



D4.1 -Report on FIEs' Path for Accelerating Resilience Finance

Pricing Resilience: Adaptation Adjustment and Sector Vulnerability in Corporate Credit Risk





CLIMATEFIT

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Introduction

Climate adaptation has moved from the margins of European climate policy to its centre, but the financial system has not moved with it. While mitigation finance benefits from mature markets, established taxonomies and a decade of methodological development, adaptation remains poorly served by the instruments and analytical frameworks that financial institutions use to allocate capital. The reasons are technical: adaptation-relevant risks are difficult to locate in a borrower's balance sheet, difficult to price over the tenor of a typical loan, and largely invisible to the credit scoring models on which lending and investing decisions still rest.

This report starts from that diagnosis and proposes a response. It sets out the **Adaptation-Adjusted Credit Risk (AACR) methodology**, an approach that embeds physical climate risk into conventional credit assessment by adjusting a borrower's baseline risk profile for two additional factors: the hazard exposure of its assets and operations, and the vulnerability of its economic sector to the hazards in question. The intention is not to replace existing credit frameworks but to extend them, using inputs that financial institutions can realistically obtain.

Because financial institutions operate within both **ESG and prudential regulatory frameworks**, the report examines these frameworks alongside the proposed methodology. This analysis provides the basis for assessing whether AACR can support adaptation finance while remaining aligned with the legal, disclosure, risk-management and capital requirements governing financial institutions. The report then moves from regulatory expectations to risk measurement, developing a sector vulnerability framework and an adaptation-adjusted credit risk methodology designed to make adaptation visible within the risk metrics that drive lending and capital allocation decisions.

Who this report is for

The primary audience is practitioners inside financial institutions and entities (FIEs) who make or govern lending and investment decisions: credit risk officers and model owners, portfolio and sector analysts, sustainability and ESG teams working at the interface between regulatory reporting and commercial strategy, and the risk governance functions that sign off on methodological change. The report assumes familiarity with standard credit risk concepts and with the EU sustainable finance framework; it does not assume prior expertise in climate science or hazard modelling.

Three secondary audiences are addressed. Supervisors and policymakers may find in the methodology a concrete illustration of how physical risk expectations can be operationalized at portfolio level, and where current reporting requirements generate data that is fit — or unfit — for that purpose. Corporate borrowers, particularly SMEs in exposed sectors, may use the sector vulnerability framework to anticipate how their adaptation investments are likely to be read by lenders. Researchers working on climate risk methodologies will find the underlying assumptions, scoring logic and empirical basis set out in sufficient detail to be tested and contested.

Scope and boundaries

The report addresses **physical climate risk only**. Transition risk, though it interacts with the exposures discussed here, is outside its remit. Within physical risk, the analysis covers acute and chronic hazards grouped into the water-, temperature-, wind- and solid-mass-related categories aligned with the EU Taxonomy classification and applies them to credit risk specifically rather than to market, liquidity or operational risk.

Vulnerability is assessed at the level of the **economic sector**, using **NACE** (Nomenclature statistique des activités économiques dans la Communauté européennecodes) **codes** as the unit of analysis and three risk transmission channels — capital intensity, labour exposure and climate dependency — to derive a Vulnerability Intensity Sector score (VIS). This is a deliberate simplification. Sector-level vulnerability is a proxy for asset-level assessment, chosen because it can be applied across a whole portfolio with data institutions already hold. Where a lender has granular asset information, the methodology is intended to accommodate it, but it does not depend on it.

Finally, the AACR methodology is presented as a **proposal for practitioner testing, not as a validated regulatory model**. The empirical analysis in this report demonstrates the approach and its sensitivity to key parameters; it does not constitute supervisory approval, and any institutional application would require calibration to the institution's own portfolio, data and internal validation standards. The geographic frame is the European Union, and the report's regulatory references are to the EU framework.

Chapter 1: The adaptation finance gap

Climate change is already reshaping Europe's economic and financial landscape. Floods, droughts, heat waves, and rising seas are causing billions in losses each year, disrupting assets, supply chains, and public services across the continent. The urgency of the response required is clear, and so is the scale of investment needed to meet it. Yet adaptation finance remains critically underfunded, dominated by public sources, and still too peripheral to mainstream financial decision-making. However, as Europe faces this growing climate adaptation finance gap, the tools, frameworks, and appetite to close it are increasing.

This chapter sets out the scale of the challenge, the opportunity, and the necessity it represents for private finance. It diagnoses the root causes of the adaptation finance gap and points to solutions. The chapter also examines the physical and financial risks that support the case for adaptation investment, documents the current state of climate finance flows and the remaining gaps, and identifies the structural barriers that have held back private actors, ranging from definitional ambiguity to data scarcity. Crucially, it also argues that adaptation offers real and measurable financial returns, that the perception of it as inherently unfinanceable is increasingly being challenged, and that the regulatory and market infrastructure needed to mobilise private capital is actively being built.

Cities and subnational governments are central to this opportunity. They bear a disproportionate share of climate risk while facing real constraints on accessing finance, but innovative financing models and projects like ClimateFit are demonstrating that these barriers can be overcome, and that cities can become credible, bankable partners for private investment in climate resilience.

1.1 Why is adaptation important?

Europe is experiencing climate change impacts at an accelerated rate, highlighting the urgent need for adaptation alongside mitigation, as global and regional temperatures surpass key thresholds despite international efforts. While States have committed to limit global warming to 1.5˚C as compared to pre-industrial levels under the Paris Agreement, a binding international treaty signed in 2015, global mean temperatures in 2024 exceeded preund d-industrial levels by 1.54±0.13˚C. In Europe, the evidence is even more damning, as average temperatures were measured at around 2.2˚C higher than pre-industrial levels. Indeed, the evidence shows that Europe is warming faster than other continents and that temperature rises in Europe are twice as high as the global average since the 1980s.[1] This does not necessarily mean that the Paris Agreement's lower 1.5˚C temperature increase limit has moved out of reach, as long-term warming has not yet surpassed the 1.5˚C mark.[2] However, climate-related extreme events are already becoming more frequent and intense,[3]

[1] Francesco Paolo Mogelli, Andrej Ceglar and Benedikt Alois Scheid, 'Why Do We Need to Strengthen Climate Adaptations? Scenarios and Financial Lines of Defense' ECB Working Paper Series No 3005, 8.

[2] 'State of the Climate 2024 Update for COP29' (World Meteorological Organization) <https://library.wmo.int/viewer/69075/download?file=State-Climate-2024-Update-COP29_en.pdf&type=pdf&navigator=1> accessed 27 June 2025.

[3] 'Climate Adaptation in the EU: Action Not Keeping up with Ambition' (2024) Special report <https://www.eca.europa.eu/ECAPublications/SR-2024-15/SR-2024-15_EN.pdf> accessed 27 June 2025.

impacting ecosystems, populations, and the economy.[4] Climate-related extreme events are likely to continue rising in frequency and severity, even if mitigation goals are met. The reason for this is the phenomenon of climate change inertia, whereby the climate system continues to change and respond at an altered rate, even though the cause of that change has ceased.[5]

Despite growing recognition of the need for climate adaptation, a persistent and widening finance gap remains a major barrier to effective implementation. As the world is approaching its safe temperature limit and climate-related events are increasing in frequency and severity, climate action, which "refers to the efforts taken to combat climate change and its impacts," has become a global priority.[6] It consists of efforts to limit global temperature rise by reducing greenhouse gas emissions (climate mitigation) and actions needed to build resilience to current and future climate impacts (climate adaptation).[7]

The international legal framework recognises that climate change adaptation is a necessity. While the Paris Agreement is better known for its mitigation goal, it also includes a 'global adaptation goal' in its text.[8] In the EU, climate adaptation has been integrated into a diverse set of legal frameworks, strategies, and action plans, including the European Climate Law, the Green Deal and its complementary EU Adaptation Strategy and Nature Restoration Law.[9] The Strategy's overarching goal is the attainment of EU-wide climate resilience by 2050, building on the upscaling of smart, systemic, and swift climate adaptation.[10] Extending beyond the legal and policy sphere, the importance of climate adaptation has also become internalised in the attitudes and perceptions of the majority of European citizens. The European Investment Bank's annual Climate survey found that 94% of people polled in Europe recognise that their country needs to adapt to climate change, and every second person identified climate adaptation as a priority.[11]

Thus, with climate change impacts intensifying and becoming more difficult to prevent, the demand for effective adaptation strategies is growing, and so are the costs. To achieve the goals set out in international and European legal frameworks and to satisfy the demand for climate adaptation expressed by populations across Europe, the necessary financial resources must be urgently allocated, ensuring that funding mechanisms align with the scale and urgency of the required climate adaptation efforts. However, funding for these initiatives continue to fall short of what is needed.

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[4] European Environment Agency., *European Climate Risk Assessment: Executive Summary.* (Publications Office 2024) <https://data.europa.eu/doi/10.2800/204249> accessed 27 February 2025.

5 'Climate Change 2001' (Intergovernmental Panel on Climate Change 2001) Synthesis report.

[6] 'Climate Action' (EUR-Lex) <https://eur-lex.europa.eu/EN/legal-content/glossary/climate-action.html> accessed 11 June 2025.

[7] ibid.

[8] The Paris Agreement (2015) Art. 7.

[9] 'Climate Adaptation Costing in a Changing World: Valuing Climate Adaptation Helps Us Orient Our Compass toward Effective and Resilient Pathways' (Economics for Disaster Prevention and Preparedness 2024) <https://civil-protection-knowledge-network.europa.eu/system/files/2024-05/EDPP2_C2%20CCA%20Cost%20report.pdf> accessed 27 June 2025.

[10] 'Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Forging a Climate-Resilient Europe - the New EU Strategy on Adaptation to Climate Change' <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0082>.

[11] 'The EIB Climate Survey: Attitude towards Climate Change Adaptation' (European Investment Bank 2024) 7th edition.

Despite its comparative wealth, Europe faces significant challenges in this regard. Overall, climate adaptation finance falls drastically behind the amount of financing mobilised for climate mitigation efforts.[12] **Adaptation finance remains significantly underdeveloped compared to mitigation.** The disparity between the funds needed to address the impacts of climate change and the funds actually available is referred to as the "**climate adaptation finance gap.**"

This gap is especially concerning, considering that mitigation itself remains significantly underfunded.[13] One of the main reasons climate adaptation lags climate mitigation in financing is the perception that adaptation investments yield limited financial benefits and uncertain returns.[14] Yet the prevailing narrative that adaptation is inherently difficult to finance can be challenged by reframing it as a strategic investment in resilience rather than a sunk cost. Building on this reframing, this report pursues two aims:

- The report makes the case for climate adaptation as both a profitable endeavour, opening new market opportunities for financial market participants, and a necessary risk-mitigation strategy against physical climate risks that are materialising faster than financial systems can adapt to them.
- **The report proposes a novel methodology to help decision-makers reorient private capital towards more sustainable and resilience-oriented investment by integrating physical climate risk in credit assessments.**

1.2. Impacts of climate-related events: people, ecosystems, economy and financial system

Europe is facing unprecedented climate challenges, with record-breaking heat, widespread flooding, and escalating droughts and wildfires causing significant social, environmental, and economic impacts. These climate events have led to substantial economic losses, exceeding EUR 44 billion in recent years, underscoring the urgent need for resilient adaptation strategies. In 2025, surface temperatures in Europe averaged 1.17˚C above the baseline, making it the third-hottest year on record for the continent, behind 2024, which saw a 1.47˚C increase, and 2023, which recorded a 1.19˚C rise.[15] The European continent also witnessed a number of severe

[12] See, for example, Baysa Naran and others, 'Global Landscape of Climate Finance 2024: Insights for COP29' (Climate Policy Initiative 2024) 1.

[13] Baysa Naran and others, 'Global Landscape of Climate Finance 2024: Insights for COP29' (Climate Policy Initiative 2024) 3.

[14] 'Climate Adaptation Investment Framework: Policy Highlights' (OECD 2024) <https://www.oecd.org/content/dam/oecd/en/publications/support-materials/2024/11/climate-adaptation-investment-framework_30362f60/CAIF%20Policy%20Highlights%20-%20Final.pdf/_jcr_content/renditions/original./CAIF%20Policy%20Highlights%20-%20Final.pdf> accessed 27 June 2025.

[15] Francesca Guglielmo, 'Global Climate Highlights 2025' (European Centre for Medium-Range Weather Forecasts 2026) 5 <https://climate.copernicus.eu/sites/default/files/custom-uploads/GCH-2025/GCH2025-full-report.pdf> accessed 28 June 2026.

storms and precipitation events throughout the year, often leading to flooding.[16] Other climate-related events that were common in 2025 included heatwaves and droughts, which created favourable conditions for the spread of wildfires in regions such as the Iberian Peninsula, Scotland, the eastern Mediterranean, and the Balkan region.[17]

Climate-related events such as the ones mentioned here frequently have ripple effects that can lead to complex impact chains that negatively affect populations, ecosystems, the economy, and the financial system. Floods, for example, pose a severe threat to populations, including by causing property damage, heightening the risk of accidental injury or death, and by exacerbating the risk of waterborne and infectious diseases and heightening the overall risk of mortality from cardiovascular disease, respiratory disease, and mental disorders.[18] Climate-related events also have economic consequences: between 1980 and 2024, weather and climate-related extreme events resulted in asset losses totalling EUR 822 billion across the European Union. Notably, more than a quarter of this figure (over EUR 208 billion) was recorded in just the four years between 2021 and 2024.[19]

One part of this is the danger posed by climate-related events to the financial sector. Climate hazards that affect infrastructures, buildings, factories, and farms can have detrimental effects on the economic activities that depend on them, causing price fluctuations and irregular inflation patterns.[20] Floods, for example, can depress real estate prices,[21] disrupt supply chains,[22] and damage valuable assets, causing significant losses for banks and investors. Recent modelling of a hypothetical 2027 flood event calibrated to historical flood depths illustrates the scale of these effects. Investment losses were found to be substantial across European economies, with cumulative declines in gross fixed capital formation ranging from around 10% to nearly 15% between 2027 and 2030, and Germany alone facing an estimated loss of roughly EUR84 billion.[23] Household disposable income was projected to fall by several percentage points over the same period, as reconstruction costs and labour-market disruptions compounded, leaving

[16] 'European State of the Climate: Extreme Events in Warmest Year on Record' (*World Meteorological Organization*, 15 April 2025) <https://wmo.int/news/media-centre/european-state-of-climate-extreme-events-warmest-year-record#:~:text=Heat%20stress%20days%20and%20tropical,across%20the%20continent%20and%20southeastern> accessed 11 June 2025.

[17] Guglielmo (n 16) 29.

[18] Jane Dee, 'Study Reveals the Human Health Costs of Exposure to Floods' (*Yale School of Public Health*, 14 December 2023) <https://ysph.yale.edu/news-article/ysph-study-reveals-the-human-health-costs-of-exposure-to-floods/> accessed 12 June 2025.

[19] 'Economic Losses from Weather- and Climate-Related Extremes in Europe' (14 October 2025) <https://www.eea.europa.eu/en/analysis/indicators/economic-losses-from-climate-related> accessed 29 June 2026.

[20] Francesco Paolo Mogelli, Andrej Ceglar and Benedikt Alois Scheid, 'Why Do We Need to Strengthen Climate Adaptations? Scenarios and Financial Lines of Defense' ECB Working Paper Series No 3005, 4.

[21] Francesco Caloia, Kees van Ginkel and David-Jan Jansen, 'Floods and Financial Stability: Sencario-Based Evidence from below Sea Level' (DeNederlandsche Bank 2023) No 796, 2.

[22] Guzmán González-Torres Fernández and Miles Parker, 'The Economic Impact of Floods' (*European Central Bank*) <https://www.ecb.europa.eu/press/economic-bulletin/focus/2025/html/ecb.ebbox202501_04~ff5de054b8.en.html> accessed 11 June 2025.

[23] 'Europe under Water: The Macroeconomic Cost of Flooding and the Economic Case for Adaptation' (Allianz 2026) 3.

households less able to absorb uninsured losses and rising insurance costs.[24] Heat stress presents a similar structural risk. Research shows that once temperatures pass roughly 30˚C, labour productivity and energy costs both deteriorate sharply with each additional degree, weighing first on corporate profitability and later on household income through slower wage growth.[25] Modelling a scenario in which countries experience their hottest years on record in succession through 2030 suggests cumulative GDP losses could reach 5 to 7% in the most exposed economies, with investment losses again outpacing consumption losses, a pattern that mirrors the flood example and further reduces future productive capacity.[26] Such findings underscore how localized physical events can generate financial exposures that extend well beyond the directly affected region or sector. Furthermore, extreme climate events can indirectly impact economic operations in a plethora of ways. For instance, extreme events might negatively affect the workforce of a company, motivating workers to move to geographic locations that face less severe climate stress.[27] This shows that private companies confront climate risks parallel to those faced by public authorities and communities, making the need for integrated adaptation solutions that leverage private sector investment alongside public efforts more pressing.

Physical and transition risks from climate change pose significant threats to the financial sector, with climate hazards impacting assets and economic activity while policy shifts drive systemic change. In the context of the financial sector, the potential harm and disruption to individuals, assets, and economic activity caused by heightened exposure to climate-related hazards, including extreme weather events like floods, droughts, wildfires, and heat stress, are referred to as 'physical risk.'[28] Physical risk is one of two risk categories faced by the financial sector, alongside 'transition risk', which describes the risks posed by the transition away from greenhouse gas-emitting activities and the sudden policy changes, legal developments, and technological innovations that accompany this shift.[29] The European Climate Risk Assessment report states that climate change poses a significant risk to the European macro-fiscal and financial system and that it presents significant hazards to Europe's sectors and regions that could trigger a systemic financial shock.[30] A financial system-wide stress test conducted by the European Central Bank as part of its Fit-for-55 climate scenario analysis projected that banks could face financial losses totalling €630 billion by 2030 under a worst-case scenario. This scenario envisions a sudden and widespread divestment from carbon-intensive ('brown') assets by investors, occurring simultaneously with severe macroeconomic shocks impacting the financial system.[31]

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[24] ibid.

[25] 'Too Hot to Grow - The Economic Costs of Extreme Heat' (Allianz 2026) 3.

[26] ibid.

[27] OECD, 'The Economic Consequences of Climate Change' <http://dx.doi.org/10.1787/9789264235410-en> 99.

[28] 'Physical vs Transition Climate Risk: What's the Difference?' (*EarthScan*, 19 June 2024) <https://www.earth-scan.com/blog/physical-vs-transition-climate-risk> accessed 12 June 2025.

[29] ibid.

[30] European Environment Agency., *European Climate Risk Assessment: Executive Summary,* 26. (Publications Office 2024) <https://data.europa.eu/doi/10.2800/204249> accessed 27 February 2025.

[31] Fit-for-55: Assessing the macroeconomic impact of the transition to a net-zero economy' (ECB Occasional Paper Series No. 2023).

1.3. The state of adaptation climate finance

Given their exposure to diverse climate-related risks, private companies have a clear financial incentive to actively engage in and support adaptation measures. Yet, the public sector is currently providing the lion's share of adaptation finance. **While estimates vary slightly, the public sector is generally understood as providing over 95% tracked adaptation finance, with the great majority of that funding being provided by development finance institutions.**[32] Generous estimates contend that roughly 3 per cent of adaptation finance comes from institutional investors and commercial banks.[33] While it is true that most adaptation costs (roughly 71%) arise in relation to activities that are usually within the financing realm of the public sector,[34] this also implies that the private sector may hold some interest in financing the remaining 29 per cent.[35] In turn, **there is an urgent necessity for creative financing methods alongside increasing public financial support.**[36]

Consequently, adaptation activities hinge on the contributions of public actors, such as the EU, States, regions, and cities, in addition to development finance institutions. In Europe, the Multiannual Financial Framework 2021-2027 pledges that 30 percent of the EU's budget will be dedicated to climate change action. However, MFF does not indicate a distinct allocation for climate adaptation within the 30% goal. This 30% target includes both mitigation and adaptation initiatives related to climate change, without clarifying the specific division between the two.[37] At present, climate mitigation tends to be prioritised in financing and the UNDRR estimates that roughly ten per cent of climate finance are currently being allocated to adaptation.[38] One encouraging development is that adaptation finance is increasing rapidly. Although global climate finance flows reached a record high of USD 2 trillion in 2024, this falls well short of what is needed. Estimates suggest that annual climate finance must reach USD 7.8 trillion between 2025 and 2030 to avert the most severe impacts of climate change, rising further to USD 9 trillion

[32] Francesco Paolo Mongelli, Andrej Ceglar and Benedikt Alois Scheid, 'Why Do We Need to Strengthen Climate Adaptations? Scenarios and Financial Lines of Defense' Working Paper Series No 3005 31 <https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp3005~35f938a452.en.pdf> accessed 24 May 2026.

[33] Matthew Cox and Luke Lightfoot, 'Climate Adaptation Finance: The Challenge for Institutional Investors and Commercial Banks' (*World Economic Forum*, 22 November 2024) <https://www.weforum.org/stories/2024/11/climate-adaptation-finance-the-challenge-for-institutional-investors-and-commercial-banks/> accessed 12 June 2025.

[34] 'Come Hell and High Water: As Fires and Floods Hit the Poor Hardest, It Is Time for the World to Step up Adaptation Actions' (UN Environment Programme 2024).

[35] 'Come Hell and High Water: As Fires and Floods Hit the Poor Hardest, It Is Time for the World to Step up Adaptation Actions' (UN Environment Programme 2024) 55.

[36] 'Come Hell and High Water: As Fires and Floods Hit the Poor Hardest, It Is Time for the World to Step up Adaptation Actions' (UN Environment Programme 2024) 16.

[37] 'Climate Mainstreaming' (*European Commission*) <https://commission.europa.eu/strategy-and-policy/eu-budget/performance-and-reporting/horizontal-priorities/green-budgeting/climate-mainstreaming_en?utm_source=chatgpt.com> accessed 27 June 2025.

[38] '100 Investments for Adaptation and Resilience: An Interactive List of Investable Activities' (*United Nations Office for Disaster Risk Reduction*) <https://www.undrr.org/financing-prevention/100-investable-activities> accessed 27 June 2025.

per year between 2031 and 2035.[39] Meeting climate adaptation needs across all sectors in the EU alone is estimated to require around €69 billion per year, amounting to a cumulative net present value of €1.2 trillion by 2050.[40]

Cities face specific challenges in view of the changing climate, as climate hazards interact with other environmental and social challenges in the urban context, including urban-specific land use, population density, social inequality, and the limited capacity of service providers.[41] For instance, heat waves can increase pressure on health systems, exacerbating pre-existing challenges in the urban context.[42] Despite the heightened need for adaptation, city and local governments face specific hurdles in accessing the finance needed to adequately address climate change on top of the general obstacles. First, cities encounter significant fiscal and institutional constraints. According to estimates of the World Bank, only 21% of the largest cities in emerging economies currently hold investment-grade ratings.[43] Additionally, more than half of all countries in the world do not authorise borrowing by local governments (including the issuance of municipal bonds) and only 16% of countries are granted taxation authority.[44] These fiscal and institutional limitations set cities apart from states (and to some extent regions) by restricting their financial independence. Given these limitations, it is imperative to design financing solutions that can effectively leverage private sector capital, as cities and local governments cannot shoulder the costs of adaptation alone. Crucially, this entails equipping cities and local governments with the tools to address the current shortage of bankable projects that are sufficiently prepared for presentation to potential investors and generating clear evidence demonstrating the financial viability and long-term sustainability of climate adaptation initiatives.[45] Most European municipalities already face a substantial pipeline of adaptation needs. The core challenge is no longer a lack of ambition or technical expertise, but the weak translation of climate plans into bankable, investable assets.

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[39] Climate Policy Initiative, Global Landscape of Climate Finance Data Dashboard (23 June 2026) https://www.climatepolicyinitiative.org/resources/data-visualizations/global-landscape-of-climate-finance-data-dashboard/ accessed 29 June 2026

[40] 'Assessment of EU and Member States Adaptation Investment Needs - Study on the Macro-Economic Impacts of the Climate Transition' (European Commission 2026) 42.

[41] Denyse Dookie and Kate Gannon, 'Why Is Climate Change Adaptation Important for Cities and How Are They Adapting?' (*London School of Economics*, 31 August 2022) <https://www.lse.ac.uk/granthaminstitute/explainers/why-is-climate-change-adaptation-important-for-cities-and-how-are-they-adapting/> accessed 27 June 2025.

[42] ibid.

[43] Priscilla Negreiros and others, 'The State of Cities Climate Finance Part 1: The Landscape of Urban Climate Finance' (Cities Climate Finance Leadership Alliance 2021) 5 <https://climatepolicyinitiative.org/wp-content/uploads/2021/06/SCCF_PART1-FINAL-1.pdf>.

[44] ibid.

[45] Priscilla Negreiros and others, 'The State of Cities Climate Finance Part 1: The Landscape of Urban Climate FInance' (Cities Climate Finance Leadership Alliance 2021) 6 <https://climatepolicyinitiative.org/wp-content/uploads/2021/06/SCCF_PART1-FINAL-1.pdf>.

1.4. Identifying the roots of the adaptation finance gap

The persistent underfunding of climate adaptation is not simply a matter of insufficient capital. It reflects a set of structural barriers that have made adaptation systematically harder to finance than mitigation. Two root causes stand out: (1) the difficulty of tracking and defining adaptation finance and (2) the gap between adaptation's broader economic value and its financial returns for private investors.

