement and areas needing further attention, including the evaluation of climate impacts on the business model and their integration into overall strategy:

"Every year, we receive a very comprehensive SREP letter from the ECB. It is structured around different points, including quantitative requirements, qualitative requirements, facts, findings, and recommendations. The ECB also outlines findings related to the business model and notes areas where we have improved. In this context, it may include observations on the integration of climate risks into strategy and the assessment of the impact of climate risks on the business model. We had something related to that." **(A1)**

The relevance of climate risks in the context of the first SREP element, i.e., business model assessment (see Figure 15), is particularly evident in the ECB's corresponding methodology paper (ECB 2023*b*). This methodology underscores that institutions, due to their business model and risk profile, may be operating in markets, sectors, or geographic areas that are particularly exposed to material transition and physical risks, making them vulnerable to the impacts of climate change. As a result, the ECB expects supervisors (e.g., joint supervisory teams) to assess how these risks affect institutions' business environment and strategies, as well as the establishment and monitoring of "key performance indicators" over short, medium, and long-term horizons (p.9, ECB 2023*b*).

In contrast, the methodology for the second SREP element, which deals with governance and risk management assessment, is less explicit in its approach to integrating climate risks. The corresponding document only mentions that the methodology will be continuously updated to address new factors arising from the evolving economic and regulatory landscape, such as risks associated with climate change and the environment (ECB 2023*d*).

Finally, in relation to the third SREP element, both the credit risk and market risk assessment methodologies explicitly address climate risks. For credit risk, the methodology specifies that the assessment should cover any credit risk-related aspect potentially affected by climate risks. This includes considering "concentrations in economic sectors or geographical areas more vulnerable" to such risks (p.10, ECB 2023*c*). It also covers other aspects, such as residual risk, settlement and delivery risk and other elements that are material to credit risk (ECB 2023*c*). Regarding market risk, the ECB indicates that supervisors should assess whether institutions have an adequate "monitoring and reporting framework for market risk in place, which includes the effect of climate-related and environmental factors on their current market risk positions and future investments", also ensuring that senior management or the management body takes prompt action when necessary (p.11, ECB 2023*e*).

4.6.3 Pillar 2 Requirement (P2R) and Pillar 2 Guidance (P2G)

As climate risks are increasingly integrated into the SREP framework (as discussed in Section 4.6.2), and considering that the first three elements of the SREP — business model analysis, internal governance and risk management, and risks to capital — are key determinants of initial Pillar 2 capital requirements (P2R) (ECB 2024*b*), the influence of climate risks on individual SREP scores and P2R levels for institutions is expected to grow. This section provides a discussion of these dynamics.

As shown in Figure 16, each SREP element generates a sub-score that contributes to an institution's overall SREP score.[56] The integration of climate risks into SREP assessments can contribute to improving or worsening sub-scores, particularly regarding the first three elements discussed in Section 4.6.1. As a result, this may lead to changes in the overall SREP score, which in turn affects the level of P2R imposed on institutions (ECB 2024*h*). The P2R represents an additional capital buffer that institutions must hold beyond the minimum capital requirements set under Pillar 1.[57]

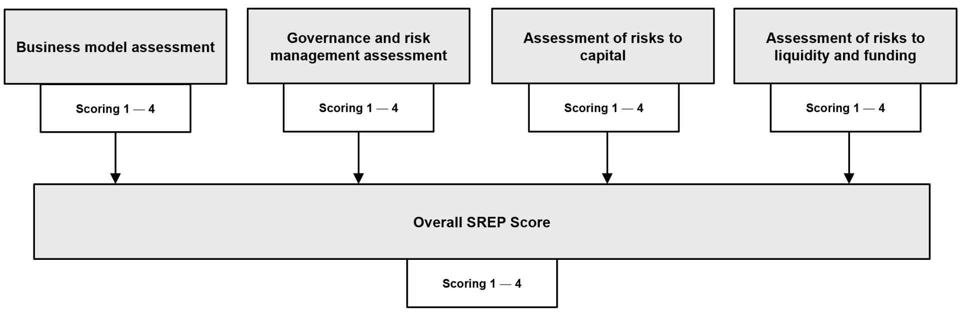

Figure 16: Simplified overview of scoring framework under the Supervisory Review and Evaluation Process (SREP). Based on EBA (2022*a*) and ECB (2023*g*).