1.4.1. Defining and tracking adaptation finance

The first root cause is definitional and informational. The high degree of context dependence in climate adaptation makes adaptation finance more difficult to define and track than climate mitigation, because adaptation measures cannot be defined in the abstract.[46] Unlike mitigation finance, which targets global emissions reductions and is relatively uniform across regions, adaptation finance is inherently location-specific. It focuses on reducing localised climate risks, such as heatwaves, floods, or droughts, which differ in intensity, timing, and effects, depending on geographical and socio-economic circumstances.[47] Whether an investment counts as adaptation finance cannot be determined in the abstract. It depends on whether an investment responds to a concrete local adaptation need arising from a clearly identified climate vulnerability in a specific location, and whether the adaptation measure addresses the vulnerability in a way that reduces that long-term risk. As a result of this, an intervention such as the construction or climate-proofing of infrastructure can be considered an adaptation measure in one place but not in another where the underlying climate risk is absent. This sets adaptation financing apart from climate mitigation financing, which has an exclusive focus on the reduction of greenhouse gas emissions that remains unaffected by geographical context.[48]

The European Union has been actively working to streamline climate-related reporting, including private adaptation finance, through an evolving regulatory framework aimed at enhancing transparency across the financial and non-financial sectors. However, the recently adopted Omnibus I Package, which was adopted with the goal of simplifying corporate sustainability reporting, has significantly narrowed the scope of the Corporate Sustainability Reporting Directive, one of the key pillars of the EU's Sustainable Finance Disclosure Framework, by raising its applicability threshold to companies with more than 1000 employees and above 450 million euros in annual net turnover. The package additionally provides deadline extensions for first-time reporting obligations for certain categories of companies.[49] Given these

[46] Gaia Larsen, Carter Brandon and Natalia Alayza, 'Adaptation Finance: 10 Key Questions, Answered' (*World Resources Institute*, 19 May 2025) <https://www.wri.org/insights/adaptation-finance-explained>.

[47] ibid.

[48] Jake Connolly and others, 'Tracking and Mobilizing Private Sector Climate Adaptation Finance' (*Climate Policy Initiative*, 25 September 2024) <https://www.climatepolicyinitiative.org/publication/tracking-and-mobilizing-private-sector-climate-adaptation-finance/> accessed 27 June 2025, 8.

[49] Council of the European Union, 'Simplification: Council gives final green light on the 'Stop-the-clock' mechanism to boost EU competitiveness and provide legal certainty to businesses (14 April 2025) https://www.consilium.europa.eu/en/press/press-releases/2025/04/14/simplification-council-gives-final-green-light-on-the-stop-the-clock-mechanism-to-boost-eu-competitiveness-and-provide-legal-certainty-to-businesses/ accessed 29 June 2026.

recent setbacks, it is unlikely that an ideal system for adaptation finance reporting will come into existence anytime soon. Considering this reality, it is even more vital for financial institutions, investors, and other stakeholders in the climate finance field, to make use of the existing regulatory framework and voluntary tools that will remain in place despite the watering down of the Sustainable Finance Disclosure Framework as a whole.

Tracking and defining private-sector adaptation finance remain challenging due to the absence of centralised disclosure practices. Unlike public investments, private investments often enhance resilience without clearly identifying or articulating their links to specific climate vulnerabilities. This lack of explicit linkage makes it especially difficult to classify, quantify, and compare adaptation finance across contexts. A report by the Climate Policy Initiative notes that private companies investing in adaptation often do so without a direct focus on climate issues, instead pursuing activities aimed at generating revenue, such as reducing water costs, minimising crop damage from high temperatures, and alleviating disaster-related losses.[50] This situation differs starkly from the public sector's adaptation funding tracking methodology, which includes that the project's context of climate change vulnerability is set out and that an intent to address this vulnerability within the project is explicitly declared.[51] This lack of visibility not only complicates accurate measurements of adaptation finance but also reduces the likelihood of guiding capital towards effective adaptation outcomes. Investors or companies might lack the tools to benchmark and assess their performance in the absence of recognised reporting channels. This, in turn, can translate to a lack in incentives for the identification for adaptation funding when investors or companies do offer it,[52] meaning that estimates of the private sector's investment in adaptation are likely to be significantly lower than the actual amount.[53] Recently, the UN Environment Programme launched its Adaptation Finance Taxonomy, aimed at streamlining and simplifying the identification and assessment of adaptation finance opportunities across countries.[54] Nevertheless, the lack of established frameworks for reporting investment in adaptation solutions represents a significant governance gap. This stands in stark contrast to the relatively mature reporting landscape for climate mitigation, where tools such as the Carbon Disclosure Project (CDP) and the Global Real Estate Sustainability Benchmark (GRESB) are already well established.[55]

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[50] Jake Connolly and others, 'Tracking and Mobilizing Private Sector Climate Adaptation Finance' (*Climate Policy Initiative*, 25 September 2024) 8 <https://www.climatepolicyinitiative.org/publication/tracking-and-mobilizing-private-sector-climate-adaptation-finance/> accessed 27 June 2025.

[51] Morgan Richmond and others, 'A Snapshot of Global Adaptation Investment and Tracking Methods' (Climate Policy Initiative 2020) 4 <https://climatepolicyinitiative.org/wp-content/uploads/2020/04/A-Snapshot-of-Global-Adaptation-Investment-and-Tracking-Methods-April-2020.pdf> accessed 27 June 2025.

[52] Jake Connolly and others, 'Tracking and Mobilizing Private Sector Climate Adaptation Finance' (*Climate Policy Initiative*, 25 September 2024) 8 <https://www.climatepolicyinitiative.org/publication/tracking-and-mobilizing-private-sector-climate-adaptation-finance/> accessed 27 June 2025.

[53] ibid.

[54] 'Adaptation Finance Taxonomy Playbook' (UN Environment Programme Finance Initiative 2026) <https://www.unepfi.org/themes/climate-change/adaptation-finance-taxonomy-playbook/> accessed 29 June 2026.

[55] Jake Connolly and others, 'Tracking and Mobilizing Private Sector Climate Adaptation Finance' (*Climate Policy Initiative*, 25 September 2024) 2 <https://www.climatepolicyinitiative.org/publication/tracking-and-mobilizing-private-sector-climate-adaptation-finance/> accessed 27 June 2025.

The lack of consistent, high-quality data on private adaptation finance not only hampers effective capital allocation but also reinforces misconceptions about the commercial viability of adaptation, underscoring the urgent need for robust and standardised reporting frameworks.[56] Closing this governance gap will require the creation of clear methodologies and reporting standards that reflect the distinct nature of adaptation finance, particularly its dependence on local conditions, extended timeframes, and often indirect financial returns. While initial steps have been taken, such as the inclusion of physical risk and adaptation considerations by the Task Force on Climate-related Financial Disclosures (TCFD) – whose recommendations have now been fully incorporated into the ISSB Standards (IFRS S1 and S2) – and the development of reporting requirements in the EU through the EU's Corporate Sustainability Reporting Directive, Sustainable Finance Disclosure Regulation, and the EU Taxonomy, these efforts remain insufficient. Broader institutional engagement and greater consistency across frameworks will be essential to mainstream adaptation within financial reporting practices.

1.4.2. Economic vs. financial viability of adaptation measures

The economic benefits of adaptation are potentially high. Early adaptation investments usually deliver an economic benefit-cost ratio between 2:1 and 10:1.[57] The main dividends of adaptation investments are avoided damages, economic gains, and socio-environmental benefits.[58] This may include, for example, the avoided economic losses from future extreme climate events, enhanced stability of agricultural systems, or the preservation of ecosystem services that are vital or beneficial to human health.[59] These returns are shared across stakeholders, accrue over long time horizons, and are difficult to monetise directly through user tariffs. As a result, **adaptation resembles a public good in that it is economically essential.**

As the UNEP Adaptation Gap Report points out, however, **there is a crucial difference between the economic and financial viability of adaptation projects.** Private returns on investment may be lower because adaptation does not always lead to positive cash flows or revenue.[60] Private companies, therefore, have more to gain from investments in adaptation where these directly align with their self-interest, for example, to safeguard their assets or supply chains. They may, for instance, wish to protect their assets against physical risks arising as a result of climate

[56] ibid.

[57] Paul Watkiss, 'The Costs of Adaptation, and the Economic Costs and Benefits of Adaptation in the UK' (2022) Policy Paper <https://www.theccc.org.uk/wp-content/uploads/2023/01/The-Costs-of-Adaptation-and-the-Economic-Costs-and-Benefits-of-Adaptation-in-the-UK-Paul-Watkiss.pdf?utm_source=chatgpt.com> accessed 27 June 2025. See also 'The Business Case for Climate Adaptation: Why It's a Profitable Investment' (21 June 2024) <https://www.goldstandard.org/news/the-business-case-for-climate-adaptation-why-its-a-profitable-investment?utm_source=chatgpt.com> accessed 27 June 2025.

[58] Mogelli, Ceglar and Scheid (n 1).

[59] Carter Brandon and others, 'The Compelling Investment Case for Climate Adaptation' (*World Resources Institute*, 3 June 2025) <https://www.wri.org/insights/climate-adaptation-investment-case> accessed 27 June 2025.

[60] 'Come Hell and High Water: As Fires and Floods Hit the Poor Hardest, It Is Time for the World to Step up Adaptation Actions' (UN Environment Programme 2024) 55.

change such as extreme weather events or resource scarcity.[61] In other words, private companies hold an interest in making themselves more resilient to climate shocks and will invest in adaptation where it enhances their chances of continuing their position in the market.[62]

From an investor perspective, maintaining the status quo carries a hidden but growing cost: physical climate risk is inherently damaging, eroding net operating income, increasing maintenance capex, shortening asset lives, and weakening counterparty credit quality. This logic extends to investors with exposure to infrastructure, real assets, municipal debt, utilities, and long-duration portfolios, for whom adaptation is no longer an optional form of risk mitigation but a structural requirement for value preservation. Yet many investors still approach adaptation opportunistically, waiting for fully standardised, de-risked products to emerge.

Financing climate adaptation is challenging due to high scientific uncertainty, long payback periods, and upfront costs that differ significantly from those of mitigation investments. One of the difficulties in conceptualising business models for adaptation stems from the fact that adaptation occurs in a context of higher scientific uncertainty than mitigation. One of the challenges of financing adaptation therefore lies in evaluating trade-offs between the investments made and the residual risks that remain, even after the implementation of adaptation measures.[63] Returns on investments tend to be uncertain whereas the cost of planning and implementing adaptation measures are usually more immediate, making it necessary that both the costs and benefits of adaptation are assessed.[64] This can prove difficult given that the concept of adaptation is not clearly delineated and that assessments of adaptation risks are subject to significant uncertainty about actual climate change.[65]

Integrating non-traditional variables, such as hazard and risk associated with climate events, into the decision-making process of financial and investment entities (FIEs) represents a complex challenge both analytically and culturally. In contrast to conventional financial variables, such as interest rates, volatility, and market cycles, climate risks are often characterized by scientific uncertainty, non-linear probability distributions, localized impacts, and long-time horizons, which make it difficult to translate them into robust, easily interpretable quantitative models for market participants. Moreover, climate information tends to come from diverse sources (meteorological, geological, insurance, ESG data) and usually requires translation into a financial language, creating a gap between climate experts and risk or credit

[61] Nora M C Pankratz and Christoph M Schiller, Climate Change and Adaptation in Global Supply-Chain Networks (2024) 37(6) The Review of Financial Studies, 1729.

[62] 'Private Investment for Climate Change Adaptation – Difficult to Finance or Difficult to See the Finance?' (*LSE Granthan Research Institute on Climate Change and the Environment*, 16 March 2023).

[63] Mogelli, Ceglar and Scheid (n 1) 16.

[64] 'Come Hell and High Water: As Fires and Floods Hit the Poor Hardest, It Is Time for the World to Step up Adaptation Actions' (n 35) 55.

[65] W. P Pauw, Not a panacea: private-sector engagement in adaptation and adaptation finance in developing countries, 583

decision makers.[66] From an organizational perspective, this puts significant pressure on data governance and reporting cycles, forcing companies and financial intermediaries to reconsider their metrics, timeframes, and investment priorities in a way that aligns with the multi-decadal view of climate risks, which is not always compatible with the short-term logic typical of traditional financial decisions. This methodological and cultural complexity also helps explain why climate finance, and in particular investments in climate adaptation, remain well below estimated needs and why scalable, replicable investment strategies have been slow to emerge.

1.5. Setting the Scene: Public Leadership, Private Participation

The majority of adaptation interventions today require public intervention. The benefits of adaptation projects are diffuse among multiple beneficiaries and stakeholders, they rarely generate direct revenue streams (and therefore lack a private market), and they frequently involve land ownership questions and other matters that fall squarely within the remit of public authorities. Adaptation, in other words, still behaves largely as a public good. It follows that Public Administrations, which currently hold the deepest experience in understanding investment needs, risk and the consequences of physical climate risk, must own and sponsor these projects.

This places a substantial burden on Public Administrations. **Although adaptation can be characterised as a public good, which should be owned by Public Administrations, the public sector cannot fund it alone.** Mobilising private capital requires applying greater quantitative and qualitative resources to the origination and execution of adaptation projects, and it requires developing, funding and proposing risk-sharing mechanisms capable of incentivizing private participation in publicly sponsored initiatives. In parallel, incentives and concessional financing should be instituted to directly support private-sector investment, particularly to accelerate the implementation of adaptation measures already within the control and influence of private actors. The EU adaptation strategy reflects precisely this dual logic, combining regulatory push with financial pull: regulation creates the conditions and the obligation to adapt, while grants, subsidies and investment mechanisms help mobilize public and private capital for resilience-building projects.

CLIMATEFIT has worked on both the public and the private sides of this equation. On the public side, the project has developed a set of instruments to support Public Administrations in taking a strategic and practical approach to opportunity development, including the Investment Strategy and Investment Plan methodology, the Incentive Mechanism selection tool and the Investment Concept Handbook.[67] Much still needs to change within Public Administrations themselves, as the required paradigm shift is considerable. To measure progress, CLIMATEFIT has also developed an Investment Concept Review Process, designed to help Public Administrations assess the maturity of their Investment Concepts and identify the corrective actions needed to make Lead Territory flagship projects more attractive to private finance.

[66] See, for example, OECD Net Zero+, Scaling up finance and investment for climate change adaptation (2025 Policy Papers No. 7) p. 10, available at < https://www.oecd.org/content/dam/oecd/en/publications/reports/2025/02/scaling-up-finance-and-investment-for-climate-change-adaptation_0bcbbdbf/b8d425a2-en.pdf>.

[67] Available at 'Financing Adaptation to Climate Change' (*CLIMATEFIT*) <https://climatefit-heu.eu/> accessed 13 September 2026.

These tools, together with the incentive mechanisms presented in D3.2, are essentially product-based solutions, aimed at improving the attractiveness and bankability of specific adaptation investments; this paper complements them by adopting a risk management perspective.

This paper turns to the private side of the financing equation. It frames adaptation not only as a public responsibility but as a risk management solution in its own right, and it contributes a tool intended to help decision-makers reorient private capital towards more sustainable and resilience-oriented investments. The expectation is that the feedback loop between CLIMATEFIT technical experts and private stakeholders, including financial institutions and investors, engaged through the Local Task Forces on climate adaptation ignite a virtuous discussion, one capable of bringing key adaptation projects to the point where public and private co-financing becomes realistic.

1.6. The CLIMATEFIT approach and the contribution of this paper

As discussed at length in this chapter, Europe faces a persistent and widening gap between the financing required to adapt to the physical impacts of climate change and the capital currently being deployed. Rather than merely a matter of insufficient funding, this gap reflects deeper structural and cultural challenges in how climate adaptation is identified, valued, and integrated into financial decision-making. Qualitative interviews with representatives of FIEs in ClimateFit's network, conducted as a baselining exercise for this report, showed that sustainability by FIEs is largely driven by the need to comply with regulations and expectations set by banks' supervisory authorities, rather than by proactive efforts to anticipate climate risks. The interviews also showed that FIEs are more motivated to invest in adaptation when their own portfolios are at risk. As a result, offensive (i.e. opportunity-driven) strategies in adaptation finance are beginning to emerge in some sectors, such as water infrastructure, real estate, agriculture, and leisure. However, these strategies remain few and far between. Their scarcity is also reflected by the marginal contribution of adaptation-related exposures to banks' overall Green Asset Ratios in the sample of European banks surveyed.[68] Closing the adaptation finance gap will require an accelerated mobilisation of FIEs, which must increasingly view adaptation as a means of mitigating their exposure to physical risk and as a genuine business opportunity. It is with this ambition that ClimateFit seeks to contribute new analytical tools and risk assessment approaches that allow FIEs to internalise adaptation considerations within their credit risk and investment frameworks.

In this report, ClimateFit presents its **Adaptation-Adjusted Credit Risk (AACR) methodology,** which translates this ambition into a concrete proposal to embed physical climate risk in credit risk assessment and investment decision-making. Moving beyond the limitations of traditional credit scoring in capturing climate-related physical risks the methodology builds on the concepts of 'economic sector vulnerability' and 'risk transmission channels' to derive an adaptation-adjusted credit risk, defined through an empirical analysis.

[68] See Appendix 1 – Green Asset Ratios.

The economic-sector vulnerability framework is operationalized via the sector vulnerability matrix, an analytical tool that correlates NACE sector codes against categorized climate hazards and determines the Vulnerability Intensity Sector score (VIS) by assessing vulnerability through three risk transmission channels: capital intensity, labour exposure, and climate dependency. The vulnerability score is determined for each climate-hazard area (water, temperatures, wind, and solid-mass-related) aligned with the EU Taxonomy definitions and classification framework.

The proposed AACR methodology modifies the baseline traditional credit assessment by incorporating two additional factors, namely hazard exposure and asset vulnerability. Hazard exposure refers to the likelihood and intensity of climate events (such as floods, droughts, landslides) that a borrower's assets or operations may face. Asset vulnerability captures how severely those events would impact the borrower's assets, based on the economic sector's sensitivity to the specific hazard.

As FIEs come to treat adaptation as an opportunity rather than solely a risk to be contained, public administrations become a natural counterparty by owning or overseeing much of the infrastructure through which adaptation is delivered, from water networks and flood defences to transport and public buildings. The methodology helps public bodies understand how lenders will assess these projects, and so structure and present pipelines that attract private capital rather than relying on public budgets alone.

Chapter 2: Literature Review

2.1 Introduction

Climate change generates financial risk through two distinct but interconnected channels: transition risk, arising from policy, technological and market shifts associated with the move toward a low-carbon economy, and physical risk, stemming from acute extreme weather events and chronic changes in climate patterns. While transition risk has attracted considerable attention in both the credit risk literature and regulatory frameworks, physical risk remains comparatively underexplored: a recent review of the literature on integrating climate risk into banks' credit risk assessment found that existing studies focus predominantly on transition risk, with none of the reviewed papers integrating both physical and transition risk within a single model. This imbalance is particularly pronounced for non-financial corporations, where credit assessment frameworks have yet to systematically incorporate physical climate risk as a distinct risk driver.

The absence of a consolidated analytical approach for integrating physical risk and sector climate vulnerability into credit scoring deters financial institutions from understanding adaptation risk and identifying adaptation investment opportunities. Adaptation considerations have been made primarily for sovereign ratings and scoring,[69] where climate vulnerability indices are increasingly incorporated into country credit assessments. In contrast, non-financial corporate ratings still lack proper integration of physical risks, leading to systematic underestimation of adaptation risk.

2.2 Literature Review Questions

This review addresses two questions:

(1) How are climate physical risks currently integrated (or not) into corporate credit scoring methodologies?

(2) What analytical tools and methodologies are needed to develop adaptation-adjusted credit scoring for non-financial corporations?

To provide an insight into these questions, the literature review is divided into three sections. Section one provides a taxonomy of the different types of 'physical climate risk' and their transmission channels and collates empirical evidence of physical risk materiality. Section two outlines the current state of physical risk integration in corporate credit scoring, identifying methodological gaps in physical risk assessment. Section 3 draws on prior literature to explain why adaptation-adjusted credit scoring is necessary.

[69] Serhan Cevik and João Tovar Jalles, 'Feeling the Heat: Climate Shocks and Credit Ratings' (2020) 20 IMF Working Papers <https://doi.org/10.5089/9781513564548.001> accessed 5 September 2025.

2.3 Physical Climate Risk: conceptualization and materiality

Physical climate risks correspond to potential economic and financial losses caused by climate-related hazards. In financial disclosure and banking regulation, as illustrated in Chapters 3 and 4 (i.e. EU Taxonomy, EBA Guidelines for Pillar3, ECB Guide on integrating climate risks), these hazards are categorized into acute and chronic risks.

- **Acute risks**: Extreme weather events (floods, storms, hurricanes, wildfires) that cause direct damage to assets and operational disruptions;
- **Chronic risks**: Progressive shifts in climate patterns (temperature increases, sea-level rise, water scarcity) that erode asset values and reduce production capacity over time.

The acute/chronic distinction of physical risk comes from financial regulation, not from climate science. Their purpose is to help institutions assess and disclose financial exposure. The IPCC uses no such labels, although its reports supply the science behind them. AR5 (2014) left the distinction implicit in its definition of a hazard as a physical "event" or "trend," and framed risk mainly around physical impacts. AR6 (2021–2022) made it more systematic through Climatic Impact-Drivers, which describes both changes in averages and extremes.

These risks affect corporate creditworthiness through four primary transmission channels[70]: cash-flow erosion, asset value depletion, collateral depreciation, and supply chain disruptions. The table below outlines the key transmission channels through which climate risks translate into credit risk, along with their corresponding impact on credit metrics.

Table 1: Transmission channels and impacts on credit metrics

Transmission Channel	Impact on Credit metrics
Cash flow erosion	Reduced revenue from decreased production capacity, lower sales, increased operating and capital costs
Asset value depletion	Direct damages to properties and factories, write-offs of assets in high-risk locations
Collateral depreciation	Reduced recovery rates (higher LGD) due to damaged collateral
Supply chain disruptions	Indirect impacts from supplier or customer disruptions, increasing operational volatility

2.3.1 Empirical Evidence of Physical Risk Materiality

Empirical research demonstrates that climate vulnerability significantly affects credit ratings at the firm level. A cross-country study of 4,427 firms across 60 countries found that firms in countries more susceptible to climate change receive lower credit ratings. The exposure variable here is measured at country level, so what the study establishes is that firms domiciled in more climate-vulnerable countries are rated lower, not that firms whose own assets stand in hazard-exposed

[70] These structural determinants describe where the damage surfaces in a borrower's accounts — in cash flow, in asset values, in collateral, in supply relationships should not be confused with the transmission channels set out in Chapter 5.

locations are. Evidence at the resolution credit assessment requires is largely absent, and supplying a route to it is the concern of this paper. The negative relationship between climate vulnerability and ratings persists across different model specifications and is economically significant.[71] Despite this evidence, according to the rating agency S&P Global, physical climate risks have influenced only a small percentage (typically less than 1%) of rating actions across all rated entities since April 1, 2020, when rating agencies began tracking rating actions underpinned by ESG factors. This discrepancy between empirical materiality and observed rating actions suggests systematic underestimation of physical risks in current credit assessment practices.[72]

2.3.2 Causal evidence at loan level

A small but growing body of work establishes the effect of physical hazards on credit outcomes at a resolution that country-level studies cannot reach. Albertazzi, Djekic and Ponte Marques (2025)[73] combine high-resolution Copernicus flood extent maps with loan-level AnaCredit data, exploiting four major European floods between 2021 and 2024 in a spatial regression discontinuity design that compares firms located just inside the flood boundary with those just outside it (within 300 to 500 metres). They find lending rises by roughly 3.5 to 5% immediately after a flood, driven by liquidity demand, followed by a contraction of similar magnitude in the subsequent quarter, and conclude that physical risk materially affects credit quality through higher default risk even where aggregate lending volumes remain broadly stable. Related work reaches consistent conclusions from different angles: Barbaglia, Fatica and Rho (2023)[74] on flood exposure and small business lending, de Carolis and Peters (2025)[75] on the corporate finance response of European SMEs to floods, and Fontana et al. (2025)[76] on whether physical risk is priced into residential mortgage rates.

Two features of this literature bear on the approach taken here. First, identification rests on geography rather than on the attribution of a default to a climate cause. Second, borrower location is taken from the registered headquarters address, an assumption the authors acknowledge introduces measurement error for firms operating from more than one site.

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[71] Harvey Nguyen and others, 'Climate Change and Corporate Credit Worthiness: International Evidence'. https://doi.org/10.1016/j.gfj.2024.101073

[72] 'The Credit Materiality Of Physical Climate Risks Is Uneven Across Asset Classes' (S&P Global 2025) <https://www.spglobal.com/ratings/en/regulatory/article/sustainability-insights-the-credit-materiality-of-physical-climate-risks-is-uneven-across-asset-classes-s101647110> accessed 4 July 2026.

[73] Albertazzi, Ugo and Djekic, Davor and Ponte Marques, Aurea, Physical climate risk, credit risk and lending activity (May, 2026). ECB Working Paper No. 2026/3224, Available at SSRN: https://ssrn.com/abstract=6728538 or http://dx.doi.org/10.2139/ssrn.6728538

[74] Barbaglia, Luca & Fatica, Serena & Rho, Caterina, 2023. "Flooded credit markets: physical climate risk and small business lending," JRC Working Papers in Economics and Finance 2023-14, Joint Research Centre, European Commission.