In fact, the ECB already observed, following the 2022 SREP cycle, that the qualitative integration of climate risks impacted the SREP scores of a few supervised institutions (ECB 2022*b*). Specifically, the ECB noted that the "qualitative integration of climate and environmental risks had an impact on the SREP scores of a small number of institutions, although this did not translate into higher overall capital requirements" (ECB 2022*b*). In contrast,

[56]For a detailed description of the SREP methodology, see EBA (2022*a*) and ECB (2023*g*).

[57]Institutions with lower SREP scores are viewed as having lower risks and sounder risk management and therefore face lower P2R levels. Conversely, higher SREP scores indicate greater vulnerabilities and weaknesses in risk management, leading to higher P2R levels to address these additional risks.

following the 2023 SREP cycle, the ECB reported a slight shift, where "in terms of quantitative measures, climate and environmental risks are seen as a factor in determining P2R levels for a larger number of institutions than in the SREP 2022" (ECB 2023*a*). This suggests that climate risks are increasingly becoming a factor that can affect Pillar 2 capital requirements.

Several respondents noted that they expect climate risks to play an increasingly important role in future SREP assessments. For example, one respondent (O1) noted that market standards are likely to develop as institutions implement the supervisory expectations outlined in the ECB's Guide on climate risks (ECB 2020*b*). Once such market standards are established, these practices are likely to be more systematically reviewed and incorporated into the SREP process, potentially influencing institutions' SREP scores:

> *"The integration will gradually be included in the standard SREP process, eventually becoming a component influencing the overall SREP score. Currently, banks are developing a variety of approaches and solutions, which are being reviewed by the ECB. I expect that a standard will eventually be established for all institutions based on these findings."* **(O1)**

Another tool available to supervisors, although less binding than the P2R but still capable of influencing risk management and climate risk integration, is the P2G. The P2G is an institution-specific recommendation that indicates the level of additional capital supervisors advise holding beyond mandatory capital requirements (ECB 2024*e*). This guidance is typically based on institutions' performance in supervisory stress tests (ECB 2024*e*).

Currently, supervisory climate stress tests do not affect institutions' P2G levels. For example, the results of the ECB's 2022 climate stress test were not used to determine capital guidance under Pillar 2. This decision reflects a broader consensus among supervisors that climate stress testing methodologies are still in development, making their integration into the P2G framework premature (Calipel & Fidel 2023). However, as climate-related stress testing practices become more advanced, it is likely that such tests will be incorporated into the P2G framework in the future.

A key advantage of the P2G is its forward-looking approach, as it is grounded in stress testing exercises that align with the long-term nature of climate risks. In addition, as a non-binding, institution-specific recommendation, it provides a flexible and tailored approach that incentivizes institutions to integrate climate risks into their risk management practices. Several respondents (A1, C2) described the P2G as a potentially useful tool for integrating climate risks and establishing market standards, particularly in the context of stress testing.

> *"I think a good approach going forward would be to use the Pillar 2 guidance. As a bank, you can look at climate risks with different stress scenarios, with different counterparties that you highlight and analyze. You have a freer and more qualitative view of things (...)."* **(C2)**

5 Discussion and conclusion

This study examines the integration of climate risks into both Pillar 1 and Pillar 2 frameworks, focusing on the main approaches and tools that institutions and supervisors are using to address these risks more effectively. We shed light on these approaches by adding the perspective of risk experts, highlighting which methodologies are currently considered practical and implementable, and identifying the key challenges institutions face in conducting this integration. We also situate these approaches within the broader regulatory landscape, highlighting the unique characteristics of the approaches required to manage climate risks compared to other risk types and drivers. Our findings aim to inform both academics and practitioners involved in developing methodologies for incorporating climate risks into risk management policies and regulatory frameworks.

Several limitations of this study suggest directions for future research. First, the majority of participants and institutions in our sample are based in Germany, potentially limiting the broader generalizability of some findings. Nevertheless, the ECB's guide on climate risks applies uniformly to all supervised institutions (ECB 2020*b*), which helps mitigate such concerns. Future research could include a wider range of institutions to develop an even more comprehensive understanding of climate risk integration in banking practices.

Second, specific aspects of capital requirements fall outside the scope of this study. In the context of Pillar 1, our focus is primarily on credit risk, especially on PD considerations, which are critical for understanding risk management under Pillar 2. Other risk types, such as market and operational risks, which are considered less relevant for climate risks, are not extensively covered. Similarly, this study does not provide a detailed examination of the integration of climate risks into collateral valuation under Pillar 1, an area that has already been extensively commented on by the EBA (see EBA 2023). In addition, this study does not examine the integration of climate risks into macroprudential capital buffers, such as the Systemic Risk Buffer (SyRB), which is designed to address systemic risks but is not specifically calibrated for climate risks (Bartsch et al. 2024). Future research could expand on our conceptual framework by exploring additional potential avenues for climate risk integration and assessing their implications for the capital requirements of supervised institutions.