[75] De Carolis, Flavio and Peters, Vinzenz, European SMEs, Corporate Finance and Economic Resilience to Floods (March 25, 2025). De Nederlandsche Bank Working Paper No. 832, Available at SSRN: https://ssrn.com/abstract=5194531 or http://dx.doi.org/10.2139/ssrn.5194531

[76] Fontana, Adele and Jarmulska, Barbara and Schwarz, Claudia and Scheid, Benedikt Alois and Scheins, Christopher, From Flood to Fire: Is Physical Climate Risk Taken into Account in Banks' Residential Mortgage Rates? (March, 2025). ECB Working Paper No. 2025/3036, Available at SSRN: https://ssrn.com/abstract=5176497 or http://dx.doi.org/10.2139/ssrn.5176497

2.4. Current State of Physical Risk Integration in Corporate Credit Scoring

2.4.1 Predominance of Transition Risk Assessment

Research reveals that credit rating agencies (CRAs) and banks have prioritized transition risk assessment over physical risk quantification:

- **Carbon footprint focus:** The dominant ESG metric in credit assessment remains carbon emissions (Scope 1–2), which captures transition risk but ignores physical risk exposure and adaptive capacity.[77]
- **Sector-level exclusion lists:** Many banks use exclusion lists for carbon-intensive sectors (e.g., coal, oil & gas) without considering firm-level physical risk exposure or adaptation investments.[78]
- **Transition plan quality:** Companies' decarbonization goals and progress are increasingly assessed, but adaptation plans and resilience investments remain rarely evaluated.[79]

Nordic banks report strong consensus that transition risks are "even more important to include in risk models" than physical risks, as they determine whether a business remains viable after 10 years. This prioritization reflects a regulatory focus on net-zero commitments and transition planning, while physical risk assessment remains underdeveloped.[80]

2.4.2 Methodological Gaps in Physical Risk Assessment

Traditional credit risk assessment relies on historical financial data, deterministic models, and relatively short time horizons (typically 1–3 years). Key metrics include probability of default (PD), loss given default (LGD), and exposure at default (EAD), which are calibrated on past data. Key methodological limitations impeding effective integration of physical risks into corporate credit scoring include the use of backwards-looking data in model calibration, a short-term time horizon, a lack of adaptation metrics and asset-specific granularity data[81].

The Network for Greening the Financial System (NGFS) highlights that "climate- or environmental-related criteria are not yet sufficiently accounted for in internal credit assessments or in credit agencies' models". This underestimation exposes creditors to potentially large losses and can result in systemic financial instability.[82]

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[77] Pierre Monnin, 'Integrating Climate Risks into Credit Risk Assessment - Current Methodologies and the Case of Central Banks Corporate Bond Purchases' (Council on Economic Policies 2018) <https://www.cepweb.org/wp-content/uploads/2019/02/CEP-DN-Integrating-climate-risks-into-credit-risk-analysis.pdf> accessed 4 July 2026.

[78] Jesko Schulte and others, 'Credit Risk Assessment From a Strategic Sustainability Perspective: The Case of the Nordic Banking Sector' (2025) 34 Business Strategy and the Environment 6457 <https://doi.org/10.1002/bse.4310>.

[79] ibid.

[80] ibid.

81 BIS Working Paper n. 1274 di Pozdyshev, Lobanov e Ilinsky (luglio 2025), "Incorporating physical climate risks into banks' credit risk models"

[82] Network for Greening the Financial System (NGFS) (2018). *First Progress Report*. NGFS, October 2018.

2.5 The Case for Adaptation-Adjusted Credit Assessment

2.5.1 The Resilience-Adjusted Credit Risk (RACR) Framework

A recent report by the University of Cambridge Institute for Sustainability Leadership (CISL) introduces the Resilience-Adjusted Credit Risk (RACR) framework, a forward-looking approach that integrates physical risk exposure, insurance adequacy, and resilience measures into core credit metrics.[83]

2.5.2 Six Compounding Barriers to Physical Risk Integration

Building on this framework, the CISL report also identifies six self-reinforcing barriers that explain why physical risk assessment remains underdeveloped:

Table 2: Barriers to physical risk integration

Barrier	Description	Impact
Regime gaps	Prudential frameworks lack explicit requirements for physical risk integration	No regulatory mandate for banks to act
Revenue paradox	A&R investment benefits are not captured in bank revenue models	No economic incentive for relationship managers
Low observed bad debts	Climate-related bad debts rarely identified separately, understating forward-looking risk	Invisible losses suppress urgency
Attribution failures	Climate losses obscured within standard risk categories (e.g., "default due to market conditions")	Cannot link losses to climate causes
Horizon mismatch	Credit tenors (1–5 years) vs. physical risk materialization (15–30 years)	Risks materialize after loan maturity
Insurance blind spot	Coverage withdraws from high-risk markets, but credit models assume static insurance	LGD underestimation as insurance gaps widen

The framework proposes that credit metrics be adjusted for three components: the borrower's exposure to physical risks, the adequacy of its insurance cover, and the adaptive capacity. The approach developed here shares the first component and departs on the other two. Insurance adequacy is not modelled: coverage data are not systematically available across a lending portfolio, and where they are, the terms on which cover will be renewed in a repricing market are not observable at all.

2.5.3 Evidence from the CLIMATEFIT baselining exercise

The barriers identified above are directly corroborated by the baselining activity conducted by CLIMATEFIT with the group of banks collaborating on the project. This activity comprised interviews with 12 FIEs across 5 jurisdictions (Italy, Romania, Slovenia, and France), conducted between May 2025 and February 2026.

[83] Annisa Sekaringtias, Gwyn Rhodes and Nina Seega, 'Resilience-Adjusted Credit Risk: Operationalising Climate Adaptation in Financial Decision-Making' (University of Cambridge Institute for Sustainability Leadership 2026) <https://www.cisl.cam.ac.uk/sites/default/files/cisl009_credt_risk_aw.pdf>.

The interviews were semi-structured and based on questionnaires comprising 27 questions for FIEs in France (developed by IDF) and 12 questions for FIEs in other jurisdictions.

A consistent finding across participating institutions is that climate-related bad debts have to date remained low, with no significant loan losses directly attributed to physical climate risk. Taken at face value, this would suggest that physical risk is not yet material to credit portfolios in practice. That reading does not survive examination, and at least three alternative explanations are consistent with the same observation. Losses may be occurring but being absorbed elsewhere — through insurance recoveries, public compensation schemes or emergency support measures (moratoria) so that they never reach the lender as credit deterioration. They may be occurring and reaching the lender but being recorded under conventional risk categories. For example, a borrower whose margins are compressed by drought is classified as suffering adverse market conditions, and the climate origin disappears from the record. Or hazards may simply not yet have crossed the thresholds at which prevalent default is triggered, in which case the absence of losses reflects a stage in a trajectory rather than a stable state.

The three explanations carry different implications, but none support treating the observed figure as a measure of underlying exposure. What the finding establishes is not immunity but invisibility where the physical climate risk is not currently distinguishable within the loss data that banks hold, which is precisely the condition the attribution barrier describes. It follows that the absence of realized climate-attributed defaults cannot serve as a basis for calibrating physical risk models. This is an empirical constraint that shapes the methodological approach adopted in this paper, and one to which Chapter 6 returns.

The barriers are, in this sense, self-reinforcing. Invisible losses suppress urgency; suppressed urgency suppresses investment in measurement; and the absence of measurement perpetuates the invisibility of the losses.

2.5.4 Analytical Tools Needed

Effective risk measurement depends on a rigorous understanding of the dimensions of exposure and vulnerability, and on a proper assessment of how those dimensions change over time. The IPCC does not treat physical risk as a standalone core term, describing it instead as closely related to the risks arising from climate change impacts and climate-related hazards, particularly where those hazards interact with exposure and vulnerability. Physical risk is therefore not a property of the hazard alone: the same event produces different consequences depending on what stands in its path and on how that exposed system responds.

This has a direct implication for credit assessment. Hazard data alone (i.e. flood probability, drought frequency, heat-day counts at a given location) cannot indicate credit consequence, because it addresses only one of the three determinants. What is missing is a systematic account of vulnerability that captures how a hazard, once it reaches an exposed economic activity, translates into deterioration of that activity's economic and financial position.

Vulnerability of this kind is structurally determined. It depends on the configuration of production — on how much value is embodied in fixed physical assets, how far output depends on labour

performed in exposed conditions, and how directly the activity relies on climate-conditioned natural inputs. Agriculture is vulnerable to drought because yield depends on water availability; real estate is vulnerable to flooding because its assets are fixed in place and cannot be withdrawn in response to a warning; manufacturing is vulnerable to flooding through interruption of inputs and distribution as well as direct asset damage. A hazard that is material to one sector may be immaterial to another with comparable exposure, because it does not reach the critical part of the business. Vulnerability, so understood, is a characteristic of the activity rather than of the individual firm, and it is observable in the underlying asset and input structure of industries.

This does not imply that firms within a sector are alike. The structural features that determine vulnerability — the weight of fixed assets in the production model above all — vary across firms, and their distribution within a sector is itself observable in company accounts. Asset intensity, measured as tangible assets or property, plant and equipment over revenue, has been used for precisely this purpose, on the reasoning that a firm's dependence on physical assets to generate revenue governs how far a local hazard translates into lost output. The sectoral assignment is therefore not read off a sector average: it is informed by how these characteristics are distributed across the individual companies that make up each sector, which is what makes concentration and within-sector dispersion visible rather than assumed away[84].

What the literature therefore identifies as necessary is a structured framework that maps economic sectors to the specific pathways through which each hazard affects economic performance. In other words, an instrument that converts hazard data into an assessment of consequences. Sectoral vulnerability assessments are long established in climate literature,[85] but integrated and transferable approaches remain rare, and those developed for policy prioritisation are not constructed to feed credit metrics.

Two boundaries should be stated. First, a framework of this kind assesses sectors, not firms: individual entities within a sector differ, and a sectoral score establishes a defensible prior when firm-level evidence is unavailable, rather than determining individual borrower risk. Second, the IPCC conception of vulnerability encompasses both sensitivity to a hazard and the capacity to cope with it, whereas the framework proposed here addresses only the first. Adaptive capacity is a firm-level attribute that is difficult to observe systematically across a lending portfolio, and it is deliberately excluded from the vulnerability assessment. The effect of adaptation is instead treated separately, as an adjustment applied to the resulting risk assessment. This scoping keeps the vulnerability measure structural and observable and locates adaptation where it belongs in a credit context — as a modification of assessed risk rather than a component of it.

The framework proposed here is delivered as a completed instrument rather than a design: all 87 NACE Rev. 2.1 divisions are assessed against each of the thirteen physical hazards, so that any borrower classified at two-digit level can be assigned a vulnerability profile without further elaboration.

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[84] Azzone, M., Bechi, C. and Sbaiz, G. (2026), Temperature Anomalies and Climate Physical Risk in Portfolio Construction, arXiv:2604.11143

[85] BCBS (2021), *Climate-related financial risk measurement methodologies*, d518 — particularly high exposure granularity may be needed to assess physical risk given the spatially varying characteristics of climate impacts.

2.6. Literature Review Conclusions

Four findings emerge from this review. The first three answer the opening question, on how physical risk is currently treated in corporate credit scoring: it is material, it is systematically under-recorded, and the conditions that keep it under-recorded are self-sustaining. The fourth answers the second question, on what is analytically required: a transferable sector vulnerability layer connecting hazard information to credit consequence.

1. **Physical climate risk is material to credit risk.** Firms in countries more susceptible to climate change receive systematically lower credit ratings, a relationship holding across model specifications and economically significant in magnitude. Physical risk is observable in current ratings at country level, not a prospective concern awaiting future validation.
2. **Yet, physical climate risk remains systematically underestimated in practice.** Physical climate risk has underpinned fewer than 1% of rating actions since agencies began tracking ESG-driven actions in 2020. This figure is difficult to reconcile with the evidence above. The gap is best explained by attribution rather than immateriality: as the barriers analysis indicates, climate-driven deterioration is routinely recorded under conventional risk categories, so the observed figure measures classification practice rather than underlying exposure. The low incidence of climate-attributed bad debts reported by CLIMATEFIT partner banks admits the same reading.
3. **The barriers are self-reinforcing.** An adaptation-adjusted approach cannot be derived from realised climate-attributed defaults, because the attribution barrier is precisely what prevents that record from forming. It must instead rest on structural characteristics of economic activity that are observable independently of loss history, and on expert judgement disciplined by quantitative evidence where such evidence exists. This is the central methodological commitment of the approach developed in this paper**.**
4. **A transferable sector vulnerability layer is the missing analytical component.** Following the IPCC conception, physical risk arises from the interaction of hazard, exposure and vulnerability. Credit assessment addresses the first two at coarse resolution. Vulnerability is not wholly absent: supervisory exercises embed sectoral sensitivity factors within their hazard scores, the EBA's 2021 pilot classifies obligors at NACE four-digit level, and the Basel Committee identifies the sectors most exposed to a range of hazards. What these have in common is that the sectoral component is either embedded inside a composite score, and so not separable or auditable, or constructed for aggregate prudential purposes rather than for assignment to an individual borrower. A transferable layer — documented, mapped to NACE, and mapping the pathways through which each hazard reaches the economic performance of an activity — does not exist, and it is this that converts location-based hazard information into an assessment of credit consequence.

Implications for this paper

The findings above define the requirements for the approach developed in this paper. **Without tools of this kind, financial institutions will continue to underestimate physical climate risk, accumulate exposures in high-risk locations, and forgo opportunities to finance adaptation investments that would protect borrower continuity and lender portfolio stability alike.** Integrating adaptation into corporate credit assessment is not solely

a technical exercise. Rather, it is the mechanism through which resilience acquires a price, and therefore a precondition for private capital to flow toward it.

Chapter 3: The Regulatory Context of Adaptation Finance

Regulatory Framing: the decision to devote two separate chapters to regulation stems from the recognition that the capacity of financial institutions to support adaptation investments is shaped by two distinct and complementary, regulatory frameworks. **The sustainable finance framework** (**Chapter 3**), including the EU Taxonomy, the SFDR, and the CSRD, determines how adaptation activities are defined, classified, and disclosed, and therefore influences whether such investments can be identified, compared, and marketed as sustainable. **Prudential regulation (Chapter 4)**, grounded in the Basel framework and its European implementation through the CRR and CRD, determines instead how financial institutions measure, manage, and hold capital against risks, including the physical climate risks that adaptation investments are designed to reduce. The first framework thus acts mainly on the demand for and visibility of adaptation finance, while the second affects its cost and risk profile on institutions' balance sheets. Since both frameworks were largely developed with climate mitigation as their primary reference point, each chapter examines the extent to which its rules create incentives, or barriers, for directing capital towards adaptation. Treating them separately allows each to be analysed in the depth its complexity requires, while their combined reading provides the basis for assessing, in Chapter 6, whether the current regulatory architecture enables financial institutions to play a meaningful role in closing the adaptation finance gap.

The European Union has built one of the most developed regulatory architectures for sustainable finance anywhere, spanning classification, disclosure and prudential supervision. That architecture is not, however, symmetrical between mitigation and adaptation. Its central instruments, i.e. the Taxonomy, CSRD, and the SFDR are oriented principally toward measuring alignment with a decarbonization pathway and toward making exposures visible to the market. Physical climate risk is increasingly recognized within them; adaptation to that risk is not systematically rewarded. Under the framework as it stands, a borrower's exposure to hazard can affect a lender's assessment and capital position, while the borrower's investment in resilience largely cannot, because no standardized method translates adaptation into expected-loss terms.

This chapter traces architecture, from the international climate regime through EU adaptation policy to the sustainable finance framework and identifies where within it an adaptation-adjusted approach to credit risk could be accommodated. Chapter 4 develops the prudential dimension where that accommodation would have to occur.

The regulatory framework for climate adaptation finance in the EU consists of two overlapping sets of laws: those that address climate change measures broadly, and those related to sustainable finance that specifically apply to adaptation activities. They intersect to form the regulatory environment for climate adaptation financing in the EU. This chapter provides an overview of the key legal and regulatory instruments shaping climate adaptation finance in the European Union, with a focus on how different layers of governance and financial regulation interact to guide adaptation-related investment. It begins by situating the EU within the broader International Climate Change Regime, where multilateral agreements establish high-level commitments that influence EU law and policy. The analysis then turns to the EU's regulatory approach to climate change adaptation itself, highlighting legal mandates and strategic frameworks that integrate adaptation into sectoral and cross-cutting policies. From there, the chapter explores the EU's Renewed Sustainable Finance Strategy, including the development and

application of the EU Taxonomy Regulation, which provides a classification system for sustainable economic activities, including those supporting climate resilience. Financial and non-financial disclosure requirements, through the Sustainable Finance Disclosure Regulation (SFDR), the Non-Financial Reporting Directive (NFRD), the Corporate Sustainability Reporting Directive (CSRD), and the Corporate Sustainability Due Diligence Directive (CSDDD), are then examined as mechanisms to increase transparency and accountability that may further incentivise investments in climate adaptation. Together, these elements form a layered and evolving regulatory architecture that shapes how climate adaptation finance is governed in the EU.

3.1. The International Climate Change Regime

Climate adaptation is a central concern in international climate governance and is addressed through multiple global frameworks, most notably the United Nations Sustainable Development Goals (SDGs) and the United Nations Framework Convention on Climate Change (UNFCCC). In the context of the SDGs, adaptation is specifically central to Sustainable Development Goal 13 on Climate Action, which calls for the strengthening of "resilience and adaptive capacity to climate-related hazards and natural disasters."[86]

While the SDGs outline broad developmental priorities, the United Nations Framework Convention on Climate Change (UNFCCC) is the principal international treaty dedicated to addressing climate change. Established in 1992 and entering into force in 1994, the UNFCCC aims to stabilize greenhouse gas concentrations in the atmosphere at levels that would prevent dangerous human interference with the climate system. As the main global framework for climate action, the UNFCCC organises international efforts around three core pillars: mitigation, which focuses on reducing greenhouse gas emissions; adaptation, which seeks to strengthen resilience and minimise the impacts of climate change; and loss and damage, which addresses the harms that occur when adaptation and mitigation are insufficient to prevent adverse effects.[87] While adaptation is concerned with the management of climate risks, loss and damage comes into play where hard limits to adaptation have already been reached, such as in the case of low-lying islands suffering from the pressures of sea level rise.[88] These pillars guide the ongoing negotiations and implementation of climate policies under the Convention and its subsequent agreements.

Within this broader framework, the importance of adaptation has been recognised since the Convention's inception and has progressively evolved through subsequent legal instruments. Article 4(1)(b) of the original UNFCCC, ratified in 1992, obliges the Convention's signatory states to "facilitate adequate adaptation to climate change"[89] in accordance with their common but differentiated responsibilities, and to cooperate in preparing to adapt to the impacts of climate

[86] Transforming our world: the 2030 Agenda for Sustainable Development 2015 (A/RES/70/1), Sustainable Development Goal 13.

[87] Morten Broberg, 'Interpreting the UNFCCC's Provisions on "Mitigation" and "Adaptation" in Light of the Paris Agreement's Provision on "Loss and Damage"' (2020) 20 Climate Policy 527, 528.

[88] About Loss and damage | UNEP - UN Environment Programme

[89] United Nations Framework Convention on Climate Change (UNFCCC) 1992 (1771 UNTS 197) Art. 4(b).

change.[90] The Paris Agreement, which takes the form of a legally binding agreement within the UNFCCC framework and was adopted in 2015, concretises this obligation. The Paris Agreement establishes the Global Goal on Adaptation – a collective commitment of signatory states to enhance the world's adaptive capacity, strengthen resilience, and reduce vulnerability to climate change."[91]

Commitments under the Convention and its Paris Agreement are discussed annually at the Conference of the Parties (COP) to the UNFCCC.[92] Review of the progress on and policy in relation to the Global Adaptation also takes place at the COP. In 2023, the COP adopted the UAE Framework for Global Climate Resilience which supplements the Global Goal on Adaptation. The framework is a non-legally binding decision which has the primary objective of furthering adaptation, reducing climate vulnerability, and guiding the achievement of the Global Goal on Adaptation.[93] The UAE Framework outlines a set of targets that States are urged to accomplish by 2030, including an increase in the resilience of infrastructure and human settlements to climate change,[94] a reduction of the adverse effects of climate change on poverty eradication and livelihoods,[95] increased resilience against climate change related health impacts,[96] and others. Notably, according to the Framework's definition, adaptation action should benefit not only the resilience of people and the built environment to climate change impacts but should also be leveraged to reduce the impacts of climate change on ecosystems and biodiversity.[97] The UAE Framework's explicit inclusion of ecosystems and biodiversity in adaptation targets marks an evolution in the conceptualization of climate adaptation, which has historically prioritized human-centric resilience over ecological preservation. By integrating ecosystem protection into its targets, the Framework positions adaptation as a dual imperative: safeguarding both societal and natural systems from climate impacts. In addition, the Framework lays down four targets that focus on strengthening the institutional capacity of states to effectively adapt to climate change, addressing key areas such as impact and vulnerability assessment, planning, implementation, and monitoring of national adaptation efforts.[98]

Progress on States' accomplishments towards the UAE's targets is measured as a part of the Global Stocktake process under the Paris Agreement.[99] The Global stocktake takes place every five years and it is based on the information provided in a set of synthesis reports prepared by the Secretariat, including a designated synthesis report on the state of adaptation efforts, experience and priorities.[100] Information for the report is largely based on adaptation

[90] ibid Art. 4(e).

[91] Paris Agreement to the United Nations Framework Convention on Climate Change 2015 (TIAS) Art. 7(1).

[92] United Nations Framework Convention on Climate Change (UNFCCC) Art. 7(4).

[93] Decision 5/CMA.2 of the 25th Conference of the Parties to the United Nations Framework Convention on Climate Change 2020 (FCCC/PA/CMA/2019/6/Add1) Para 8.

[94] ibid para 9(e).

[95] ibid para 9(f).

[96] ibid para 9(c).

[97] ibid para 9(d).

[98] ibid para 10(a-d).

[99] ibid para 17.

[100] Decision 19/CMA 1 of the 24th Conference of the Parties to the United Nations Framework Convention on Climate Change 2019 (FCCC/PA/CMA/2018/3/Add2) para 23(c).

communications by the Parties to the UNFCCC under Article 7 of the Paris Agreement, which might include a party's priorities, implementation and support needs, plans and actions.[101] The submission of periodical adaptation communications is not a hard requirement, however, meaning that the information available for the synthesis report may be incomplete or inconsistent, potentially limiting the comprehensiveness of the Global Stocktake's assessment of global adaptation progress. This limitation will be somewhat ameliorated by the operationalisation of the Enhanced Transparency Framework (ETF) under the Paris Agreement.[102] Under the ETF, Parties need to submit biennial transparency reports and national inventory reports with a view to providing a better understanding of climate change action under the UNFCCC.[103] While the ETF has always been enshrined in the Paris Agreement (adopted in 2015), the first biennial reports were due by 31 December 2024.[104] The ETF makes it mandatory for parties to report information on anthropogenic emissions sources and removals and on the progress they have made in implementing their nationally determined contributions.[105] Climate change adaptation is included in the ETF via reference to the periodical adaptation communications under Article 7.[106] The ETF does therefore not establish an obligation to report on adaptation beyond Article 7 requirements. Nevertheless, the structured and standardised nature of the ETF and its clear guidance on the information to be reported with respect to adaptation may be reasonably expected to enhance the quality and consistency of the information submitted,[107] thereby indirectly strengthening the knowledge base on adaptation. As more Parties integrate adaptation-related data into their biennial transparency reports, whether voluntarily or as part of their adaptation communications under Article 7, the ETF can contribute to a more robust and coherent understanding of global adaptation efforts, challenges, and support needs, ultimately enriching the Global Stocktake process.

The first Global Stocktake concluded at COP28 in Dubai in 2023 noted that the gap between the needs of developing country Parties and the available finance was steadily growing[108] and that the scaling up of additional grant-based, highly concessional finance and non-debt instruments is a necessity to enable the just transition in developing countries.[109] Furthermore, recognising the role of the private sector, the Stocktake highlighted that Parties need to strengthen policy guidance, incentives, regulations and enabling conditions to mobilise investments in climate mitigation and resilience, thus encouraging parties to foster an enabling environment for private climate finance.[110]

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[101] Paris Agreement to the United Nations Framework Convention on Climate Change Art 7(1).

[102] ibid Art 13.

[103] Decision 18/CMA.1 of the 24th Conference of the Parties to the UN Framework Convention on Climate Change 2019 (FCCC/PA/CMA/2018/3/Add2) Annex, Section I.A.

[104] ibid para 3.

[105] Paris Agreement to the United Nations Framework Convention on Climate Change Art 13(7).

[106] ibid Art 13(8).

[107] 'Reference Manual for the Enhanced Transparency Framework under the Paris Agreement: Understanding the Enhanced Transparency Framework and Its Linkages' <https://unfccc.int/sites/default/files/resource/v2_ETFreferencemanual.pdf>.

[108] Decision 1/CMA.5 of the 28th Conference of the Parties to the United Nations Framework Convention on Climate Change (FCCC/PA/CMA/2023/16/Add1) para 67.

[109] ibid para 69.

[110] ibid para 70.

While the transparency and reporting mechanisms under the Paris Agreement, particularly the ETF and adaptation communications, are expected to enhance the global understanding of adaptation efforts, these processes also underscore the extent to which the effectiveness of frameworks like the UAE Framework ultimately depends on adequate support and measurable progress indicators. Yet, from the standpoint of climate adaptation finance, the framework currently lacks two key aspects. First, no target for climate adaptation finance has been negotiated under the framework. Reports of negotiations under the Glasgow-Sharm el-Sheik work program suggest that the objective would be to raise adaptation funding to match mitigation funding by 2030 and increase it further as the effects of climate change worsen, but this ambition has not been translated into specific commitments, leaving the gap between financial needs and available resources largely unaddressed.[111] Secondly, the Framework does not propose or mandate strategies for mobilising climate finance, instead leaving it to individual states to determine how they mobilize finance at the national level.[112] A more general absence is the overall lack of quantifiable and measurable indicators. These are currently being developed by the UAE-Belém work programme on indicators. Given the current state of discussions, it is possible but not certain that the indicators would include the topic of finance, as views on the inclusion of indicators that relate to the means of implementation diverge between those actors that submitted proposals to the work programme.[113]

3.2. European regulation on climate change adaptation

In the European Union, the objectives set forth under the UNFCCC framework are transposed to the regional level through the EU climate law, adopted in 2021, and through mainstreaming into distinct sectors.[114] The European Climate Law (CL) forms part of the European Green Deal, a package of proposals by the European Commission which encompasses a set of environmental goals. In relation to climate mitigation, the CL aims to make Europe a climate-neutral continent by 2050. Regarding adaptation, the CL obliges the Member States of the European Union to "ensure continuous progress in enhancing the adaptive capacity, strengthening resilience and reducing vulnerability to climate change in accordance with (…) the Paris Agreement."[115] In addition, it tasked the European Commission with the adoption of a EU strategy on adaptation for the implementation of the Paris Agreement.[116] The EU Adaptation Strategy is now the main practical framework that

[111] 'Understanding the Paris Agreement's "Global Goal on Adaptation"' (*World Resources Institute*, 28 March 2025) <https://www.wri.org/insights/global-goal-on-adaptation-explained> accessed 5 June 2025.

[112] ibid.

[113]'Synthesis of Submissions on the UAE - Belém Work Programme on Indicators' para 26 <https://unfccc.int/sites/default/files/resource/Synthesis%20of%20Submissions%20edited%20PDF.pdf>. For a list of actors that provided submissions, see para 8.

[114] Juliane Albrecht, 'Climate Adaptation Law: A European Perspective' [2024] China-EU Law Journal <https://doi.org/10.1007/s12689-024-00109-8> accessed 14 March 2025.

[115] Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law') (PE/27/2021/REV/1) Art 5(1).

[116] ibid Art 5(2).

guides the European Union's path to becoming climate resilient by 2050.[117] The Strategy recognises the need for the public and private sector to work together closely in financing climate adaptation. Indeed, the adaptation strategy itself is intended to help the private sector in identifying climate risks direct investment toward actions that promote adaptation and resilience, while also preventing maladaptation.[118] In this regard, the Adaptation Strategy is supplemented by the EU's legal framework on Sustainable Finance, in particular the EU's renewed sustainable finance strategy.

3.3 EU Financial Regulation: the EU Renewed Sustainable Finance Strategy

Sustainable finance is an indispensable part of delivering on the policy objectives of the EU Green Deal, including the Climate Law. The EU Renewed Sustainable Finance Strategy was therefore adopted within the context of the European Green Deal, driven by the Commission's goal to establish a stronger framework that supports sustainable investments from both private investors and the public sector.[119] The Strategy is made up of three composite parts: The EU Taxonomy, a comprehensive disclosure regime for the private sector, and a set of tools that private actors can use when engaging with sustainable investments.[120] This means that the renewed sustainable finance strategy enhances the regulatory framework for ESG financial products by defining a clear taxonomy, increasing transparency for companies and financial institutions, and modifying financial market regulations.[121]

3.3.1. The EU Taxonomy

The EU Taxonomy was created in the context of the EU's sustainable finance framework, and it functions as the cornerstone of the EU's regulatory landscape on market transparency in support of the European Green Deal objectives.[122] The EU Taxonomy's main objective is to increase finance flows in the areas of climate and environment. It is a science-based classification system for economic activities that provides an objective basis against which their alignment with the EU's net zero objective and other environmental goals can be measured.[123] Taxonomies in the field of sustainable finance are often likened to legal 'dictionaries' that define

[117] 'Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Forging a Climate-Resilient Europe - the New EU Strategy on Adaptation to Climate Change' (n 10).

[118] ibid 4.

[119] 'Renewed Sustainable Finance Stratgy' (*Legislative Train Schdule of the European Parliament*, 21 May 2025) <https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-renewed-sustainable-finance-strategy> accessed 26 June 2025.

[120] 'The EU Sustainable Finance Framework' (World Bank FinSac Conference, 18 May 2022) <https://thedocs.worldbank.org/en/doc/8dea75f98f65a824e389bdbd422f06d8-0430012022/related/Andreas-Rajchl-EU-Commission.pdf> accessed 26 June 2025.

[121] Volker Brühl, 'Green Finance in Europe: Strategy, Regulation and Instruments' (Goethe Unviersity Frankfurt, Center for Financial Studies 2021) Working Paper No. 657, 11.

[122] 'EU Taxonomy for Sustainable Activities' (*European Commission*) <https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en> accessed 26 June 2025.

[123] ibid.

and categorise economic activities that are supported by private or public investments.[124] Thus, the EU Taxonomy functions as a common baseline or 'green list' of economic activities that are deemed environmentally sustainable and creates a 'common language' for investors who want to invest in projects and economic activities with a positive impact on the environment and climate, including climate adaptation.[125] By doing so, the Taxonomy works towards two objectives in the EU: it facilitates the transition to a sustainable economy by identifying economic activities and investments that support this goal and prevents greenwashing by ensuring that economic activities that are advertised as green meet certain criteria.[126]

The EU Taxonomy is a system that consists of a set of legislative instruments: the EU Taxonomy Regulation, the Climate Delegated Act, and the Commission's Delegated Regulation amending the Climate Delegated Act.

While the EU Taxonomy establishes the overarching framework, the Climate Delegated Act and the Delegated Regulation specify the technical screening criteria—namely, the thresholds and requirements—that determine whether specific economic activities qualify as contributing substantially to climate change adaptation. These criteria guide how activities are assessed in sectors such as infrastructure, construction, water management, and other areas where adaptation measures are implemented. Together, the Taxonomy and the delegated acts form a comprehensive system for classifying economic activities, such as building resilient infrastructure, improving water efficiency, or restoring ecosystems, that support adaptation efforts and contribute to the EU's environmental objectives.

Central to this system is a collection of fundamental criteria that dictate if an activity can be categorized as environmentally sustainable within the Taxonomy framework. To begin with, the taxonomy establishes four overarching requirements for environmentally sustainable economic activities (hereafter 'activities'):

(1) that the activity **contributes substantially** to one or more of the environmental objectives set out in the Taxonomy,

(2) that the activity **does not significantly harm** any of the other environmental objectives included in the Taxonomy,

(3) that the activity is carried out in accordance with a set of **minimum safeguards** laid down in the Taxonomy,

(4) and that it complies with **technical screening criteria** that supplement the Taxonomy.[127]

[124] Nathan de Arriba-Sellier, 'Sustainable Finance: Green Taxonomies as Instruments of System Change?', *A Research Agenda for Environmental Law* (Edward Elgar 2025) 157, 159.

[125] 'Questions and Answers: Taxonomy Climate Delegated Act and Amendments to Delegated Acts on Fiduciary Duties, Investment and Insurance Advice - Main Contents' (*EU Monitor*, 21 April 2021) <https://www.eumonitor.eu/9353000/1/j9vvik7m1c3gyxp/vli5hg8dlixi?ctx=vhsjgh0wpcp9> accessed 26 June 2025.

[126] de Arriba-Sellier (n 105) 160-161.

[127] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, Art. 3.

These requirements apply to six environmental goals outlined by the Taxonomy, one of which pertains to climate change adaptation.[128] In the context of the taxonomy, climate change adaptation is defined as "the process of adjustment to actual and expected climate change and its impacts."[129] As a result, climate adaptation investments must meet the standards outlined in the taxonomy for an economic activity to be considered ecologically sustainable. The criteria under the Taxonomy apply to all financial products offered by financial market participants in the EU.[130]

Article 11 Checklist

Criteria	Internal adaptation (Art. 11(1)(a))	External adaptation (Art. 11(1)(b))
Substantial reduction of risk (current and future)	✅	✅
Substantial reduction of actual impacts occurred	✅	❌
Creates adverse impact ('harm')	❌	❌
Does not meet Art. 16 'lock-ins' criteria	✅	❌

Article 11 of the EU Taxonomy outlines the criteria an economic activity must meet to be deemed as contributing substantially to climate change adaptation. According to Article 11, an economic activity can be regarded as contributing substantially to climate change adaptation if it either (a) includes adaptation solutions that substantially reduce the risk of the adverse impact of the current climate and the expected future climate on that economic activity itself or reduce that adverse impact, or (b) provides adaptation solutions that contribute substantially to preventing or reducing the risk of the adverse impact of the current climate and the expected future climate on people, nature or assets. In other words, Article 11 refers to economic activities that either incorporate adaptation measures to internally reduce the risk of climate impacts on themselves as well as activities that deliver products or services that benefit people, nature, or assets with the reduction of climate risk, thus supporting adaptation beyond the activity's own operations. Economic activities that fall within the second category, i.e. that provide adaptation solutions that contribute to the reduction of climate risk, or its adverse impacts must additionally satisfy the conditions under Article 16 of the Taxonomy. Article 16 prescribes that an economic activity must not "lead to a lock-in of assets that undermine long-term environmental goals, considering the economic lifetime of those assets"[131] and must have "a substantial positive environmental impact, on the basis of life-cycle considerations."[132] This means that when a financial institution or company invests in a project or asset, it should avoid investments that

[128] ibid.

[129] ibid, Art. 2(6).

[130] ibid, Art. 2.

[131] ibid, Art. 16(a).

[132] ibid, Art. 16(b).

could cause stranded assets down the line by locking in outdated or harmful infrastructure incompatible with climate targets. The activity should instead provide lasting environmental benefits throughout its whole life.

Additionally, in both cases, in order to qualify as sustainable, the economic activity must not create separate adverse impacts on people, nature or assets.[133] This includes the issue known as 'maladaptation,' which refers to unintended negative consequences of climate adaptation activities which result in an increased vulnerability to climate change. A well-known example of maladaptation is the construction of a seawall in the Fiji Island which, instead of protecting the community from rising tides, exacerbated flooding by acting as a dam that trapped water and debris inland.[134]

The issue is further regulated by the 'do not significant harm' (DNSH) requirement : economic activities that fall under the Taxonomy and are deemed to contribute significantly to one of its objectives must not cause harm to any of the other objectives specified in the Taxonomy.[135] For economic activities that substantially contribute to climate change adaptation but present a risk to any of the other objectives, the Climate Delegated Act establishes a list of technical criteria that ensure the respect of the DNSH principle..[136] The technical criteria are organised by sector, covering forestry, environmental protection and restoration, construction and real estate, financial and insurance activities, among others.[137] The technical requirements are extensive and varied, however some examples may help illustrate how this works in practice.

In line with the DNSH criterion, economic activities that contribute substantially to climate change adaptation must not produce significant greenhouse emissions.

To this end, the Climate Delegated Act sets out distinct carbon ceilings that apply to manufacturing activities.[138] In the case of climate adaptation, the 'do no significant harm' rule is especially likely to come to bear in relation to construction activities. The construction, modernisation, or operation of different types of transport infrastructure can lead to significant CO2 emissions linked to the manufacturing of materials such as cement, steel, and metals.[139] In addition, the EU Taxonomy prescribes that adaptation activities relating to the construction or major renovation of infrastructure enabling road transport and public transport, water transport, or airport infrastructure, new infrastructures or major innovation projects must ensure that the infrastructure is climate proof. This

[133] ibid, Art. 11(a).

[134] Ritodhi Chakraborty and Claire Burgess, 'Climate Adaptation Projects Sometimes Exacerbate the Problems They Try to Solve – a New Tool Hopes to Correct That' (29 October 2023) <https://theconversation.com/climate-adaptation-projects-sometimes-exacerbate-the-problems-they-try-to-solve-a-new-tool-hopes-to-correct-that-213969> accessed 25 June 2025.

[135]Taxonomy Regulation, Art. 3(b).

[136] Commission Delegated Regulation (EU) 2021/2139 of 4 June 2021 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives (Climate Delegated Act) para 49-55.

[137] ibid, Annex II.

[138] ibid, para 50.

[139] ibid, Annex II Section 6.14-17.

includes a measuring of all greenhouse gas emissions directly produced by the infrastructure (scope 1), indirect emissions from purchased energy (scope 2), and other indirect emissions arising across the value chain (scope 3).[140] In other words, the measured carbon footprint of the infrastructure should include direct, indirect, and life cycle emissions.[141]

Scope 1-3 emissions

- *Scope 1: Arise during the production phase and are released during product manufacturing or service delivery.*
- *Scope 2: Indirect emissions released off-site, e.g. electricity or cooling.*
- *Scope 3 (life cycle emissions): Arise upstream and downstream the value chain. On average, they make up around 90% of companies' total emissions.*

Besides this, however, the Climate Delegated Act falls short of explicitly outlining Scope 1-3 emissions reporting for mitigation or adaptation activities or detailed definitions of the scopes. This lacuna is less pronounced in the case of mitigation, as the Greenhouse Gas (GHG) Protocol[142] – the main internationally recognized standard for greenhouse gas accounting and reporting developed by the World Resources Institute and the World Business Council for Sustainable Development – lays out comprehensive and standardized methods to quantify direct (Scope 1), indirect energy-related (Scope 2), and other indirect (Scope 3) emissions. In contrast, adaptation activities lack similarly detailed and standardised emissions accounting frameworks, making it difficult to accurately measure and manage their greenhouse gas impacts. This gap limits transparency and risks underestimating the emissions associated with adaptation projects, underscoring the need for greater granularity in CO2 emissions reporting to ensure these activities align with the 'do no significant harm' principle.

This asymmetry between mitigation and adaptation is not confined to emissions accounting. Instead, it recurs in how the Taxonomy's alignment criteria are applied at entity level. The Green Asset Ratio (GAR), the main Taxonomy-based KPI for credit institutions, illustrates this in practice: bank reporting consistently shows adaptation-aligned exposures lagging far behind mitigation-aligned exposures on the same balance sheets.[143] The Green Asset Ratio is the main Taxonomy-alignment KPI for credit institutions, introduced under Article 8 of the EU Taxonomy Regulation. It measures the proportion of a bank's covered assets (i.e. loans, debt securities, and equity holdings in the banking book) that finance economic activities aligned with the Taxonomy's environmental objectives. Because banks calculate the GAR by applying their counterparties' own Taxonomy KPIs (turnover, capex, and opex) at portfolio level, GAR functions as the point at which the criteria set out above, namely substantial contribution, do no significant harm, minimum

[140] ibid.

[141] 'What Are Scope 1, 2, and 3 Emissions?' (*McKinsey & Company*, 17 September 2024) <https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-are-scope-1-2-and-3-emissions> accessed 26 June 2025.

[142] 'Standards and Guidance' (*Greenhouse Gas Protocol*) <https://ghgprotocol.org/standards-guidance> accessed 26 June 2025.

[143] See Annex 1

safeguards, and technical screening criteria, are aggregated across an institution's entire balance sheet. Bank reporting consistently shows adaptation-aligned exposures lagging far behind mitigation-aligned exposures on the same balance sheets. Among other things, this is connected to how the underlying KPIs are constructed and to the scope of assets the ratio captures. Annex I sets out this pattern in detail, drawing on a sample of European banks' FY2024 disclosures.

The Omnibus I simplification package, adopted via Delegated Act in July 2025 and applying from FY2025/2026 reporting, amended the Taxonomy Disclosures, Climate, and Environmental Delegated Acts with a number of changes relevant to GAR. Two of these are particularly relevant from the perspective of adaptation finance. First, banks were granted the option not to report detailed Taxonomy KPIs, including the GAR, until 31 December 2027, provided they do not claim that their activities are associated with Taxonomy-aligned activities.[144] Second, exposures to counterparty undertakings not subject to Directive 2013/34/EU, such as SMEs and non-EU entities, are now excluded from the GAR denominator, unless the counterparty reports voluntarily or the exposure involves a loan with a known use of proceeds.[145] This second change is relevant to the mitigation-adaptation imbalance examined in Annex I. Under the previous rules, SME and non-EU exposures were excluded from the numerator but retained in the denominator, effectively counting them as entirely unsustainable regardless of what they financed. Annex I argues this asymmetry weighed more heavily on adaptation than mitigation, since adaptation finance needs are concentrated in exactly these segments (farms, SMEs, and local authorities) that the numerator could not otherwise reach. To the extent that reasoning holds, removing these exposures from the denominator should ease that pressure specifically on adaptation reporting, though it is a general fix to GAR's scope rather than a change targeted at adaptation.

3.4. Disclosure and reporting requirements of financial institutions and corporates

The second important category of the EU's Sustainable Finance Regulatory Framework is the corpus of disclosure requirements that apply to financial institutions and corporates operating in the EU. The disclosure regulations oblige entities to provide investors with the information needed to make sustainability-oriented decisions and to enhance transparency for other stakeholders.[146] Indeed, disclosure requirements are vital for the functioning of the EU Taxonomy, as they oblige or encourage companies and financial institutions to report the extent to which their activities align with the taxonomy's criteria. Disclosures therefore play a crucial role in supporting private investment in sustainable projects by offering investors and stakeholders consistent and trustworthy information on how companies and financial institutions manage environmental, social, and governance (ESG) factors, which aids in making informed choices and helps deter greenwashing by confirming that sustainability assertions are backed by evidence.

[144] COMMISSION DELEGATED REGULATION (EU) 2026/73 of 4 July 2025 art 1(6)(e).

[145] ibid 1(6)(a) amending Article 7(3) of Delegated regulation (EU) 2021/2178.

[146] Brühl (n 115).

Disclosures under the EU's Sustainable Finance Regulatory Framework fall into two main categories: those focused on financial products such as investment funds and insurance-based investment products, and those related to non-financial reporting by companies.

In the EU, the most important legal instrument that addresses financial products is the 2019 Sustainable Finance Disclosure Regulation (SFDR). It aims to improve the transparency of investment funds and other financial products (e.g. life insurance policies that contain investment elements, workplace pension plans, and pooled investment funds that allow individuals to purchase shares) allowing investors to identify and channel capital to companies whose products and services support climate action or address other environmental and social issues.[147] The main instruments that address non-financial disclosures in the EU are the Corporate Sustainability Reporting Directive (CSRD) and its associated European Sustainability Reporting Standards (ESRS).

This two-pronged strategy ensures that both financial institutions and corporations deliver clear, standardised information that allows stakeholders to evaluate sustainability risks and effects through the financial industry and the real economy. It reflects the EU's dual approach to sustainable finance: on one hand, by enhancing transparency at the level of financial products through the SFDR; and on the other, by mandating detailed sustainability reporting at the corporate level through the NFRD, CSRD, and the ESRS. The following sections will analyse each of these frameworks thoroughly, starting with the SFDR and then progressing to the regime for non-financial disclosures in the EU.

3.4.1. Financial Disclosures in the EU: the EU SFDR

The EU Sustainable Finance Disclosure Regulation is a European Union regulation. It requires financial market participants to disclose how they manage sustainability risks. The EU SFDR Framework consists of a set of legislative acts, including the SFDR itself as well as two Delegated Regulations. First, the Sustainable Finance Disclosure Regulation sets out the main disclosure requirements for financial market participants.[148] This is complemented by the first Delegated Regulation, which specifies detailed technical standards for financial disclosures.[149] Finally, a second Delegated Regulation introduces further amendments that require financial market participants to "disclose the extent to which their portfolios are exposed to gas and nuclear-related activities that comply with the Taxonomy and its Climate Delegated Act."[150]

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[147] Ian Cochran, Craig Mackenzie and Matthew Brander, 'EU's Sustainable Finance Disclosure Regulation: Does the Hybrid Reporting Regime Undermine the Goal to Reorient Capital to Climate Action?' (2025) 25 Climate Policy 76, 77.

[148] Regulation (EU) 2019/2088 of the European Parliament and of the Council of 27 November 2019 on sustainability-related disclosures in the financial services sector (Sustainable Finance Disclosure Regulation).

[149] Corrigendum to Commission Delegated Regulation (EU) 2022/1288 of 6 April 2022 supplementing Regulation (EU) 2019/2088 of the European Parliament and of the Council with regard to regulatory technical standards specifying the details of the content and presentation of the information in relation to the principle of 'do no significant harm', specifying the content, methodologies and presentation of information in relation to sustainability indicators and adverse sustainability impacts, and the content and presentation of the information in relation to the promotion of environmental or social characteristics and sustainable investment objectives in pre-contractual documents, on websites and in periodic reports.

[150] 'Sustainability-Related Disclosure in the Financial Services Sector' (*European Commission*) <https://finance.ec.europa.eu/sustainable-finance/disclosures/sustainability-related-disclosure-financial-services-sector_en> accessed 26 June 2025.

These three instruments establish the combined framework that ensures the consistency and transparency of sustainability disclosures in the EU financial sector.

The EU SFDR requires all financial market participants and financial advisers operating in Europe to measure and report on the integration of sustainability considerations in their decision-making process concerning investments and on the potential impacts of their investments or investment advice on sustainability factors.[151] Under the EU SFDR, financial market participants and advisors are financial institutions and advisors that offer financial products or advice on financial products, including asset managers, investment firms, insurance companies, pension funds, and any other entity that gives advice on financial products in the EU.[152] These actors must, accordingly, be transparent about how they take issues such as climate change, social responsibility, and good governance into account when making investment decisions, and openly share any potential negative environmental or societal impacts their investments could have.

Financial institutions and advisors must report the overall Sustainability Investment percentage for their financial products if those products promote ESG characteristics or have sustainable investment as their objective. The obligation to disclose applies at both the product and the entity level.[153] At the entity level, financial institutions and advisors must disclose how sustainability risks are incorporated into the investment decision-making process or financial advice.[154] This serves to provide a general overview of their overall approach to sustainability. At the product level, financial institutions and advisers are to categorise individual financial products based on their sustainability focus. Products can be classified as 'grey' products which have no focus on ESG characteristics (Article 6), 'light green' products,, which promote ESG characteristics among other characteristics (Article 8 financial products), or as 'dark green' products which have sustainable investment as their explicit objective (Article 9 financial products).[155] ,For Article 8 financial products, minimum targets for sustainable investments (SI) are optional but financial institutions have to report on the overall percentage they have actually achieved.[156] Article 9 financial products, by contrast, must commit to a 'significant' Sustainable Investment percentage, although there is no formal minimum threshold specified in the regulation.[157] A financial product is considered to be a sustainable investment if it falls within Article 2(17), which includes investment(s) in an economic activity that contribute to either a social or environmental objective. According to this wide provision, an investment contributes to an environmental objective when it helps protect the environment, for example, by saving water, using renewable sources, reducing waste or pollution, or supporting nature and recycling.

[151] Sustainable Finance Disclosure Regulation, Art. 1.

[152] For a precise list of entities targeted by the Regulation, see ibid Art. 2(1) and 2(11).

[153] ibid Art. 7.

[154] ibid Art 4.

[155] ibid Arts. 6, 8, and 9.

[156] Commission Delegated Regulation (EU) 2023/363 of 31 October 2022 amending and correcting the regulatory technical standards laid down in Delegated Regulation (EU) 2022/1288 as regards the content and presentation of information in relation to disclosures in pre-contractual documents and periodic reports for financial products investing in environmentally sustainable economic activities, Annex II.

[157]ibid, Annex III.

The sustainable investment percentage represents a binding commitment by the financial product to invest in activities meeting the three cumulative criteria established by Article 2(17). To qualify as a sustainable investment under Article 2(17), the investment must (1) make a positive contribution to an environmental or social objective, (2) not significantly harm any other such objective, and (3), be made in companies that follow good governance practices. In calculating this percentage, fund managers may apply one of two methodologies. Under a pass-or-fail approach, a company that meets the ESG criteria is counted in full, meaning that 100% of the investment in that company contributes to the financial product's sustainable investment percentage, regardless of the proportion of its activities that are actually sustainable.[158] Alternatively, under a proportional or look-through approach, only the share of the company's revenue attributable to sustainable activities is counted. While the latter produces a lower figure, it is generally considered more precise and transparent. The choice of methodology is left to the discretion of the financial market participant.

Article 8 example

A fund might invest in a range of companies, including some that are improving their resilience to climate change – for instance, by upgrading infrastructure to cope with extreme weather. While it promotes environmental characteristics, adaptation is just one of several factors it considers. In contrast, an Article 9 fund could focus entirely on financing projects aimed at climate adaptation, such as restoring wetlands to prevent flooding or funding drought-resistant agriculture. These investments have a clear objective of contributing to sustainable outcomes related to climate resilience.