Lastly, we also do not address in detail expected credit loss models under IFRS 9. This is an aspect that is likely to become increasingly relevant in the context of climate risks and merits additional research. It is worth noting that institutions appear to increasingly combine the integration of climate risks into credit loss provisions with the allocation of capital buffers for

A. Auzepy and C. E. Bannier, *Integrating Climate Risks in Bank Risk Management and Capital Requirements*,
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climate risks. As credit loss provisions reduce available capital, while capital buffers require to hold additional reserves, analyzing the net impact on capital in this context would provide valuable insights.

Despite these limitations, our findings have broader implications for risk managers, supervisors and policymakers. First, our study indicates that financial institutions are making significant strides in integrating climate risks into risk management practices, including the ICAAP. Nonetheless, our findings also reveal considerable disparity among institutions and persistent uncertainty regarding specific methodologies, particularly with regard to climate risk stress testing. In addition and related to this issue, our study highlights that supervisory practices and expectations strongly shape this integration. For example, the climate risk scenarios selected by institutions for the ICAAP and exploratory stress tests are heavily influenced by those used by the ECB in its 2022 supervisory climate stress test. Supervisors and policymakers therefore have a critical role to play in establishing market standards and best practices.

While a degree of ambiguity may be beneficial in the early stages, providing institutions with the necessary flexibility to develop and test different methodologies, it may also hinder a more robust and consistent integration of climate risks into risk assessments and governance structures at a later stage. We therefore recommend that supervisors and regulators publish comprehensive best practice guidance once the 2024 deadlines for implementing the ECB's expectations have been met. By providing a rigorous analysis of the current state of climate risk integration into bank risk management practices and advancements in related methodologies, we hope that our study contributes meaningfully and constructively to this endeavor.

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Appendix

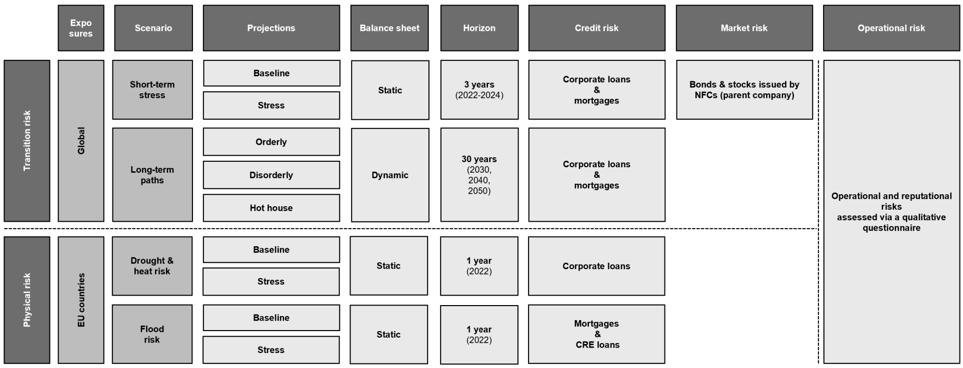

Figure 17: Scenarios and risk types of the 2022 ECB climate risk stress test. Adapted from ECB (2022*a*). Note: CRE stands for commercial real estate. NFC refers to non-financial corporation.

A. Auzepy and C. E. Bannier, *Integrating Climate Risks in Bank Risk Management and Capital Requirements*,
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Table 8: Overview of climate scenarios developed by the NGFS and the ECB for stress testing purposes. This table presents key features related to the scenario narratives and their macro-financial risk assumptions. Green means "low risk", yellow means "medium risk", red means "high risk". Based on and adapted from ECB (2022*a*) (see p.13-18); NGFS (2023*b*) (see p.21); NGFS (2024*b*).