After counting towards the SI percentage, Article 8 and 9 financial products that contribute to an environmental objective within the meaning of Article 2(17) of the SFDR must additionally report on their alignment with the EU Taxonomy. Article 8 and 9 financial products that promote or have as their focus an environmental objective under Articles 8 and 9 SFDR must report on their alignment with the EU Taxonomy.[159] Because Article 2(17) of the SFDR defines sustainable investment broadly, not all investments that meet this definition necessarily align with the more specific criteria of the EU Taxonomy. However, any financial product that is Taxonomy-aligned will also fall within the scope of Article 2(17).[160] Investments under Articles 8 or 9 will qualify as taxonomy-aligned if they comply with the four overarching criteria detailed in Article 3 of the Taxonomy: (1) a substantial contribution to environmental objectives, (2) adherence to minimum safeguards, and (3) compliance with the technical screening criteria, in addition to (4) the avoidance of significant harm to other environmental objectives.[161] Accordingly, a financial product which claims climate adaptation as a co-benefit or objective under Articles 8 or 9 respectively would need to demonstrate Taxonomy alignment, thus investing in economic activities that meet the strictest legally standardised criteria set by the European Union. This is the case even though climate adaptation is not explicitly mentioned

[158] Sustainable Finance Disclosure Regulation art 2(17).

[159] Taxonomy Regulation, Art. 5 and 6.

[160] Sustainable Finance Disclosure Regulation, Art. 2(17).

[161] Taxonomy Regulation, Art. 5 and 6.

under the environmental objectives outlined under Art. 2(17) of the SFDR.[162] The reason for this is that the EU Taxonomy does include climate adaptation under its objectives, thus automatically bringing it within the focus of Article 2(17) SFDR.

The broad definition of sustainable investments under Article 2(17) has created a fragmented reporting landscape where financial institutions can choose to apply detailed taxonomy criteria or general principles, weakening comparability, leaving the door open to greenwashing, and potentially leading to underreporting of climate adaptation investments. However, the requirement that financial products must report on their taxonomy alignment does not imply that the percentage of taxonomy-aligned investments automatically equals the SI percentage of the product under Article 2(17). As the Sustainable Investment percentage thresholds in Articles 8 and 9 of the SFDR are not specified, financial institutions and advisers are free to choose between the application of the EU Taxonomy or the principle-based guidance offered under Article 2(17) of the SFDR when investing in financial products that specify ESG.[163] According to these principles, sustainable investments should 'contribute' to an environmental or social 'objective', should not do significant harm to any of those objectives, and should follow good governance practices. Financial institutions and advisors would then develop their own concrete interpretation of the principles. As a result, the choice between the Taxonomy's demanding rules and the general principles in Article 2(17) means that financial products can receive vastly different SI scores, depending on the company's interpretation of the sustainability criteria under Article 2(17).[164] This unintentional hybrid regime under the EU Taxonomy and the EU SFDR has resulted in some loopholes in the reporting regulation that may jeopardise the flow of funds towards climate adaptation.

Risks of Sustainable Investment percentage reporting loopholes for climate adaptation

The risk that SI percentages of financial products will be reported according to the general principles under Article 2(17) may be especially strong in the case of climate adaptation, where the end goal of projects is often social in nature. Financial institutions might therefore evade mandatory reporting under the EU taxonomy by classifying the financial product as promoting sustainability or having a sustainability object that is social rather than environmental in nature. For example, a project may primarily seek to protect or enhance various aspects of human wellbeing, such as health and safety, food and water security, or the protection of communities' livelihoods. The calculation of SI percentages under Article 2(17) might in those cases be more advantageous as well as appealing in terms of the complexity of the reporting process. In this context, the European Commission has been discussing the introduction of a Social Taxonomy, which would follow the basic structure of the environmental taxonomy.

In any event, because of the lack of standardised sustainability criteria, Article 2(17) could potentially include a large range of economic activities and is therefore susceptible to 'sustainability-washing' or inconsistent classifications of investments, potentially making it more difficult for investors to pick financial products that have the desired sustainability outcomes.[165]

[162] Sustainable Finance Disclosure Regulation, Art. 2(17).

[163] Cochran, Mackenzie and Brander (n 125) 78.

[164] ibid 81.

[165] ibid 82.

Beyond this, preferential reporting under Article 2(17) may also mean that not all activities that contribute to EU Taxonomy objectives, including the objective of climate adaptation, will be reported as Taxonomy-aligned.[166] This could in turn hamper opportunities to funnel finance into the most critical areas of climate adaptation as well as undermine the EU's prospects of meeting its adaptation goals under the UNFCCC and the Green Deal.

Under the SFDR, large financial market participants with more than 500 employees are obliged to publish a Principal Adverse Impact (PAI) statement, which details the negative impact of their activities at the entity and product level.[167] The PAI statements must provide information detailing the institution's approach to identifying and prioritising principal adverse sustainability impacts, along with a description of the measures implemented or planned in response. Additionally, they must outline relevant shareholder engagement practices, reference adherence to responsible business conduct frameworks and international due diligence standards, and, where applicable, indicate the extent of alignment with the goals of the Paris Agreement.[168] To support consistent, robust, and transparent reporting, firms are required to apply a set of Principal Adverse Impact indicators outlined under the 2022 Delegated Regulation, a key tool in assessing and communicating the sustainability-related risks and impacts of financial products.[169] Under the indicators, financial market participants must report on climate and other environment-related matters, such as their greenhouse gas emissions (including scope 1-3 emissions), biodiversity, water, and waste.[170] They must also report on social matters.[171] In addition, the Regulation sets out 31 supplementary indicators covering climate, environmental, and social factors. Financial market participants are required to select and report on at least one environmental and one social indicator from this list.[172]

Smaller financial market participants do not have to publish a PAI statement and are instead subject to a general comply-or-explain regime. This regime requires them to publish information regarding the sustainability impacts of their investment decisions and the due diligence policies with respect to those impacts on their websites.[173] Where such information is not provided, the financial market participant is required to publish a statement detailing the reasons for this omission, as well as whether and when the decision's sustainability impacts will be considered.[174]

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[166] ibid 83.

[167] Commission Delegated Regulation (EU) 2022/1288 of 6 April 2022 supplementing Regulation (EU) 2019/2088 of the European Parliament and of the Council with regard to regulatory technical standards specifying the details of the content and presentation of the information in relation to the principle of 'do no significant harm', specifying the content, methodologies and presentation of information in relation to sustainability indicators and adverse sustainability impacts, and the content and presentation of the information in relation to the promotion of environmental or social characteristics and sustainable investment objectives in pre-contractual documents, on websites and in periodic reports, Arts. 4 and 7.

[168] Corrigendum to Commission Delegated Regulation (EU) 2022/1288, Art. 4.

[169] Commission Delegated Regulation (EU) 2022/1288, Preamble.

[170] ibid, Annex I, Table 1, Indicators 1-9.

[171] ibid, Annex I, Table 1, Indicators 10-14.

[172] Commission Delegated Regulation (EU) 2022/1288, Annex I, Table 2.

[173] SFDR Art. 4(1)(a)

[174] SFDR, Art 4(1)(b)

Case Example: The Gap Between Taxonomy Alignment and Sustainable Investment

Consider a fund invested in a company operating three energy projects: an offshore wind farm, a natural gas plant, and a hydroelectric dam in a protected river area.

Under the EU Taxonomy, only the wind farm qualifies as aligned. The gas plant fails the technical screening criteria on emissions, and the dam violates the Do No Significant Harm principle by disrupting fish migration in a protected river. If the wind farm generates 30% of the company's revenue, only 30% of the fund's investment counts as Taxonomy-aligned.

Under Article 2(17) SFDR, however, the fund manager may additionally classify the hydroelectric dam as a sustainable investment, on the basis that it produces zero-emission electricity and that the disruption to fish populations does not meet their internal threshold for significant harm. The fund's sustainable investment percentage would accordingly be 50%, exceeding its Taxonomy alignment figure by 20 percentage points.

This divergence illustrates the practical consequences of the hybrid regime where the same investment can qualify as a sustainable investment under the SFDR while failing Taxonomy alignment criteria. This produces materially different figures for the same pool of capital and creates scope for inconsistent classification.

In response to confusion and risks of greenwashing created by the reporting system under Articles 8 and 9 of the SFDR, the European Commission proposed a set of amendments to the Regulation in November 2025.[175] Most significantly for the analysis above, the proposal would replace the current Article 8/Article 9 regime with three new product categories: Sustainable, Transition, and ESG Basics. For products in these categories, the proposal foresees a 70% portfolio threshold. Furthermore, the proposed amendments would remove the existing "sustainable investment" concept under Article 2(17) altogether[176] and replace entity-level principal adverse impact (PAI) disclosures with a narrower, product-level approach.[177] These changes would directly affect the hybrid regime and the ambiguities identified above regarding the relationship between Taxonomy alignment and the SI percentage under Articles 8 and 9, since the concept at the centre of that ambiguity would no longer exist in its current form. As of the Council's negotiating position adopted on 24 June 2026, the proposal remains under negotiation between the Parliament and the Council and has not yet been adopted.[178] This report accordingly treats the current SFDR framework, as described above, as the applicable law, while flagging that the analysis may need to be revisited once the revised regulation is finalised.

[175] 'Commission Proposes Improvements to SFDR' (*European Commission*, 21 November 2025) <https://finance.ec.europa.eu/news/commission-proposes-improvements-sfdr-2025-11-21_en> accessed 14 July 2026.

[176] Proposal for a Regulation of the European Parliament and the Council amending Regulation (EU) 2019/2088 on sustainability-related disclosures in the financial services sector (SFDR), Regulation (EU) No 1286/2014 on key information documents for packaged retail and insurance-based investment products (PRIIPs) and repealing g Commission Delegation Regulation (EU) 2022/1288 (Brussels, 20 November 2025) p. 18.

[177] Ibid p. 10.

[178] 'Council Agrees Position on Simpler Transparency Rules for Sustainable Financial Products' (*Council of the European Union*, 24 June 2026) <https://www.consilium.europa.eu/en/press/press-releases/2026/06/24/council-agrees-position-on-simpler-transparency-rules-for-sustainable-financial-products/> accessed 14 July 2026.

3.4.2. Non-financial reporting in the EU

While the SFDR primarily targets financial market participants and aims to improve transparency on how sustainability risks are integrated into investment decisions, it forms just one part of the EU's broader sustainability disclosure regime. In parallel, the EU has introduced separate legislative measures targeting corporate sustainability reporting directly.

The evolution of non-financial reporting requirements in the EU has been gradual. Beginning in the 1990s, the EU promoted voluntary sustainability disclosures through soft law instruments. This approach remained in place for nearly two decades. A significant shift occurred in 2014 with the adoption of the Non-Financial Reporting Directive (NFRD), which amended the 2013 Accounting Directive. As the first binding legislation on ESG disclosures at the corporate level, the NFRD marked a turning point—embedding environmental, social, and governance considerations into corporate reporting and laying the foundation for a more sustainable corporate ecosystem. In 2024, the NFRD was superseded by EU Corporate Sustainability Directive (CSRD) – a much more ambitious framework. The CSRD introduced more far-reaching and stringent requirements for non-financial reporting in the EU as well as a detailed reporting framework to guide the reporting of ESG data by companies known as the European Sustainability Reporting Standards (ESRS). Together, the CSRD and the ESRS now form the backbone of European non-financial reporting.

Financial reporting

- *Sustainable Finance Disclosure Regulation (SFRD)*

Non-financial reporting

- *Non-Financial Reporting Directive (NFRD): Largely replaced, but partially still relevant*
- *Corporate Sustainability Reporting Directive (CSRD): Replaces the NFRD*
- *European Sustainability Reporting Standards (ESRS): Flesh out CSRD requirements*

Although the Non-Financial Reporting Directive (NFRD) remains formally part of EU legislation, its provisions have largely been overtaken by the broader scope and higher standards of the CSRD.

This has rendered the NFRD's provisions effectively outdated for the entities now encompassed by the CSRD. Nevertheless, the NFRD continues to hold significance for companies that are not yet subject to the CSRD until the phased rollout is fully implemented.[92] For instance, certain smaller organisations may still follow NFRD standards until their obligations under the CSRD take effect. Furthermore, the NFRD's underlying principles remain intact and continue to underpin the CSRD's functioning, meaning that an understanding of the current EU non-financial disclosures regulatory landscape still starts with an overview of the NFRD.

(a) The Non-Financial Reporting Directive (NFRD)

The evolution of non-financial reporting requirements in the EU has been gradual. Beginning in the 1990s, the EU promoted voluntary sustainability disclosures through soft law instruments. This

approach remained in place for nearly two decades.[179] A significant shift occurred in 2014 with the adoption of the Non-Financial Reporting Directive (NFRD), which amended the 2013 Accounting Directive.[180] As the first binding legislation on ESG disclosures at the corporate level, the NFRD marked a turning point—embedding environmental, social, and governance considerations into corporate reporting and laying the foundation for a more sustainable corporate ecosystem.[181] In 2024, the NFRD was superseded by EU Corporate Sustainability Directive (CSRD) – a much more ambitious framework. The CSRD introduced more far-reaching and stringent requirements for non-financial reporting in the EU as well as a detailed reporting framework to guide the reporting of ESG data by companies known as the European Sustainability Reporting Standards (ESRS). Together, the CSRD and the ESRS now form the backbone of European non-financial reporting.

Although the Non-Financial Reporting Directive (NFRD) remains formally part of EU legislation, its provisions have largely been overtaken by the broader scope and higher standards of the CSRD. This has rendered the NFRD's provisions effectively outdated for the entities now encompassed by the CSRD. Nevertheless, the NFRD continues to hold significance for companies that are not yet subject to the CSRD until the phased rollout is fully implemented.[182] For instance, certain smaller organisations may still follow NFRD standards until their obligations under the CSRD take effect. Furthermore, the NFRD's underlying principles remain intact and continue to underpin the CSRD's functioning, meaning that an understanding of the current EU non-financial

Despite being a foundational step in EU sustainability reporting, the NFRD faced significant criticism for its limited scope and lack of clarity, ultimately prompting the need for more robust and standardised frameworks. The NFRD was criticised on two main accounts: scope and ambiguity. Its limited application to large listed companies meant that many businesses were not subject to non-financial disclosure obligations, leaving them unaccounted for.[183] Where the NFDR did apply, its effectiveness was hampered by a lack of guidelines as to the practical application of disclosure requirements, which rendered data reported under the Directive inconsistent and of limited use for the purpose of comparison between companies.[184] In essence, the NFRD established a general disclosure obligation without prescribing detailed metrics or a unified reporting format. This open-ended approach, though insufficient by itself, laid the groundwork for more standardized and enforceable frameworks introduced later through the CSRD and ESRS.

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[179] Pietro Fera and others, 'Towards the Regulation of Non-Financial Reporting: The Impact on Environmental Disclosure Within the Oil and Gas Sector' [2025] Corporate Social Responsibility and Environmental Management 1, 2.

[180] Directive 2013/34/EU of the European Parliament and of the Council of 26 June 2013 on the annual financial statements, consolidated financial statements and related reports of certain types of undertakings, amending Directive 2006/43/EC of the European Parliament and of the Council and repealing Council Directives 78/660/EEC and 83/349/EEC (EU Accounting Directive).

[181] 'Briefing Implementation Appraisal: Non-Financial Reporting Directive' 3 <https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/654213/EPRS_BRI(2021)654213_EN.pdf>.

[182] Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting (Corporate Sustainability Reporting Directive) Art. 5.

[183] NingShan Hao, Voicu D Dragomir and Oana Marina Radu, 'Effects on Corporate Stakeholders and Limitations of the Implementation of the Non-Financial Reporting Directive (2014/95/EU)' (2023) 22 Journal of Accounting and Management Information Systems <https://doi.org/10.24818/jamis.2023.04002> accessed 26 June 2025.

[184] ibid.

(b) The Corporate Sustainability Reporting Directive (CSRD)

The CSRD was born out of the European Green Deal, which proposed a revision of the provisions concerning non-financial reporting under the Accounting Directive (and as amended by the NFDR).[185] The CSRD originally sought to address the shortcomings of the Non-financial Reporting Directive by expanding non-financial reporting from public-interest entities with more than 500 employees to a much broader group, including all large companies and listed SMEs except micro-enterprises, which would have increased coverage from roughly 11,700 to nearly companies across the EU.[186] After the Omnibus revision, however, the scope was significantly narrowed: CSRD reporting is now limited to large undertakings with more than 1,000 employees, with a €450 million net turnover threshold in the Council position, listed SMEs removed from the mandatory regime, and reporting deadlines for later waves postponed by two years.[187] As a result, the Omnibus reform substantially reduces the number of companies subject to mandatory sustainability reporting, even though many smaller companies will still face indirect ESG disclosure pressure through supply chains and financial market expectations.[188]

The CSRD also transforms the nature of sustainability disclosures. An important development for the field of climate adaptation finance is that the CSRD tightens and expands on the sustainability reporting criteria. Similar to the NFRD, the CSRD requires affected entities to include sustainability information in their reports, with the goal of explaining "how sustainability matters affect the undertaking's development, performance, and position."[189] Instead of requiring reports on five broad sustainability topics, however, the Directive specifies the particular information that must be included in the report. This includes, *inter alia*, the company's plans to implement actions and related financial investment plans to ensure that its business model and strategy are in line with the transition to a sustainable economy as foreseen under the Paris Agreement and the European Climate Law.[190]

In this regard, businesses are asked to assess their specific influence not just on environmental matters as a whole, but specifically on climate change. Under the CSRD, companies should also disclose climate-related information that presents an undertaking's "physical and transition risk, and about their resilience as regards, and plans to adapt to, different climate scenarios."[191] In other words, disclosures under the CSRD can provide valuable information on the climate-related risks that could impact a company's financial stability. This includes the physical risks posed to a company's assets by the increasing frequency and severity of extreme weather events. For the companies themselves, the identification of such physical risks is an important first step in catalysing investment towards climate adaptation measures to prevent future losses.

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[185] Corporate Sustainability Reporting Directive, para 1.

[186] Directive (EU) 2026/470 of the European Parliament and of the Council of 24 February 2026, Art. 2(1)(a).

[187] Should SMEs Be Subject to Mandatory Sustainability Reporting? https://www.degruyterbrill.com/document/doi/10.1515/ecfr-2025-0023/html

[188] Sustainable Directors' Duties: European and French Perspectives in Light of the Omnibus I Simplification Package or the Dilemma of the Hare and the Tortoise, https://www.degruyterbrill.com/document/doi/10.1515/ecfr-2026-0007/html

[189] ibid Art. 1(4).

[190] ibid Art. 1(4) amending Art 19(a) of the EU Accounting Directive.

[191] ibid para 47.

The provisions make clear that companies must consider both how external sustainability risks may affect the company ('outside-in risks' or financial materiality) and how the company affects society and the environment ('inside-out risks' or impact materiality).[192] This dual consideration of impact and financial risks is subsumed under the concept of 'double materiality.' Although double materiality was already a key principle underpinning the NFRD, the CSRD further develops the concept by mandating disclosures on both pillars of materiality and providing standards for assessing each pillar in the ESRS. The clarification of the double materiality concept is one of the key contributions of the CSRD in the context of climate adaptation finance. For investors, reporting according to the double materiality perspective promises a better understanding of the risks and opportunities that are posed to their investments by environmental circumstances and grants investors insights into how their investments may impact the environment.[193] Operationalizing this dual-materiality mandate requires standardized indicators and thresholds, which the CSRD delegates to the ESRS technical standard.

(c) ESRS

The European Sustainability Reporting standards further specify the information that must be reported under the disclosure obligations under the CSRD.[194] These standards were adopted by the Commission in 2023 under the title of the European Sustainability Reporting Standards.[195] Climate adaptation is covered as a separate sub-topic under the topic of climate change (E1) alongside climate mitigation under the ESRS.[196] The reporting standards outlined give a clear view of the requirements a company faces in terms of reporting on the impact and financial pillar of the double materiality concept.

Where a company's double materiality assessment identifies climate change mitigation or adaptation as material, Disclosure Requirement E1-2 prescribes that the undertaking 'shall describe its policies adopted to manage its material impacts, risks, and opportunities related to climate change mitigation and adaptation.' [197] Additionally, the company must outline the actions it performs and resources it allocates to the accomplishment of those policies, and must set a target with the goal of facilitating the tracking of the effectiveness of the policies adopted and actions undertaken by the company.[198]

The key provision regarding financial materiality is Disclosure Requirement E1-9. Reporting under this disclosure requirement is not automatic for all in-scope companies. Like E-2, it applies only where the company's double materiality assessment has identified climate change as a material

[192] 'Briefing Implementation Appraisal: Non-Financial Reporting Directive' (n 153) 3.

[193] Corporate Sustainability Reporting Directive para 9.

[194] EU Accounting Directive, Chapter 6a, Art 29(b)(1).

[195] Commission Delegated Regulation (EU) 2023/2772 of 31 July 2023 supplementing Directive 2013/34/EU of the European Parliament and of the Council as regards sustainability reporting standards (European Sustainability Reporting Standards).

[196] ibid para 3.

[197] ibid, Disclosure Requirements 1-2.

[198] ibid, Disclosure Requirements 1-4, para 32.

topic and, more specifically, where material financial risks or opportunities linked to physical or transition risks have been identified. Where this threshold is met, E-9 mandates companies to disclose the expected financial impacts of climate-related risks, as well as potential opportunities, to provide transparency on how these factors may influence their financial performance over different time horizons. Companies are obliged to disclose the anticipated financial effects from material physical risk and material transition risk, as well as the potential to benefit from material climate-related opportunities.[199] More specifically, the requirement mandates companies to reveal the financial value and percentage of assets facing significant physical risk in the short, medium, and long term before evaluating climate change adaptation strategies; with the financial values of these assets broken down by acute and chronic physical risks.[200] Building on this, companies must also specify the proportion of assets at material physical risk that is addressed by the company's climate change adaptation actions.[201]

(d) GRI Standards

In addition to the reporting requirements under EU regulation, organisations may refer to the global GRI standards for sustainability impact in the reporting process. The GRI standards are a voluntary system of reporting standards.[202] Although the GRI standards are voluntary and fall outside the EU regulatory framework, they hold substantial influence in shaping sustainability reporting practices. Notably, 18% of global regulations reference or incorporate the GRI framework, underscoring its critical role in guiding corporate transparency and accountability. Their purpose is to facilitate the reporting of organisation's impacts on the economy, environment, and people, as well as the organisation's management of these impacts. [203]

The system of GRI standards consists of sets of interrelated standards that are applicable either universally or to specific sectors or material topics. The selection of material topics is to be done by each organisation according to the selection criteria set out by the universally applicable standards.[204] Organisations which have identified climate change as a material topic under these criteria are required to report on select disclosure requirements under the GRI standards which are relevant to the organisation's climate change-related impacts.[205] In 2025, the GRI released a set of disclosure targeted standards applicable to climate change. While most disclosures under this set of standards focus on climate change mitigation, addressing areas such as transition plans, greenhouse gas emissions and removals, and the use of carbon credits, they also require organizations to disclose their climate change adaptation plans.

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[199] ibid, Disclosure Requirements 1-9, para 64.

[200] ibid, Disclosure Requirements 1-9, para 66(a).

[201] ibid, Disclosure Requirements 1-9, para 66(b).

[202] 'A Short Introduction to the GRI Standards' <https://www.globalreporting.org/media/wtaf14tw/a-short-introduction-to-the-gri-standards.pdf> accessed 5 August 2025.

[203] 'Sustainability Disclosure Still Driven by Voluntary Policies' (*GRI*, 18 November 2024) <https://www.globalreporting.org/news/news-center/sustainability-disclosure-still-driven-by-voluntary-policies/> accessed 5 August 2025.

[204] 'GRI 3: Material Topics 2021'.

[205] 'GRI 102: Climate Change 2025'.

According to the requirements, organisations shall 'describe their impacts on people and the environment associated with its climate change-related risks and opportunities and how they were considered in the development of the adaptation plan.' The organisation must also provide a detailed description of its adaptation plan, outlining the policies and actions adopted to address climate change and explaining the resulting impacts on people and the environment from implementing these measures. If an adaptation plan is not yet in place, the organisation should instead provide a clear justification for its absence and specify the steps and timeline for developing such a plan.[206] The entirety of the adaptation plan should be underpinned by climate change scenario analysis drawing either on the IPCC's scenarios or scientifically justifying the utilisation of alternative scenarios.[207]

Examples of positive and negative adaptation impacts

Positive impacts: Biodiversity or community resilience benefits derived from the implementation of nature-based solutions such as the planting of mangroves along coastlines.

Negative impacts: Contribution to land use change arising from foresting practices using non-native species to control erosion or construct climate-resilient infrastructure.

As the focus of the disclosures is to show how organisations are impacting on people and the environment, the information included should show how physical risks experienced by the company translate to such impacts. For instance, organisations might report how physical risk might affect its production facilities, leading to the dismissal of workers as a result. It may also refer to transition risks relating to the adoption of novel regulations on adaptation or social pressures exerted on organisations to change their practices in accordance with adaptation needs.[208] Reporting on how the organisation's adaptation activities are impacting on people and the environment may include negative and positive impacts of adaptation. In all respects, the adaptation plan should also specify the investments allocated for the plan's implementation. Disclosures therefore provide incentives for organisations to develop adaptation plans and invest in adaptation activities which improve their standing in light of sustainability criteria.

(e) CSDDD

Since 2024, the sustainable finance regime in the EU is further complemented by the Directive on corporate sustainability due diligence (CSDDD). At the heart of this Directive is the establishment of a corporate due diligence duty, under which companies are obliged to identify and address potential and actual adverse impacts of their extended dealings on human rights and the environment.[209] The obligations under the Directive are far-reaching, as companies must ensure due diligence in their own operations, those of their subsidiaries, and those of their direct

[206] 'GRI 102: Climate Change 2025' Disclosure 102-2.

[207] 'GRI 102: Climate Change 2025' 102 Guidance to 102-2-b-ii.

[208] 'GRI 102: Climate Change 2025' 102 Disclosure 102-2, Guidance to 102-a.

[209] Directive (EU) 2024/1760 of the European Parliament and of the Council of 13 June 2024 on corporate sustainability due diligence and amending Directive (EU) 2019/1937 and Regulation (EU) 2023/2859 (Corporate Sustainability Due Diligence Directive).

and indirect business partners throughout their value chains.[210] These rules apply to large EU limited liability companies and partnerships of more than 5000 employees and a net global turnover of more than 1.5 billion Euros in the past financial year.[211] Some companies registered in third countries are also subject to the Directive where they have either generated a net turnover of more than 1.5 billion Euros within the European Union in the financial year preceding the last, are the parent company of a group that reached that threshold, or are the parent company of a group that entered into franchising or licensing agreements in the EU in return for royalties with independent third-party companies subject to additional conditions.[212]

(f) Omnibus I

In 2025-2026, the Commission proposed eight thematic 'Omnibus Simplification Packages' to streamline the complex legislative system that regulates the EU economy. Among these initiatives, the 'Omnibus I package' on sustainability includes a set of legislative measures aimed at simplifying the corpus of EU law as it relates to sustainable finance and the carbon border adjustment mechanism.[213] The objective of the simplification measures is to boost EU competitiveness and attract investment by easing the administrative burdens placed on companies by stringent regulation.[214] The package, which proposed amendments to the CSRD and CSDDD, as well as an overhaul of ESRS data points was highly debated. The European Parliament and the Council reached a provisional agreement on the final text on 9 December 2025,[215] which the Parliament formally adopted on 16 December 2025. Following publication in the Official Journal on 26 February 2026 as Directive (EU) 2026/470,[216] the Directive entered into force on 18 March 2026.[217]

Omnibus I significantly narrowed the scope of the CSRD, raising its applicability threshold to companies with more than 1,000 employees and net annual turnover above €450 million. It also extended the deadlines for first-time reporting obligations for certain categories of companies

[210] ibid Art 8.

[211] Directive (EU) 2026/470 of the European Parliament and of the Council of 24 February 2026, Art. 4(2)(a)(i).

[212] ibid Art 2(2).

[213] 'Simplification: Council Agrees Position on the "Stop-the-Clock" Mechanism to Enhance EU Competitiveness and Provide Legal Certainty to Businesses' (*European Council*, 26 March 2025) <https://www.consilium.europa.eu/en/press/press-releases/2025/03/26/simplification-council-agrees-position-on-the-stop-the-clock-mechanism-to-enhance-eu-competitiveness/> accessed 7 May 2025.

[214] 'Omnibus Package' (*European Commission*, 1 April 2025) <https://finance.ec.europa.eu/news/omnibus-package-2025-04-01_en> accessed 26 June 2025.

[215] 'Council and Parliament Strike a Deal to Simplify Sustainability Reporting and Due Diligence Requirements and Boost EU Competitiveness' (*Council of the European Union*, 9 December 2025).

[216] Directive (EU) 2926/470 of the European Parliament and of the Council of 24 February 2026 amending Directives 2006/43/EC, 2013/34/EU, (EU) 2022/2464 and (EU) 2024/1760 as regards certain corporate sustainability reporting requirements and certain corporate sustainability due diligence requirements.

[217] Ibid art. 6.

previously in scope.[218] Beyond the scope, the final agreement removed several provisions directly relevant to climate adaptation finance. Most significantly, the requirement for in-scope CSDDD companies to adopt and implement a climate transition plan aligned with the Paris Agreement's 1.5˚C goal was deleted entirely.[219] The mandatory EU-wide civil liability regime for CSDDD breaches was also removed, leaving liability to national rules and procedures.[220] On the reporting side, the number of mandatory ESRS data points was cut by roughly 70%, from 1,073 to 320, and sector-specific reporting standards were removed altogether, pending possible future guidance.[221]

The Omnibus I package removed a climate transition plan requirement previously included in the CSDDD, meaning that companies are no longer legally required under the due diligence framework to adopt and implement a transition plan. Climate transition plans nevertheless remain relevant under the CSRD for companies that continue to fall within its scope, as the ESRS still require companies to disclose their transition plan or explain whether and when they intend to adopt one. This makes the narrowing of the CSRD's scope even more significant. Companies that are no longer subject to the revised CSRD are not required to prepare a transition plan under the CSDDD and are no longer subject to the related disclosure requirements under the CSRD. Consequently, many companies will no longer be required at the EU level to prepare or report on climate transition planning, reducing both transparency and incentives to develop credible transition strategies.[222]

While the simplification measures aim to reduce administrative burdens and enhance competitiveness, these finalised changes therefore appear to confirm, rather than allay, the concerns raised at the proposal stage that the reforms could slow the pace and scale of climate adaptation investment. The removal of the mandatory climate transition plan obligation and the sharp reduction in both reporting scope and data granularity mean that a significantly smaller pool of companies will now be required to produce climate-related disclosures, and those that do will report against a substantially lighter set of indicators. For investors and FIEs seeking to identify, price, and monitor adaptation-relevant risk and opportunity, this reduces the volume and depth of standardised sustainability data available at precisely the moment when more granular integration of physical risk into financial decision-making is needed.[223]

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[218] Council of the European Union, 'Simplification: Council gives final green light on the 'Stop-the-clock' mechanism to boost EU competitiveness and provide legal certainty to businesses (14 April 2025) https://www.consilium.europa.eu/en/press/press-releases/2025/04/14/simplification-council-gives-final-green-light-on-the-stop-the-clock-mechanism-to-boost-eu-competitiveness-and-provide-legal-certainty-to-businesses/ accessed 29 June 2026.

[219] Ibid art. 4(16).

[220] Ibi art. 4(20).

[221] 'Commission Adopts Revised Sustainability Reporting Standards to Reduce Administrative Burdens for EU Businesses While Maintaining High-Quality Disclosures' (*European Commission*, 3 July 2026) <https://finance.ec.europa.eu/news/commission-adopts-revised-sustainability-reporting-standards-reduce-administrative-burdens-eu-2026-07-03_en>.

[222] Directive (EU) 2026/470 of the European Parliament and of the Council of 24 February 2026 amending Directives 2006/43/EC, 2013/34/EU, (EU) 2022/2464 and (EU) 2024/1760 as regards certain corporate sustainability reporting requirements and certain corporate sustainability due diligence requirements [2026] OJ L 2026/470.

[223] 'Eurosif Position on the Omnibus I Package' <https://www.eurosif.org/wp-content/uploads/2025/05/2025.05.13-Eurosif-Omnibus-position.pdf> accessed 26 June 2025.

Chapter 4: Prudential Regulation and the Case for Adaptation-Adjusted Credit Risk

In addition to the European Union's sustainable finance strategy, which plays a crucial role in aligning financial flows with environmental objectives, another essential component of financial regulation that significantly impacts climate adaptation financing is the prudential regulation. Prudential regulation, which focuses on ensuring the stability and resilience of financial institutions, is pivotal in managing risks related to climate change.

As the financial sector increasingly faces the reality of climate-related risks, prudential measures become critical for safeguarding financial stability and ensuring that financial institutions are adequately equipped to support climate adaptation. Climate risk is therefore increasingly being recognized as an additional systemic risk that banks must manage, alongside traditional systemic risks arising from the amplification of financial shocks due to the interconnectedness among systemically important banks in the financial system.[224] Risks to the banking sector due to climate change can be categorised into physical risk and transition risk. The physical risk posed by climate change is the threat of physical damage and disruption posed by extreme weather events and temperature changes to the assets, workers, and overall productivity of a bank. Because extreme weather events cannot be accurately foreseen and because climate change has the potential to generate "cascading" effects once a tipping point has been reached, it is impossible to determine the precise exposure of banks to physical risk.[225] Transition risk is a consequence of technological innovations, regulatory developments, and economic changes that arise in the context of climate change and could lead to stranded assets.[226] In concrete terms, this would mean for example that banks should align their financial products with the goals under international climate change law. However, it is estimated that up to 90% of banks have loans and financial investments that are misaligned with the Paris goals, leaving them exposed to devaluations in carbon-intensive sectors like fossil fuels and heavy industry.[227]

4.1 The Basel Framework and EU Banking Regulation

As the EU advances its sustainable finance agenda, prudential regulation is increasingly being adapted to address climate-related financial risks. Climate change poses both physical and transition risks that can affect the solvency and resilience of financial institutions, with potential spillover effects on the broader financial system. Recognising these risks, EU regulators have begun integrating climate considerations into the supervisory frameworks that govern banks and insurers. This emerging strand of climate-related prudential regulation seeks to ensure that

[224] Domenico Curcio, Igor Gianfrancesco and Davide Vioto, 'Climate Change and Financial Systemic Risk: Evidence from US Banks and Insurers' (2023) 66 Journal of Financial Stability 101132 <https://doi.org/10.1016/j.jfs.2023.101132>.

[225] Mario Noera, 'Climate Risk and Banks' Capital Requirements: A Level for the Transition?' (ECCO The Italian Climate Change Think Tank 2024) Technical Report, 10.

[226]Elisa Di Febo and Eliana Angelini, 'Transition Risk in Climate Change: A Literature Review' (2025) 13 Risks 66 <https://doi.org/10.3390/risks13040066>.

[227] Noera (n 191) 7.

financial institutions identify, assess, and manage climate risks as part of their core risk management processes, and that supervisors account for these risks when evaluating institutional soundness and systemic stability. In this context, the European Supervisory Authorities (ESAs), the European Central Bank (ECB), and national competent authorities are playing key roles in aligning prudential oversight with climate objectives. To understand this evolution, it is useful to examine the conceptual foundations of banking regulation and the ways in which climate risk is being incorporated into both its micro- and macroprudential dimensions.

Prudential regulation refers to the set of supervisory policies and standards aimed at promoting the safety and soundness of financial institutions and the stability of the financial system as a whole. It is commonly divided into two complementary approaches: microprudential and macroprudential regulation. Microprudential regulation focuses on the health of individual financial institutions, seeking to ensure they remain solvent and capable of withstanding idiosyncratic shocks. In contrast, macroprudential regulation targets systemic risk, aiming to mitigate vulnerabilities that could trigger or amplify financial instability across the broader system.

At the global level, traditional financial risks are addressed by the Basel Framework (Basel III), a set of financial reforms that requires banks to hold capital reserves, maintain liquidity buffers, and conduct stress testing to ensure they can survive various threats to their financial stability, including those that might trigger systemic risks. Basel III was developed by the Basel Committee in the aftermath of the 2008 Global Financial Crisis, which brought to the fore the necessity of raising the resilience of the banking sectors in countries across the globe.[228] While traditionally considered a microprudential framework, the Basel III regulatory architecture—developed in response to the global financial crisis—incorporates both dimensions. Basel III is supposed to improve Banks' resilience to financial shocks and, in turn, reduce the likelihood of another global financial crisis.[229] These regulations ensure that banks can withstand financial shocks and maintain stability by actively identifying and addressing risks. Banks must establish robust processes to assess and manage these risks effectively. Furthermore, they must maintain sufficient capital to absorb unexpected losses, thereby protecting depositors and maintaining confidence in the banking system.

While the Basel Framework provides a foundation, its non-binding nature necessitates implementation through regional or national law.[230] In the EU, Basel III is therefore implemented into EU law via the EU Capital Requirements Directive (CRD)[231] and the EU Capital Requirements Regulation (CRR).[232] In the EU, the requirements of the Basel Framework apply in the EU to all EU

[228] 'Basel III: A Global Regulatory Framework for More Resilient Banks and Banking Systems' paras 4-6.

[229] 'Basel III' (*European Commission*, 25 July 2024) <https://finance.ec.europa.eu/news/basel-iii-2024-07-25_en> accessed 26 June 2025.

[230] Banks and supervisory agencies from a total of 28 jurisdictions commit to implementing the Framework. See 'Basel Committee Membership' (*Bank for International Settlements*, 14 May 2024) <https://www.bis.org/bcbs/membership.htm> accessed 26 June 2025.

[231] Directive 2013/36/EU of the European Parliament and of the Council of 26 June 2013 on access to the activity of credit institutions and the prudential supervision of credit institutions and investment firms, amending Directive 2002/87/EC and repealing Directives 2006/48/EC and 2006/49/EC (EU Capital Requirements Directive).

[232] Regulation (EU) 2024/1623 of the European Parliament and of the Council of 31 May 2024 amending Regulation (EU) No 575/2013 as regards requirements for credit risk, credit valuation adjustment risk, operational risk, market risk and the output floor (EU Capital Requirements Regulation).

banks.[233] The current set of rules effective in the EU is the CRR3/CRD6 Banking package which includes the Capital Requirements Regulation III and the Capital Requirements Directive VI, amending the original Capital Requirements Regulation and Directive initially adopted in 2013.

Basel III is divided into three pillars: Minimum capital Requirements, supervisory review process, and market discipline.[234] The EU Capital Requirements Directive and Regulation transpose all three pillars of the Basel III Framework into EU law. The first pillar establishes a formula for the calculation of a minimum capital ratio. The calculation of the minimum capital ratio builds on the classification of the bank's assets depending on risk. Assets with a higher risk weight (e.g. debentures) require a bank to hold more capital than low risk-weighted assets (e.g. government bonds).[235] Pillar two establishes a supervisory review process. According to the requirements under pillar two, banks must assess their own internal capital adequacy (known as the Internal Capital Adequacy Assessment Process "ICAAP") for covering all potential risks, including certain risks not covered under pillar one. [236] Based on the ICAAP, the banking supervisory authority of the country in which the bank is headquartered may set a minimum capital requirement that includes an additional capital buffer for risks covered under pillar two. Such risks include, for example, systemic risks which depend on the connections between banks and therefore require an assessment that goes beyond examining the risk faced by the assets of an individual institution. Finally, Pillar three of Basel III spells out a set of disclosure requirements to ensure market discipline.

4.2 Market Discipline: Pillar 3 disclosures on ESG risks

At the European regional level, ESG requirements were first integrated into the Basel Framework through the EBA Standards on Pillar 3 disclosures on Environmental, Social, and Governance Risks.[237] These standards implement Article 449a of the Capital Requirements Regulation (III), which obliges institutions to disclose ESG risk information, disaggregated into physical and transition risk categories.[238] The technical standards were adopted into EU law in late 2022 through a Commission Implementing Regulation (the Article 449a implementing regulation),[239] amending an earlier version of the same disclosure standards.

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[233] 'Basel III: A Global Regulatory Framework for More Resilient Banks and Banking Systems' (n 226).

[234] The three pillars approach was established by the Basel II Framework. See 'International Convergence of Capital Measurement and Capital Standards: A Revised Framework' (Basel Committee on Banking Supervision 2004) <https://www.bis.org/publ/bcbs107.pdf>.

[235] 'Risk-Weighted Assets' (*Corporate Finance Institute*) <https://corporatefinanceinstitute.com/resources/career-map/sell-side/risk-management/risk-weighted-assets/> accessed 25 June 2025.

[236] 'Pillar 2 Requirement' (*European Central Bank*) 2 <https://www.bankingsupervision.europa.eu/activities/srep/pillar-2-requirement/html/index.en.html> accessed 26 June 2026.

[237] 'Final Report Draft Implementing Technical Standards on Prudential Disclosures on ESG Risks in Accordance with Article 449a CRR' (European Banking Authority 2022) EBA/ITS/2022/01 <https://www.eba.europa.eu/sites/default/files/document_library/Publications/Draft%20Technical%20Standards/2022/1026171/EBA%20draft%20ITS%20on%20Pillar%203%20disclosures%20on%20ESG%20risks.pdf>.

[238] EU Capital Requirements Regulation, Art 1(229)(1).

[239] Commission 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.

Following the Article 449a implementing regulation, banks must disclose the interactions between climate risks and other risks on their balance sheets, and the mitigating actions already taken, through comprehensive quantitative metrics and qualitative explanations.[240] Quantitative metrics are numerical data measuring a bank's exposure to ESG risks—physical and transition risks—and mitigation actions such as green asset shares or carbon emissions. Qualitative explanations, by contrast, provide narrative context on the bank's strategies, governance, and risk management processes. Together, these elements give a comprehensive view of how banks address sustainability challenges.

For climate adaptation financing, the technical standards introduce two formulas for uniform, comparable reporting on how banks' financing activities contribute to the Paris Agreement's objectives: the Green Asset Ratio (GAR) and the Banking Book Taxonomy Alignment Ratio (BTAR).[241] Rooted in the EU Taxonomy framework, both ratios assess whether banks are directing funds toward environmentally sustainable activities. The GAR aligns with the reporting obligation under Article 8 of the EU Taxonomy Regulation and describes the percentage of a bank's assets that are taxonomy-aligned.[242] It may only include exposures to companies required to report under the CSRD (or NFRD).[243] The EU-wide average GAR currently stands at 7.9%, according to the European Banking Authority.[244] The BTAR complements the GAR by broadening the assessment to exposures not covered by CSRD (or NFRD) reporting obligations, including non-EU non-financial corporations.[245] Unlike GAR disclosure, which is mandatory, BTAR disclosure remains optional for institutions.[246]

For qualitative disclosures, banks must report on strategy and process, governance, and risk management across the three ESG categories.[247] The requirements vary slightly by category; given this report's scope, a focus on environmental risk suffices. On strategy, banks report how they integrate environmental risk into their business strategy, objectives and targets across different time horizons, and their progress in aligning investments with the EU Taxonomy.[248] On

[240] ibid Article 1(1). Inserting Article 18(a)(1) into Commission Implementing Regulation (EU) 2021/637 of 15 March 2021 laying down implementing technical standards with regard to public disclosures by institutions of the information referred to in Titles II and III of Part Eight of Regulation (EU) No 575/2013 of the European Parliament and of the Council and repealing Commission Implementing Regulation (EU) No 1423/2013, Commission Delegated Regulation (EU) 2015/1555, Commission Implementing Regulation (EU) 2016/200 and Commission Delegated Regulation (EU) 2017/2295.

[241] Commission 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, Templates 7 and 9.

[242] ibid, Template 8(5)(a).

[243] ibid.

[244] 'EBA Publishes Results of EU-Wide Pilot Exercise on Climate Risk' (*European Banking Authoritz*, 21 May 2021) <https://www.eba.europa.eu/publications-and-media/press-releases/eba-publishes-results-eu-wide-pilot-exercise-climate-risk> accessed 26 June 2025.

[245] Commission 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, Templates 9(2) and 9(8).

[246] ibid, Template 9(1)(1).

[247] ibid Art 1(1) insering Art 18(a)(1)(1) into Implementing Regulation (EU) 2021/637.

[248] ibid Table 1(a)-(d) and table 2(a)-(c).

governance, banks disclose the management body's role in ESG risk oversight, the integration of ESG risk into institutional structures and reporting lines, and the alignment of remuneration with environmental risk factors.[249] On risk management, banks must explain the definitions, methodologies, and standards underpinning their environmental risk approach; the processes used to identify, measure, and monitor exposures sensitive to environmental risk; the transmission channels through which these risks affect their financial condition; the tools used for risk assessment and their outcomes, including impacts on capital and liquidity; and how environmental risk is linked to credit, market, liquidity, operational, and reputational risk within the broader risk management framework.[250]

In sum, the Article 449a regulation marks a significant advance in embedding ESG considerations into the European application of Basel Pillar 3, promoting transparency and comparability in how banks report ESG risk exposure—particularly by distinguishing physical from transition risk. Standardised indicators such as the GAR and BTAR help stakeholders assess banks' alignment with the EU Taxonomy and the Paris Agreement, while qualitative disclosures add context on governance and risk management. Looking forward, this improved transparency is likely to incentivise investment in climate adaptation, as institutions are encouraged to shift capital toward activities that build resilience to climate change and are rewarded by market discipline for doing so.

4.3. Supervisory review process and risk management: ESG Considerations in Pillar 2

Beyond disclosure obligations under Pillar 3, the Basel framework also requires institutions to actively manage ESG risks as part of their internal risk processes and through supervisory engagement under Pillar 2. The integration of ESG risks into Pillar 2 of the Basel framework reflects the growing recognition that environmental and social factors can pose material prudential risks. Under Article 87(1) of the Capital Requirements Directive VI (CRD VI), institutions are required to have sound, effective and comprehensive strategies and processes for assessing and maintaining adequate capital, including in relation to ESG risks.[251] This obligation is further specified in the EBA Guidelines on the management and supervision of ESG risks, which provide supervisors and institutions with a common framework for embedding ESG considerations into internal governance and risk management.[252] While not legally binding, the Guidelines guide supervisory assessments under the SREP (Supervisory Review and Evaluation Process). The guidelines became effective for significant institutions on 11 January 2026. Small and non-complex institutions are given one more year and will therefore have to comply by 11 January 2027. This phased implementation reflects proportionality principles while ensuring all institutions integrate robust ESG risk management frameworks into their operations.[253] Complementary publications, such as the EBA's 2021 report on ESG risk management and the one-off climate risk scenario analysis conducted under the Fit-for-55 package, offer additional insights into

[249] ibid Table 1(e)-(i).

[250] ibid Table 1(j)-(r).

[251] EU Capital Requirements Directive Article 87 as amended by Directive 2024/1619/EU Art 1(28).

[252] ibid Article 87a(5)(b) as amended by Directive (2024/1619 (EU) Art. 1(28).

[253] 'Guidelines on the Management of Environmental, Social and Governance (ESG) Risks' (European Banking Authority 2025) EBA/GL/2025/01Preamble paras 23-28 <https://www.eba.europa.eu/sites/default/files/2025-01/fb22982a-d69d-42cc-9d62-1023497ad58a/Final%20Guidelines%20on%20the%20management%20of%20ESG%20risks.pdf>.

supervisory approaches and emerging practices, although they do not themselves impose legal obligations. Among the various instruments shaping the supervisory treatment of ESG risks under Pillar 2, the EBA Guidelines on the management and supervision of ESG risks stand out as the most comprehensive and authoritative reference point. A closer examination of their content reveals how ESG considerations are being systematically integrated into risk management expectations and supervisory practices. The EBA Guidelines introduce three new key requirements for financial institutions. The preparation of forward-looking transition plans, the conduction of scenario analysis, and the retainment of a minimum amount of capital and liquidity.

4.3.1 Transition plans (EBA)

Institutions now need to prepare forward-looking transition plans with specific timelines, quantifiable targets, and milestones aligned with EU sustainability objectives.[254] On the basis of the transition plans, institutions should be able to assess and integrate forward-looking ESG risks into their planning and policy processes and ensure that they can develop the necessary resilience to withstand future risks.[255] The EBA Guidelines only address the prudential dimension of transition planning. The dimension of transition planning referred to in this context is therefore distinct from the requirements established under the CSRD and the CSDDD, which focus on aligning the business activities of companies with a net-zero emissions pathway, in addition to minimising the company's own systemic climate transition risk.[256]

Financial Institutions need to maintain both prudential transition plans and broader transition plans aligned with the CSRD and the CSDDD. Despite their different scope, the EBA has made clear that transition planning and policy processes should integrate all applicable regulatory requirements, including the obligation to develop a transition plan laid down in the CSRD and CSDDD.[257] In practice, this means that banks should integrate the two transition plans into a single, coherent document.

4.3.2 Materiality assessments and credit ratings

Secondly, institutions must prepare materiality assessments of ESG risks, which also consider the effects of ESG risks on other traditional financial risk categories.[258] The EBA Guidelines explicitly state that these assessments must correspond to materiality assessments under the Accounting Directive and the European Sustainability Reporting Standards, implying that the EBA Guidelines adopt the concept of double rather than single materiality.[259] The results of this assessment are then to be taken into consideration in the institutions ICAAP,[260] thus integrating ESG risks into pillar II of the Basel.

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[254] ibid Preamble paras 15-22.

[255] ibid Preamble para 12.

[256] Pietro Nannerini Calderini, 'Come L'EBA Sta Interpretando La Redazione Dei Piani Prudenziali Delle Banche.' (*Corriere 2030*, 22 October 2024) <https://www.corriere2030.org/2024/10/22/come-leba-sta-interpretando-la-redazione-dei-piani-prudenziali-delle-banche/>.

[257] ibid Preamble para 15.

[258] ibid Section 4.1. para 12.

[259] ibid.

[260] ibid.

On the basis of materiality assessments, institutions are also expected to adjust internal credit ratings to reflect environmental and social risks, ensuring that credit evaluations are forward-looking and aligned with EU sustainability and transition objectives, as outlined in the required forward-looking transition plans.[261] This integration enables a more nuanced understanding of borrower risk profiles, especially in sectors vulnerable to climate-related disruptions, and supports embedding ESG considerations into credit risk models and ICAAP processes. By doing so, institutions lay the groundwork for more targeted methodologies, such as climate adaptation adjustments, that better reflect the evolving risk landscape and regulatory expectations.