Organization	Scenario name	Scenario category	Time horizon	Average warming	Policy reaction	Technology change	Carbon dioxide removal	Regional policy variation	Overall description
NGFS	Net zero 2050	Orderly	Until 2100	1.4°C	Immediate and smooth	Fast change	Medium - high use	Medium variation	Net zero 2050 limits global warming to 1.5°C through stringent climate policies and innovation, reaching global net zero CO_2 emissions around 2050. Jurisdictions such as the US, EU, UK, Canada, Australia and Japan reach net zero for all GHGs by this point Physical risks are relatively low but transition risks are high.
NGFS	Below 2°C	Orderly	Until 2100	1.6°C	Immediate and smooth	Moderate change	Medium - high use	Low variation	Below 2°C gradually increases the stringency of climate policies, giving a 67% chance of limiting global warming to below 2°C. The scenario assumes that climate policies are introduced immediately and become gradually more stringent though not as high as in the net zero 2050 scenario. Physical and transition risks are both relatively low.
NGFS	Delayed transition	Disorderly	Until 2100	1.6°C	Delayed	Slow/ Fast change	Low - medium use	High variation	Delayed transition assumes annual emissions do not decrease until 2030. Strong policies are needed to limit warming to below 2°C. This scenario assumes new climate policies are not introduced until 2030 and the level of action differs across countries and regions based on currently implemented policies. Higher transition and physical risks than in the net zero 2050 and below 2°C scenarios.
NGFS	Fragmented world	Too-little too-late	Until 2100	2.3°C	Delayed and fragmented	First slow, then fragmented	Low - medium use	High variation	The Fragmented world scenario assumes delayed and divergent climate policy ambition globally, leading to high transition risks in some countries and high physical risks everywhere due to the overall ineffectiveness of the transition. Countries without zero targets follow current policies, while others reach them partially.
NGFS	Current policies	Hot house world	Until 2100	3°C	None - current policies	Slow change	Low use	Low variation	Current policies assumes that only currently implemented policies are preserved, leading to severe physical risks. Emissions grow until 2080 leading to about 3°C of warming. Irreversible changes like higher sea level rise.
ECB	Long-term orderly transition	Orderly	30 years/until 2050	1.4°C	Immediate and smooth	Fast change	Medium - high use	Medium variation	The orderly scenario assumes that climate policies are introduced early and gradually become more stringent. It is based on the NGFS net zero 2050 scenario and includes stringent climate policies and innovation, with net zero carbon emissions reached around 2050. Both physical and transition risks are relatively limited. The smooth and gradual nature of the transition ensures that the costs resulting from the energy transition are minimized, while restricting global warming to only 1.5°C helps mitigate physical risks.
ECB	Long-term disorderly transition	Disorderly	30 years/until 2050	below 2°C	Delayed	Slow/ Fast change	Low medium use	High variation	The disorderly scenario explores higher transition risks due to delays in the implementation of policies. It is based on the NGFS delayed transition scenario, which assumes new climate policies are not introduced until 2030. Strong policy actions are needed to limit warming to below 2°C. This leads to higher transition risks than in the orderly transition scenario. Physical risks are also higher, as the delay in implementing policies leads to a greater increase in temperature and a rise in the frequency and magnitude of extreme weather events.
ECB	Hot house world	Hot house world	30 years/until 2050	3°C	None - current policies	Slow change	Low use	Low variation	The hot house world scenario assumes that no new climate policies are implemented. The scenario calibration is based on the NGFS current policies scenario. Even though European emissions decline in this scenario, global emissions grow until 2080, leading to about 3°C of warming. Transition risks are negligible. The absence of transition costs is more than offset by the adverse impact of extreme physical risks on the economy. The physical damages arising during 2050-2080 are frontloaded to 2040 and 2050 to limit the scenario horizon to 2050 while still including relevant physical risks.
ECB	Short-term disorderly transition	Disorderly	3 years/until 2024	1.7°C	Immediate	Slow/ Fast change	Low medium use	High variation	The short-term disorderly transition risk scenario assesses institutions' short-term vulnerabilities triggered by a sharp, abrupt increase in the price of carbon emissions. The calibration of the scenario is based on the NGFS delayed transition scenario. To focus on a short-term horizon, the carbon price increase is frontloaded to 2022, 2023 and 2024.
ECB	Drought and heat risk scenario	n.a.	1 year	n.a.	n.a.	n.a.	n.a.	n.a.	This scenario models the economic effects of a severe drought and heatwave, which is assumed to hit Europe. The calibration is based on NGFS estimates for labor productivity shocks due to heat stress across relevant countries until 2050. To limit the scope of the exercise, the scenario only models the shocks to sectoral gross value added growth. Given the one-year time horizon, a 100% pass-through of a labor productivity shock to GDP is assumed.
ECB	Flood risk scenario	n.a.	1 year	n.a.	n.a.	n.a.	n.a.	n.a.	Severe floods are assumed to take place across Europe. Flood risk is heterogeneous across Europe and can differ significantly even within a few kilometers. Therefore, the flood risk scenario accounts for within-country variation in risks. A flood risk map at the NUTS3 level is constructed.