4.3.3 Scenario analysis

In addition, the Guidelines set criteria for the testing of institutions in terms of their resilience to long-term negative factors under multiple scenarios (scenario analysis) which represent baseline as well as adverse circumstances.[262] This is particularly important for climate change risk, as institutions are expected to start by conducting scenario analysis for climate-related factors. A baseline scenario in this case may be represented by a gradual implementation of climate policies, which does not lead to sudden shocks to the financial system, and a mild warming trajectory which does not surpass the 1.5˚C limit of the Paris Agreement. By contrast, an adverse scenario might include a warming trajectory that surpasses the 2.0˚C and heightened exposure to extreme weather events, accompanied by sudden regulatory changes driven by an intensified urgency to adapt.[263] These examples illustrate that climate scenarios should take into account how emissions levels and their climate impact and climate policies may develop in the future. In addition to this, institutions should also consider related elements, which might include the socioeconomic context they might find themselves in in the future, technological developments, future sources of energy production, consumer preferences, and sectoral pathways to net zero.[264] On 5 November 2025, following the public consultation, the EBA published its final Guidelines on environmental scenario analysis, which set out how institutions should conduct such analysis in practice.[265] The final Guidelines distinguish between two complementary tools: a stress test, used to assess an institution's short-term financial (capital and liquidity) resilience to environmental shocks, and a resilience analysis, which evaluates the medium- to long-term adaptability of its business model over a horizon of at least ten years.[266] In response to the consultation feedback, the EBA also narrowed the scope of the Guidelines to environmental risks, with climate as the priority; scenario analysis on social and governance factors is not required at this stage, although it may be incorporated in future revisions as the

[261] Ibid.

[262] 'Guidelines on the Management of Environmental, Social and Governance (ESG) Risks' (n 219); EU Capital Requirements Directive Art 87a(3) as amended by Directive 2024/1619 Art 1(28).

[263] 'Draft Guidelines on ESG Scenario Analysis' (European Banking Authority 2025) Consultation Paper EBA/GL/2025/02, para 80.

[264] ibid.

[265] 'Guidelines on Environmental Scenario Analysis' (European Banking Authority 2025) EBA/GL/2025/04; European Banking Authority, 'The EBA Publishes Its Final Guidelines on Environmental Scenario Analysis' (Press Release, 5 November 2025) <https://www.eba.europa.eu/publications-and-media/press-releases/eba-publishes-its-final-guidelines-environmental-scenario-analysis> accessed 29 September 2026.

[266] 'Guidelines on Environmental Scenario Analysis' (European Banking Authority 2025) EBA/GL/2025/04, paras 17, 27 and 59.

relevant methodologies mature. The Guidelines apply from 1 January 2027, later than the 11 January 2026 application date of the EBA Guidelines on the management of ESG risks, to give institutions additional time to build the necessary capabilities.[267]

These guidelines represent a critical step in enhancing investments in climate adaptation by integrating resilience-centred considerations into the fundamental risk management and planning frameworks of financial institutions. By mandating that institutions create forward-looking transition plans with measurable targets in line with EU sustainability goals, they encourage the identification and funding of climate adaptation projects, including resilient infrastructure and technologies designed to mitigate physical climate risks. Likewise, the mandated materiality assessments, which incorporate a double materiality approach, ensure that institutions consider both the financial implications of climate risks and their wider environmental impacts. This dual emphasis promotes investments that tackle systemic vulnerabilities while catering to societal adaptation requirements. Additionally, focusing on scenario analysis—which includes negative scenarios with temperature increases exceeding 2°C and severe weather events—underscores the necessity of being ready for the most unfavourable scenarios. By mandating that institutions assess their ability to withstand such conditions, the guidelines effectively promote investments in adaptation strategies that minimise vulnerability to physical risks. In this regard, institutions may also be encouraged to apply the EU Taxonomy to identify financial products that are deemed sustainable and thus exposed to lower climate risk.

4.4. Minimum capital (and liquidity) requirements: ESG risk considerations in pillar 1

In contrast to the more established integration of ESG risks within Pillars 2 and 3 of the Basel framework, the incorporation of these risks into Pillar 1 remains at a formative stage. While capital requirements under Pillar 1 are intended to be risk-sensitive and rules-based, the integration of environmental and social risks poses methodological and conceptual challenges that have yet to be fully resolved. The European Banking Authority (EBA) has begun to explore these issues through non-binding publications, notably its 2022 Discussion Paper on the role of environmental risks in the prudential framework and its 2023 Report on the role of environmental and social risks in the prudential framework. In its more recent report, the EBA recommends further integration of environmental and social risks into financial institutions' risk management practices. Specifically, it highlights the need to include environmental risks in stress testing frameworks. It also encourages the incorporation of environmental and social factors in credit assessments by rating agencies, due diligence processes, and the valuation of real estate collateral. Furthermore, institutions should identify environmental and social factors that may lead to operational risk losses, and supervisors are advised to gradually develop metrics to monitor environmental concentration risk in their oversight activities.[268] However, unlike the guidance developed under Pillars 2 and 3, these contributions are exploratory in nature and do not currently impose any formal prudential requirements. As such, the regulatory treatment of ESG risks under Pillar 1 remains a work in progress, with further evidence and methodological development needed before concrete reforms can be implemented.

[267] ibid, para 9 (scope) and paras 13 and 18 (date of application).

[268] 'Report on the Role of Environmental and Social Risks in the Prudential Framework' (2023) EBA/REP/2023/34.

4.5 Central banks: Integration of climate-related and environmental risk into banking regulation

The process of integrating climate-related and environmental risks into banking regulation in the European Union has been led by the European Central Bank. At the same time, Supervisory Authorities across the EU have played an increasingly active role in operationalising this agenda at the national level. A critical element of this integration has been the use of climate stress testing, which has been adopted by several national supervisors as well as the European Banking Authority (EBA) to assess the resilience of financial institutions to climate-related risks. The ECB has also drawn heavily on the work of the Network for Greening the Financial System (NGFS), aligning its approach with international best practices to ensure consistency and credibility in the development of climate-related prudential tools. This coordinated effort has laid the groundwork for more systematic climate risk assessments across the European banking sector.

4.5.1 ECB Guidelines

The European central Bank oversees the integration of climate-related and environmental risks into the prudential supervision of significant financial institutions in the euro area. The ECB's two main responsibilities are to ensure price stability within the euro area and to shepherd the robustness of the European banking system. Regarding the ECB's latter competency, the Bank is tasked with the supervision of banks in the euro area, ensuring their stability and compliance with regulatory standards. Prior to the development of regulatory initiatives from the EU, such as the 2024 "banking package" that amended the Capital Requirements Regulation and Directive, the European Central Bank had already begun to develop a policy framework for the euro area with the goal of clarifying the supervisory expectations relating to risk management and disclosure in view of climate-related risks. The main document in this regard is the ECB's "Guide on climate-related and environmental risks", published in 2020, which emphasizes the importance of integrating climate-related and environmental risks into the prudential supervision of financial institutions. In the document, the ECB asserts that climate-related and environmental risks should be viewed as factors that can influence existing prudential risk categories. On this basis, the guidelines outline how the ECB expects banks to incorporate these risks into their business strategies, governance structures, and risk management practices. Furthermore, it explains how institutions should improve transparency by conducting more detailed climate and environmental disclosures.[269]

Even though the EU framework has now developed to mandate the management and disclosure of climate-related and other ESG risks, the ECB guide remains relevant as a supervisory tool for banks and supervisors. While the EU banking regulation spells out the legal requirements banks must abide by, the ECB guidelines translate these obligations into practical expectations that the ECB, as a supervisory body, has towards its supervisee banks

[269] 'Guide on Climate-Related and Environmental Risks Supervisory Expectations Relating to Risk Management and Disclosure' 3 <https://www.bankingsupervision.europa.eu/framework/legal-framework/public-consultations/pdf/climate-related_risks/ssm.202005_draft_guide_on_climate-related_and_environmental_risks.en.pdf> accessed 7 May 2025.

within the euro area (i.e. supervisory expectations). The ECB Guidelines are also tailored to the integration of climate-related and environmental risk into supervisory expectations and therefore have a narrower scope than the more general EBA Guidelines on ESG risks, which include, but do not focus on climate and environmental risk.

In line with the ECB's mandate, the guidelines apply to significant institutions that are directly supervised by the ECB. Significant institutions are those banks which the ECB deems significant in terms of their size, economic importance, extent of its cross-border activities, or because it has received direct public financial assistance from a European rescue fund.[270] Less significant institutions, including those located in the euro area, are supervised by national competent authorities, which are recommended to apply the ECB guidelines to less significant institutions under their jurisdiction, but may additionally issue or have issued their own guidance on climate-related or environmental risks.[271]

The ECB Guidelines set out supervisory expectations for banks, organized into four key areas: business models and strategy, governance and risk appetite, risk management, and disclosures. In terms of their content, the ECB Guidelines zoom in on how physical risk and transition risk drive prudential risk by exacerbating credit risk (e.g. stranded asset default), operational risk (e.g. the disruption of operations through natural disasters), market risk (e.g. changes in the prices of food commodities affected by climate change), and liquidity risk (e.g. sudden withdrawals from accounts in order to finance damage repairs).[272] The Guidelines then establish a set of supervisory expectations for banks, which are divided into four categories as they relate to business models and strategy, governance and risk appetite, risk management, and disclosures. Supervisory expectations relating to risk management are especially salient in the context of climate adaptation finance. This section therefore undertakes a focused analysis of Chapter 6 of the ECB Guidelines, which sets out supervisory expectations for the integration of climate-related and environmental risks within institutions' broader risk management frameworks. Establishing a solid understanding of how these expectations are structured and operationalized, especially in relation to credit risk, is critical for identifying potential entry points where policy tools, such as strategies for increasing finance in climate adaptation, could be most effective.

Overall, the expectation placed on banks is that they should "incorporate climate-related and environmental risks as drivers of existing risk categories into their risk management framework."[273] This implies, most fundamentally, that institutions should have a risk management framework that spans the whole institution. Institutions should then analyse how climate-related and environmental risks affect the traditional risk areas of liquidity, credit, operational, and market risk, as well as any other risk that could have a substantial impact on the institution's capital. This exercise should result in a holistic assessment of the risks posed by climate-related

[270] ECB, What makes a bank significant?, https://www.bankingsupervision.europa.eu/framework/supervised-banks/criteria/html/index.en.html

[271] European Central Bank, Guide on climate-related and environmental risks: Supervisory expectations relating to risk management and disclosure (November 2020) p. 7.

[272] European Central Bank, Guide on climate-related and environmental risks: Supervisory expectations relating to risk management and disclosure (November 2020) p. 10-11.

[273] 'Guide on Climate-Related and Environmental Risks Supervisory Expectations Relating to Risk Management and Disclosure' (n 235) 31.

and other environmental risks on the existing risk categories in the short, medium, and long term.[274] Institutions should then do their best to quantify those risks, drawing on metrics developed by international networks and standard setters, using in particular the methods of scenario analysis and stress testing.[275] The results of the assessment should be well-documented by the institution, which is additionally expected to develop a risk management framework that spells out how the institution might manage or mitigate the climate-related and environmental risks it has identified.[276] Furthermore, as part of their risk strategy, banks are expected to conduct environmental due diligence when they establish new relationships with clients and throughout the maintenance of that relationship. In other words, institutions should gather information on the client's impact on, vulnerability to, and conduct regarding climate-related and environmental risks.[277] This expectation ensures that banks protect themselves against credit and financial risks that they might face if a client's exposure to climate and environmental risks forces them to default on payments. In line with this, institutions should also assess their own capital adequacy to deal with climate-related and environmental risks and include in this assessment their perspective on how they meet the capital adequacy requirements they are subject to and predictions and an economic value perspective, which details how climate-related and environmental risk might impact the institution's financial performance.[278] In order to guarantee the effectiveness of these measures, institutions are supposed to regularly review and evaluate the approaches and methodologies used to determine the information they are required to establish.[279]

Banks are expected to incorporate climate-related and environmental risks into credit risk assessment through loan pricing, borrower evaluation, collateral valuation, and portfolio monitoring.

As previously mentioned, the consideration of climate-related and environmental risk in credit risk management processes is of particular importance to the topic of climate finance. Expectation 8 of the ECB Guidelines refers to Article 79 of the Capital Requirements Directive, according to which competent authorities must ensure that institutions grant credit on the basis of "sound and well-defined criteria" and that the process for approving, amending, renewing and refinancing credit is clearly established.[280] The EBA Guidelines on loan origination and monitoring further prescribe in this regard that institutions must consider risks associated with climate-related and environmental factors in their credit risk policies and procedures.[281] Institutions are therefore expected to take the following measures when granting credit to a client:

[274] ibid, Expectations 7.1. and 7.2.

[275] ibid, Expectation 7.3.

[276] ibid, Expectation 7.4.

[277] ibid, Expectation 7.5.

[278] ibid, Expectation 7.6.

[279] ibid, Expectation 7.7.

[280] EU Capital Requirements Directive Art 79.

[281] 'Guidelines on Loan Origination and Monitoring' (European Banking Authority 2020) EBA/GL/2020/06, para 56.

- Consider how climate-related and environmental risks affect the borrower's default risk.[282]
- Develop indicators or ratings that consider climate-related and environmental risk to be able to assess whether a borrower is affected by heightened climate-related and environmental risks.[283]
- Include the potential impact of climate-related and environmental factors in determining the (future) value of real estate that serves as collateral in credit.[284]
- Monitor the impact of climate-related and environmental risks in distinct geographical locations and sectors to identify concentrations of credit risk in their portfolios.[285]
- Price their loans with consideration to their credit risk appetite and business strategy. This means that if the credit risk appetite and business strategy foresee a reduction of lending activities in sectors harmful to the environment, the institution's loan pricing should reflect this decision.[286]
- Price their loans in according to the actual costs associated with the climate-related and environmental risks of the loans or the assets underlying them.[287]

In summary, institutions are expected to systematically integrate climate-related and environmental risks into all aspects of their credit risk assessment processes, ranging from borrower evaluation and collateral valuation to portfolio monitoring and loan pricing, in line with evolving regulatory expectations.

4.5.2 EBA Stress test

At the EU level, the European Banking Authority responded to these initiatives by launching a pilot climate evaluation with participation from financial institutions throughout the European Union.[288] The EBA pilot exercise was conducted with the goal of collecting data and identifying methodological challenges to the categorisation of exposures in light of climate risk factors. As the exercise was not designed as a formal stress test, it focused on evaluating how effectively existing approaches can identify and categorize climate-related risks within banks' corporate loan portfolios, while also highlighting key data limitations. This assessment included an estimate of the extent to which banks' current exposures align with the EU Taxonomy.[289] Insights from this pilot are intended to inform future EBA efforts in developing climate stress testing frameworks.[290]

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[282] 'Guide on Climate-Related and Environmental Risks Supervisory Expectations Relating to Risk Management and Disclosure' (n 235) Expectation 8.1.

[283] ibid, Expectation 8.2.

[284] ibid, Expectation 8.3.

[285] ibid, Expectation 8.4.

[286] ibid, Expectation 8.5.

[287] ibid, Expectation 8.6.

[288] Alix Auzepy and Christina E Bannier, *Integrating Climate Risks in Bank Risk Management and Capital Requirements* (Springer Fachmedien Wiesbaden 2025) 10 <https://link.springer.com/10.1007/978-3-658-47061-6> accessed 7 April 2025.

[289] 'Mapping Climate Risk: Main Findings from the EU-Wide Pilot Exercise' (European Banking Authority 2021) EBA/Rep/2021/11, 10.

[290] ibid.

Alongside regulatory shifts, central banks have played a key role in operationalising climate risk by embedding it into prudential frameworks, most notably through the development and application of climate stress testing. In 2018, the Dutch central bank De Nederlandsche Bank set a significant precedent by introducing the first mandatory stress test with a transition risk focus.[291] The pioneering exercise modified the Dutch central bank's existing method for assessing banks' credit risks by incorporating the potential financial impacts of the transition to a low-carbon economy. It demonstrated how traditional prudential tools can be adapted to capture emerging risks related to climate change.[292] This methodological innovation demonstrated how existing prudential tools could be modified to address emerging climate-related financial risks. In 2020, the Banque de France further developed the example set by the Dutch central bank by initiating a pilot exercise in which voluntary stress tests were performed on nine large banking groups and several insurance groups.[293] The stress tests performed by the Banque de France significantly expanded the scope of the test, drawing on the guidelines on the construction of climate change scenarios issued by the Network for Greening the Financial System.[294] Most notably, the tests considered three different transition scenarios and one physical risk scenario, all projected over a 30-year timeframe.[295] Following these developments, the Bank of England further advanced climate risk assessments for financial institutions in 2021. The Bank implemented a climate-related stress test targeting key UK banks, examining both the risks linked to climate transition and those stemming from physical climate impacts. This exercise was specifically designed to assess the resilience of the entirety of the UK financial system to climate risk over a thirty-year period, including both transition and physical climate risk into a system-wide stress test.[296]

Among the five states hosting CLIMATEFIT leader territories – Italy, France, Belgium, Romania and Slovenia, France's ACPR (Autorité de contrôle prudentiel et de résolution) was the pioneer in climate stress testing analysis. None of the supervisory authorities across the five states have introduced mandatory stress tests to assess the resilience of their supervisors. In 2024, researchers from the Network for Greening the Financial System (NGFS) and the Banca d'Italia carried out an analysis using NGFS scenarios to explore the potential long-term impacts of climate-related risks on Italy.[297] However, this analysis focused solely on projections for Italy's GDP and inflation across three NGFS scenarios and did not evaluate the resilience of the Italian banking

[291] Auzepy and Bannier (n 265) 10.

[292] Robert Vermeulen and others, 'An Energy Transition Risk Stress Test for the Financial System of the Netherlands' (DeNederlandsche Bank) Volume 16-17 <https://www.dnb.nl/media/pdnpdalc/201810_nr-_7_-2018-_an_energy_transition_risk_stress_test_for_the_financial_system_of_the_netherlands.pdf>.

[293] Paul J Forrester, 'The Results Are In! France's ACPR Publishes Report Of 2020 Pilot Climate Risk Assessment (AKA Stress Test) For Participating French Banks And Insurers' (*Mayer Brown*, 10 May 2021) <https://www.eyeonesg.com/2021/05/the-results-are-in-frances-acpr-publishes-report-of-2020-pilot-climate-risk-assessment-aka-stress-test-for-participating-french-banks-and-insurers/> accessed 27 June 2025.

[294] 'A First Assessment of Financial Risk Stemming from Climate Change: The Main Results of the 2020 Climate Pilot Exercise' (Banque de France) No 122-2021, 2.

[295] ibid 9.

[296] 'Key Elements of the 2021 Biennial Exploratory Scenario: Financial Risks from Climate Change' (*Bank of England*, 8 June 2021) <https://www.bankofengland.co.uk/stress-testing/2021/key-elements-2021-biennial-exploratory-scenario-financial-risks-climate-change> accessed 27 June 2025.

[297] Maria Alessia Aiello and others, 'Climate-Related Risks for Italy: An Analysis Based on the Latest NGFS Scenarios' 847 <https://www.bancaditalia.it/pubblicazioni/qef/2024-0847/QEF_847_24.pdf?language_id=1> accessed 27 June 2025.

sector. As a result, no EU or national authority uses climate stress test results to directly impose capital charges, supervisory authorities across the five States currently possess limited insight into the potential consequences of climate change for their respective banking systems.

4.6 From regulatory requirements to risk measurement

The analysis developed in this chapter shows that prudential regulation increasingly acknowledges climate-related risks as drivers of traditional financial risk categories, and that supervisors now expect financial institutions to integrate physical risks into their risk management frameworks. However, the framework remains largely principles-based: it establishes that physical risks should be identified, measured, and reflected in credit risk assessment, but offers limited guidance on how this should be done, and even less on how the risk-reducing effect of adaptation investments should be recognised. As long as this methodological gap persists, the potential of prudential rules to reward adaptation through lower risk parameters, and ultimately lower capital requirements, remains largely theoretical.

The following two chapters address this gap by moving from the regulatory level to the level of risk measurement. **Chapter 5** develops a **sector vulnerability framework** that assesses the exposure and sensitivity of economic sectors to physical climate hazards thereby providing a structured basis for identifying where physical risk is most material for credit portfolios. Building on this framework, **Chapter 6** proposes a **method for adjusting probabilities of default (PD)** to reflect sector-level vulnerability, showing how differences in exposure can be translated into a core parameter of credit risk models. Taken together, the two chapters aim to demonstrate how the supervisory expectations discussed in this chapter can be operationalised, and how adaptation can become visible in the risk metrics that drive lending and capital decisions.

Chapter 5: Sector Vulnerability Framework

Economic activities are not equally vulnerable to climate risk, and they are not vulnerable in the same way.[298] Vulnerability depends on the structure of production — on how much value is embedded in fixed physical assets, how widely output depends on labour performed in exposed conditions, and how directly the activity relies on climate-conditioned natural inputs. The same hazard can produce very different levels of risk across sectors that are nominally exposed to it in the same way. What differs is whether the hazard actually reaches the critical elements of the business, such as key assets, supply chains or revenue drivers, and how vulnerable those elements are, meaning how sensitive they are and how well they can cope or adapt. Exposure and vulnerability together determine the level of risk and the potential impact that determine financial materiality.

The Sector Vulnerability Framework proposed by ClimateFit, generates for each NACE divisions[299] (2-digit) a Vulnerability Intensity Sector score (VIS) for each physical climate hazard considered. VIS is an ordinal assessment expressing how severely that hazard is expected to affect the sector through three risk transmission channels: tangible assets, workforce and climate. These risk transmission channel-level assessments are combined into the Vulnerability Intensity Sector score (VIS), expressed on a common 1–100 scale organized in 7-classes of score, at three levels of aggregation: for a single event, for four physical risk areas, and for an overall set of 13 physical risks.

Hazard exposure at the location of the entity establishes whether an entity stands in the path of a physical risk; the assessment and score (VIS) derived from it, establishes how severely that risk, if realized, would translate into deterioration of the entity's economic performance and creditworthiness. The Vulnerability Intensity Sector score feeds into the Adaptation Adjusted Credit Risk (AACR) methodology described in the next chapter.

Chapters 5 and 6 are therefore best read in sequence. This chapter ends with the overall VIS for each sector; the chapter that follows takes that score and uses it as the vulnerability term of the climate adjustment factor. The sections below summarise the framework approach, the evidence and judgement behind the intensity levels, the mapping of hazards to transmission channels, the construction and aggregation of the score, the results across sectors, and the limitations that bear on its use in credit risk. The full methodology, including the sector-by-sector assessments and their rationale, is set out in Annex II.

[298] Schrapffer, A. (2024). Assessing Economic Sector Vulnerability to Climate Physical and Transition Risks: A Comprehensive Methodological Framework (SSRN working paper).

[299] See box on the following page

5.1. Purpose and role in the credit risk methodology

The Probability of Default (PD)[300] adjusted for the climate factor rests on two independent inputs. The hazard component measures the probability that a significant climate event occurs where the borrower is located. The vulnerability component measures how severely such an event would affect the borrower's economic activity. The Sector Vulnerability Framework produces the second of these, as an ordinal assessment for each NACE 2-digit sector.

The VIS measures the vulnerability of a production model, meaning its inherent susceptibility to harm from climate hazards. It does not measure the exposure of individual firms, which depends on the location of their assets and operations[301]. It does not vary with a borrower's adaptative capacity, asset configuration or insurance cover. It is not a probability, so it says nothing about how likely a hazard is to occur at a given location. It is not a damage estimate, so it does not quantify the loss an event would cause. It ranks sectors by how much of their operating model lies in the path of a hazard, on an ordinal scale whose classes carry the same meaning across hazards and across levels of aggregation.

BOX: What is NACE

NACE is the statistical classification of economic activities used in the European Union (from the French *Nomenclature statistique des activités économiques dans la Communauté européenne*). A NACE code identifies the activity a business carries out, so that data from different countries and sources can be compared on a common basis. It is maintained by Eurostat, and the current version is NACE Rev. 2.1, which replaced Rev. 2 for reference years from 2025 onward.

The structure is hierarchical, with each level adding a digit of detail:

- **22 Sections** — a letter, e.g. C for manufacturing
- **87 Divisions** — two digits, e.g. 10, manufacture of food products
- **287 Groups** — three digits, e.g. 10.7, manufacture of bakery and farinaceous products
- **651 Class** — four digits, e.g. 10.71, manufacture of bread, fresh pastry goods and cakes

Member States often add a national fifth or sixth digit; es. Italy's version is ATECO, which extends NACE with further detail and is used for tax and administrative purposes. NACE itself is aligned with the UN's ISIC at higher levels.

[300] Probability of default (PD) is the likelihood that a borrower will fail to meet its debt obligations over a specified time horizon, expressed as a number between 0 and 1 (or as a percentage). It is one of the three core parameters of expected credit loss, alongside loss given default (LGD) and exposure at default (EAD): expected loss = PD × LGD × EAD.

[301] Following the IPCC (AR6), climate risk is understood as the potential for adverse consequences arising from the interaction of three components. A hazard is the potential occurrence of a physical event or trend, such as a heatwave or rising temperatures, that may cause damage or loss. Exposure is the presence of people, assets, activities or resources in places that could be adversely affected. Vulnerability is the propensity to be adversely affected, combining sensitivity (or susceptibility) to harm with the capacity to cope and adapt. The same hazard can therefore produce different levels of risk depending on exposure and vulnerability. See also Chapter 6 and IPCC's physical risk definition.

5.2. What the framework measures

Vulnerability is assessed through three risk transmission channels, each capturing a distinct way in which a hazard translates into a financial impact for a firm operating in the sector.[302] (Table 3)

Table 3: Risk transmission channels

Transmission channel	What it captures	Basis of assessment
Capital intensity	The extent to which a sector's output depends on fixed physical assets — plant, machinery, buildings, infrastructure — that can be damaged or rendered inoperable by an event.	Capital Intensity ratio, cluster analysis and expert judgement
Human workforce	The extent to which productivity depends on labour performed in conditions a hazard can make unsafe or unproductive: outdoor, on-site and physically demanding work, and work concentrated in narrow seasonal windows.	Human Workforce Intensity indicator, cluster analysis and expert judgement
Climate dependence	The extent to which core inputs, processes or outputs rely on climate-conditioned natural resources such as water availability, agricultural raw materials or temperature-controlled processes.	Expert judgement only

Source: Annex II, construction of intensity indicators.

Each channel is assessed on the same three-point ordinal scale, so that a level assigned on one channel is comparable in meaning to a level assigned on another. Level 0 denotes minimal sensitivity, level 1 an intermediate sensitivity where hazards can affect operations under specific conditions, and level 2 a pronounced sensitivity, with large exposed fixed assets, continuous on-site or outdoor operations, or output directly shaped by climatic conditions[303,304].

5.3. Evidence base

5.3.1 Portfolio

The framework is supported by a portfolio of corporate financial statements drawn from the same four Italian provinces that will be used in the credit risk adaptation adjustment exercise — Ravenna,

[302] See Schrapffer, A. and Bres, J., Assessing Economic Sector Vulnerability to Climate Physical and Transition Risks: A Comprehensive Methodological Framework, version 1.0 (17 May 2024), available at SSRN: https://ssrn.com/abstract=4831795.

[303] The ENCORE database for Exploring Natural Capital Opportunities, Risks, and Exposure is a platform developed by the Natural Capital Finance Alliance in partnership with the World Conservation Monitoring Centre (UNEP WCMC). It assesses both the impacts and dependencies of 89 production processes on 21 ecosystem services and 11 factors affecting natural capital assets.

[304] Sector-Impact Map considers the positive and negative associations between industries / sectors / activities on the three pillars of sustainable development (economic, environmental and social). The industries / sectors / activities used are those of ISIC Rev 4, with additions. The impact areas and topics are those of the UNEP FI Impact Radar (2022 edition).

Forlì-Cesena, Prato and Pistoia[305] — which keeps the two analyses methodologically consistent. The portfolio included 26,468 companies[306]. This is 80% of the active corporations in the four provinces, representing a high level of coverage.

The portfolio deliberately excludes firms subject to insolvency proceedings, protests or other adverse public records, and firms in liquidation. Because the framework describes the structural characteristics of an on-going concern, firms already in distress would distort the measurement of capital and workforce intensity. This differs from the adjustment credit portfolio, which is built for a different purpose and applies different filters[307]; the two portfolios share geography and sources but are not identical in composition.

5.3.2 Quantitative Indicators

Two indicators support the first two channels. Capital Intensity is the ratio of tangible fixed assets to total assets, expressed as a percentage. Human Workforce Intensity is measured by employee headcount, with personnel costs used to treat missing values. Both are computed as multi-year averages over the three most recent financial years, falling back to two years or to the latest year where data is incomplete, which limits the influence of year-specific fluctuations.

Each indicator is also expressed as a three-level categorical variable, using thresholds drawn from the observed distribution for capital intensity and from European Commission Recommendation 2003/361/EC for workforce size[308] (Table 4).

Table 4: Thresholds for the categorical intensity variables

Intensity level	Capital Intensity ratio	Employee headcount
Low [0]	≤ 5%	< 10 (micro-enterprises)
Medium [1]	> 5% and ≤ 25%	10 to 49 (small enterprises)
High [2]	> 25%	≥ 50 (medium and large enterprises)

Source: Annex II, vulnerability intensity development.

5.3.3 Segmentation

The categorical variables described above rest largely on qualitative judgement. To place the assignment of vulnerability levels on firmer ground, the sectors were also examined through a

[305] In 2023 these territories were impacted by the most destructive weather-related events that Italy has faced in recent decades. Both regions (Emilia-Romagna and Tuscany) were hit by exceptionally heavy rainfall events, with return periods of over a century in several basins, in areas that are highly vulnerable due to densely populated settlements and rich industrial infrastructure, but also with significant geomorphological sensitivity, especially in the Apennine areas.

[306] See Annex II Data quality checks and exclusions.

[307] See Annex III Portfolio Definition, Data quality checks and exclusions

[308] EUR-Lex - 32003H0361 - EN - EUR-Lex

grouping exercise based on two continuous indicators (cluster analysis[309]). Each company is described by two financial indicators described above: capital intensity and human workforce. Since the two indicators are measured on different scales, they are first put on a common footing so that neither one dominates the result. Companies are then grouped so that those with similar profiles end up together: a first pass compresses the data into a manageable number of small provisional groups, and a second pass merges these step by step into a smaller set of larger ones. The merging rule keeps each group as internally homogeneous as possible, which matters because financial ratios tend to be widely dispersed and to include a few extreme values; alternative rules that merge groups on the basis of the single closest pair of companies are easily distorted by such cases. The exercise is carried out company by company rather than on sector averages[310]. The clusters were not used to determine an optimal number of groups. They were used as evidence in assigning each sector to one of the three predefined intensity levels, corroborating the assignment in most cases and prompting revision in others. The quantitative analysis is therefore an input to the assessment rather than an independent validation of it.

5.3.4. Assignment of intensity levels

Each of the 87 NACE Divisions are assigned an intensity level on each risk transmission channel. The assignment combines the cluster evidence, the categorical segmentation, the existing literature[311] and expert judgement, and takes account of factors the indicators do not capture — the relevance of inventory and possible losses of raw materials or finished goods, and whether activities are performed indoors in dedicated facilities or outdoors in exposed environments. Where a sector is thinly represented in the portfolio, the assignment relies more heavily on judgement. Climate dependence is assessed by judgement alone, with no quantitative indicator behind it.

[309] Cluster analysis aims to identify similarities and differences among entities, producing clusters with two complementary properties: maximum similarity within each cluster and maximum difference between clusters. Methods fall into two families. Hierarchical methods reconstruct the full hierarchy of the objects under analysis — the dendrogram — in either ascending or descending order. Partitioning methods require the number of clusters to be specified in advance.

[310] The two continuous indicators are standardised and segmented in two stages: a k-means step with 250 centroids reduces the dataset to a tractable structure, and Ward hierarchical clustering is then applied to the resulting pre-clusters. Ward's method minimises within-cluster variance, which handles the dispersion typical of balance-sheet ratios better than linkage rules based on single pairwise distances. See Bank for International Settlements, 'Using statistical clustering to identify business models', BIS Quarterly Review, December 2014 (www.bis.org/publ/qtrpdf/r_qt1412.htm) and Anna Bieniasz & Anna Majchrzak (2011) "Applying The Ward Method in the Analysis of Financial Situation of Commercial Banks," "e-Finanse", University of Information Technology and Management, Institute of Financial Research and Analysis (https://ideas.repec.org/a/rze/efinan/v7y2011i3p1-12.html).

[311] See Banca d'Italia - No. 77 - Hydrogeological and credit risk: the Italian firms' physical risk-adjusted probability of default and Lavecchia, L. *et al.* (2024). Data and Methods to Assess Climate-Related and Environmental Risks in Italy. In: Mingione, M., Vichi, M., Zaccaria, G. (eds) High-quality and Timely Statistics. CESS 2022. Studies in Theoretical and Applied Statistics. Springer, Cham. https://doi.org/10.1007/978-3-031-63630-1_10; and https://www.eea.europa.eu/en/analysis/publications/european-climate-risk-assessment

Figure 1: Sector intensity assessment – worked example (sector 01)

01-Crop and animal production, hunting and related service activities

		RATIONALE	INTENSITY LEVEL
RISK TRANSMISSION DRIVERS	CAPITAL INTENSITY	Relies on high investment in mechanised farming, land use livestock facilities, irrigation systems, storage structures for feeds and/or cultivated agricultural products (smallholder and labor-intensive crops can be less capital but even more workforce-intensive)	2
	HUMAN WORKFORCE INTENSITY	Highly dependent of manual and outdoor work, especially in small and medium farms (smallholder and labor-intensive crops can be less capital but even more workforce-intensive)	2
	CLIMATE DEPENDENCE	Production strongly depends on temperature, precipitation, water availability, and extreme events	2

Example - *Sector 01, crop and animal production, illustrates the process. The categorical indicator shows high tangible assets while the cluster analysis shows a bipolar distribution, reflecting the coexistence of small flexible farms and large capital-heavy operations; since even small holdings depend on essential physical assets, the sector is assigned level 2 for capital intensity. The quantitative indicators suggest low labour reliance, but the work is predominantly outdoor and physically demanding, cannot be fully automated and peaks seasonally, which supports level 2 for human workforce. Production cycles are tied directly to temperature, precipitation and water availability, giving level 2 for climate dependence.*

5.3.5. The vulnerability matrix

Not every channel is relevant to every hazard. Flooding damages fixed installations and interrupts operations, while chronic heat acts mainly on labour productivity and occupational health, with a secondary effect on capital through cooling demand and equipment operating below rated capacity. A vulnerability matrix therefore maps each event against the channels through which it reaches a business. Risk transmission channels that are not material for a given hazard are treated as having a low intensity level.

The mapping was carried out through expert judgement: for each hazard, the authors identified the risk transmission channels through which its impacts propagate, drawing on the available scientific and sectoral evidence. The mapping was then independently reviewed by an expert from the Euro-Mediterranean Center on Climate Change (CMCC).

Table 5: Physical risk areas, events and material transmission channels

Physical Risk Area	Event	Capital	Workforce	Climate dependence
Water-related	Flood	●	●	●
	Drought		●	●
	Heavy precipitation		●	●
	Changing precipitation patterns		●	●
	Sea level rise	●		
Temperature-related	Heat wave	●	●	●
	Cold wave and frost	●	●	●
	Changing temperature patterns		●	●
Solid mass-related	Landslide and subsidence	●		
	Coastal erosion	●		
	Soil erosion and degradation		●	●
Wind-related	Cyclone, storm and tornado	●	●	●
	Changing wind patterns	●		●

Note: a marker indicates that the channel is material for that event. Source : Annex II, vulnerability matrix.

The hazards are those listed in the Appendix to the Taxonomy Regulation (EU) 2020/852[312]. Closely related hazards reaching a business through the same channels were consolidated, giving thirteen events grouped into four physical risk areas (Table 6).

Table 6: Physical risk area groups

Risk area	Events	No. of events
Water-related	Flood; drought; heavy precipitation; sea level rise; changing precipitation patterns / precipitation variability	5
Temperature-related	Heat wave; cold wave / frost; changing temperature patterns / temperature variability	3
Solid mass-related	Landslide / subsidence; coastal erosion; soil erosion / degradation	3
Wind-related	Cyclone / storm / tornado; changing wind patterns	2
TOTAL		13

This structure allows to produce vulnerability scores at three levels of aggregation: Event Score for a single event, Area Score for each of the four physical risk areas, and the Overall Score for the 13 risk events combined.

[312] https://ec.europa.eu/sustainable-finance-taxonomy/assets/documents/CCA%20Appendix%20A.pdf

5.4. Construction of the Vulnerability Intensity Sector score (VIS)

Each sector is assessed against every hazard material to it, producing a Vulnerability Intensity Sector score (VIS) for each hazard: a synthetic measure of how far that hazard reaches into the sector's operating model and how severely it would impair it.

The assessment is constructed in three stages:

- **Event VIS** — the normalized score for one sector against one hazard, derived from the combination of its three risk channel levels.
- **Area VIS** — the normalized score for one sector across all hazards within a physical risk area, obtained as a combination of event scores.
- **Overall VIS** — the normalized score for one sector across all thirteen hazards, obtained as a combination of all event scores.

The VIS is the framework's principal output. Together with hazard exposure at the location of the entity, it constitutes one of the two adjustment factors applied to the probability of default associated with the standalone credit rating, as set out in Chapter 6. The approach proposed is the following: hazard exposure establishes whether an entity stands in the path of a physical risk, while the VIS establishes how severely that risk, if realized, would translate into deterioration of the entity's creditworthiness.

5.4.1 VIS Event score

For each sector and each event, the three risk transmission channel levels are combined into a single assessment. With three channels at three levels there are 27 possible configurations, consolidated into seven vulnerability classes according to two rules. The channels are equally weighted and interchangeable, so (2,0,0) and (0,0,2) fall in the same class. The criterion is conservative in the sense that concentration counts for more than breadth: a hazard reaching a sector through one channel at maximum intensity is treated as more severe than one reaching it through three channels at mild intensity, so (2,0,0) sits in class 5 while (1,1,1) sits in class 4.

Table 7: Thresholds for the categorical intensity variables

VIS-Event Class	Risk Channels Combinations	Description
1-Non intensive	0–0–0	All channels at level 0. Overall vulnerability is negligible
2-Very Low Intensity	1–0–0; 0–1–0; 0–0–1	Only one channel at level 1. Very limited vulnerability
3-Low Intensity	1–1–0; 1–0–1; 0–1–1	Two channels at level 1. Low but non-negligible vulnerability
4-Medium Intensity	1–1–1	All channels at level 1. Structurally medium vulnerability
5-High Intensity	2–0–0; 0–2–0; 0–0–2; 2–1–0; 2–0–1; 1–2–0; 0–2–1; 1–0–2; 0–1–2; 2–1–1; 1–2–1; 1–1–2	One channel at level 2 and others at level 1 or 0. Elevated vulnerability across single or multiple dimensions
6-Very High Intensity	2–2–0; 2–0–2; 0–2–2; 2–2–1; 2–1–2; 1–2–2	Two channels at level 2 and one at level 1 or 0. Very high vulnerability with broader structural intensity
7-Extreme Intensity	2–2–2	Maximum intensity across all dimensions. Vulnerability is extreme

Take sector 01 - Crop and Animal Production as an example of the intensity class assignment. Sector 01 is characterised by the maximum intensity level (2) across all three vulnerability risk transmission channels at the sector level. As a result, the event-level configuration for floods (VIS Event Score) corresponds to a combination where three risk transmission channels retain intensity level 2. This configuration maps into the '7-Extreme Intensity' class, reflecting the maximum sensitivity of agricultural activities to flood-related disruptions through the relevant risk transmission channels.

5.4.2 VIS Area Score and VIS Overall Score

Each physical risk area is described by a VIS Area score, obtained by aggregating the hazard events assigned to that area - eg. Water-related Area includes five hazard events: flood; drought; heavy precipitation; sea level rise; changing precipitation patterns; precipitation variability, the VIS Area score captures the combination of the 5 single hazards. Since the VIS Event variable is expressed in classes, to move from each class to a combined classes result, the class is first converted into a normalized score on a 1–100 scale, taking the upper bound of the class as the score. The Area score is then computed from these normalized event scores:

$$N_e = 1 + (Ce - 1) * \frac{(100 - 1)}{(C_{max} - 1)}$$

where C_e is the intensity class of event e and C_{max} = 7. The first class has no lower reference of its own, so its value is set at half the value of the second class. The resulting scale is shown in Table 8.

Table 8: Vulnerability classes, channel configurations and normalized scores

Class	Risk transmission channel configuration	Score range	Normalised score N_e
1 – Non intensive	All channels at level 0	1–9	9
2 – Very low intensity	One channel at level 1	10–18	18
3 – Low intensity	Two channels at level 1	19–34	34
4 – Medium intensity	All channels at level 1	35–51	51
5 – High intensity	One channel at level 2, others at level 1 or 0	52–67	67
6 – Very high intensity	Two channels at level 2, one at level 1 or 0	68–84	84
7 – Extreme intensity	All channels at level 2	85–100	100

Source: Annex II, VIS event score and intensity class normalization.

A simple average was not used, because it would allow severe vulnerability to one event to be offset by low vulnerability to the others. The aggregation is a weighted average in which each event's own class number serves as its weight, so more severe events count for more and the weights adjust automatically to the profile of the sector:

$$VIS_{\text{area}} = \frac{\sum_e C_e * N_e}{\sum_e C_e}$$

The VIS Overall score is calculated in the same way, but directly from all thirteen events rather than from the four area scores. Aggregating from the events avoids a second round of averaging, so each event contributes exactly as assessed. Because every level shares the same 1–100 normalization, event, area and overall scores are expressed on a single comparable scale, and the same vulnerability class definitions apply throughout. The figure below for Sector 01 illustrates the calculation. Its thirteen event scores range from class 5 to class 7. For the water-related area, the normalized scores sum to 419 across five events, giving a weighted score of 85. Across all thirteen events the normalized scores sum to 1,105, giving an overall score of 86, which falls in class 7.

Figure 2: VIS Overall score calculation - example

Event	VIS Event	Ne	Weight	%	Ne Weighted	VIS Overall
Flood	7-Extreme Intensity	100	7	8,9	9	
Drought	6-Very High Intensity	84	6	7,6	6	
Heavy Precipitation	6-Very High Intensity	84	6	7,6	6	
Sea Level Rise	5-High Intensity	67	5	6,3	4	
Changing Precipitation Patterns	6-Very High Intensity	84	6	7,6	6	
Heat Waves	7-Extreme Intensity	100	7	8,9	9	
Cold Waves/Frost	7-Extreme Intensity	100	7	8,9	9	
Changing Temperature Patterns	6-Very High Intensity	84	6	7,6	6	
Landslide/Subsidence	5-High Intensity	67	5	6,3	4	
Coastal Erosion	5-High Intensity	67	5	6,3	4	
Soil Erosion/Degradation	6-Very High Intensity	84	6	7,6	6	
Cyclone/Storm/Tornado	7-Extreme Intensity	100	7	8,9	9	
Changing Wind Patterns	6-Very High Intensity	84	6	7,6	6	
Total Event Normalised Scores		**1105**				
Total Weights (den)			**79**	**100**		
Total VIS Overall Score					**86**	**7-Extreme Intensity**

The VIS Overall score is mapped onto an ordinal seven-class scale, which provides a synthetic framework for reading how vulnerability to climate hazards increases in intensity. Each class is accompanied by a definition of the vulnerability profile it represents, ranging from negligible to extreme intensity.

Figure 3: Vulnerability Intensity Scale

SCORE min	SCORE max	Vulnerability Intensity	Description
1	9	1 – Negligible	The economic activity exhibits negligible or very low vulnerability to climate risk
10	18	2 – Very Low	
19	34	3 – Low	The economic activity exhibits moderate vulnerability to climate risk,reflecting a combination of sectoral characteristics and driver interactions that generate a non-negligible but still contained sensitivity to physical hazards
35	51	4 – Medium	
52	67	5 – High	The economic activity presents an high vulnerability to climate risk, with multiple drivers contributing meaningfully to sensitivity, a structural dependencies and significant exposure to relevant hazards, resulting in a higher likelihood of disruption and damages under adverse physical events
68	84	6 – Very High	
85	100	7 – Extreme	The economic activity exhibits strong and simultaneous vulnerabilities to climate risk from all relevant drivers, placing the sector among those most exposed and sensitive to climate-related damages and disruptions

5.5 Results

The framework produces an event, area and overall score for each of the 87 NACE 2-digit sectors[313]. The overall scores span the full scale, from sectors whose production model is essentially insensitive to physical hazards to sectors exposed through all three channels simultaneously (Table 9).

Table 9: Overall VIS for selected sectors

NACE	Sector	Overall VIS class
01	Crop and animal production	7 – Extreme intensity
41	Construction of buildings	7 – Extreme intensity
55, 56	Accommodation and food service activities	7 – Extreme intensity
10–15	Manufacture of food products, beverages, textiles apparel	6 – Very high intensity
35	Electricity, gas, steam and air conditioning supply	6 – Very high intensity
68	Real estate activities	6 – Very high intensity
61	Telecommunication	5 – High intensity
46, 47	Wholesale and retail trade	4 – Medium intensity
26, 27, 32	Manufacture of computer, electronic and electrical equipment.	2 – Very low intensity
62	Computer programming and consultancy	1 – Non intensive
64, 66	Financial service activities	1 – Non intensive

Source: Annex II, VIS area and overall by group of sub-sectors.

5.6 Use in the PD climate adjustment

The credit risk methodology uses the VIS Overall, normalized to the unit interval through division by 100, as the vulnerability term v(s) of the climate adjustment factor. The overall score is preferred to the area score because the adjustment is intended to cover physical climate risk as a whole; the area score variant is retained as an alternative specification in the sensitivity analysis and is the more appropriate choice where the exercise is restricted to a specific hazard.

Two properties of the score shape the behaviour of the adjustment. First, because the VIS is defined at the NACE 2-digit level, the adjustment factor takes a single value for every firm in the same sector and municipality, and within-sector differences in adaptation, asset configuration or insurance are not reflected. Second, because the class structure caps the normalized score at 100, the adjustment factor has a hard ceiling, reached only by a sector in class 7 located in a municipality in the highest hazard class.

[313] The full process and results described in this chapter are available in the supporting VIS Calculation tool (excel), which comes with a User Guide.

5.7 VIS Calculation Tool

To support the practical application of the Sector Vulnerability Framework, a dedicated VIS Calculation Tool has been developed. It translates the framework's methodology into a ready-to-use Excel instrument, so that financial institutions can assess the inherent sensitivity of economic sectors to physical climate hazards consistently and transparently. The tool provides a common sector-level starting point for physical risk analysis. It can be used for portfolio screening, prioritising counterparties for due diligence and engaging clients on adaptation, and it also feeds directly into the credit risk methodology set out in Annex III. Box 2 summarises the tool's structure, outputs, intended uses and main limitations.

Box 2: VIS Calculation Tool (v1.0)

What it is. An Excel tool showing how sensitive economic sectors are to physical climate hazards. It applies the Sector Vulnerability Framework to every NACE Rev. 2.1 code, providing one consistent sector-level baseline for physical risk analysis.
How it works. The tool links four building blocks:

- **Sectors**: each 2-digit NACE division is assessed; groups and classes inherit their division's result.
- **Hazards**: 13 physical climate events from the EU Taxonomy, each marked acute or chronic, in four risk areas: water (5), temperature (3), solid mass (3), wind (2).
- **Risk transmission channels**: *capital intensity* (damage to fixed assets), *human workforce* (unsafe or unproductive work), *climate dependence* (climate-sensitive inputs). For each hazard, a channel is material or not; each sector gets a level per channel: Low [0], Medium [1], High [2].
- **Vulnerability Intensity Score (VIS)**: channel levels combine into a 1–100 score per event, per risk area and overall, mapped to seven classes from *1 – Negligible* to *7 – Extreme*.

Outputs. A sector look-up with channel levels and rationale · a results table with one row per NACE code, ready for look-ups and portfolio mapping · hazard-by-hazard detail per risk area.

Flexibility. Users can change which channels are material for each hazard and adjust intensity levels down to 4-digit NACE codes. New hazards or channels cannot be added.

Intended use. Screening credit and investment portfolios · prioritising counterparties for due diligence · sector benchmarking and heatmaps · supporting client dialogue on adaptation · feeding the Adaptation Adjustment in the credit risk methodology (Annex III).

Limitations. The VIS measures a sector's inherent vulnerability. It is not a hazard probability, a damage estimate or a company-specific risk rating, and it covers physical risk only, not transition risk. Always combine results with location-specific hazard data and company data (assets, workforce, adaptation measures, insurance).

→ The VIS Calculation Tool v1.0 is available on demand (please email: info@sustainadvisory.it)

Chapter 6: Adaptation-Adjusted Credit Rating ('AACR') Methodology

The Adaptation-Adjusted Credit Rating methodology proposed by ClimateFit reframes risk as a function of physical climate risk, credit exposure and economic sector vulnerability.

Traditional credit scoring relies on historical financial, qualitative and sector data to generate the estimate and metrics of credit risk (Probability of Default 'PD', Loss Given Default 'LGD' and Exposure At Default 'EAD') which feed into a final score or rating determining credit limits, pricing and capital requirements.

Physical climate risk is essentially absent from this approach, as it is neither an explanatory variable nor a calibration factor: the data used are historical and economic-financial, rarely incorporating georeferenced hazard data (floods, heatwaves, droughts, landslides) or counterparty asset/supply-chain vulnerability. Climate-related impacts on PD and LGD therefore only appear retrospectively in historical series, never as a distinct, forward-looking risk component[314].

The AACR proposed approach moves from the definition of physical risk provided by the Intergovernmental Panel on Climate Change (IPCC) in the IPCC Sixth Assessment Report: '*physical risk is not a standalone core term, but it is described as closely related to risks arising from climate change impacts and climate-related hazards, especially where those hazards interact with exposure and vulnerability*[315]'. Basically, physical risk is the potential for adverse consequences from climate-related hazards, depending on exposure and vulnerability. The IPCC's broader risk definition is the "potential for adverse consequences for human or ecological systems".

Risk = f(Hazard, Exposure, Vulnerability)

In the context of the AACR approach, exposure refers to the outstanding credit at risk, while vulnerability refers to sector-level sensitivity. The AACR methodology is designed to complement existing credit risk models while remaining adaptable to different regulatory approaches and institutional contexts. Drawing on diverse regulatory approaches and market best practices, this proposal adopts a flexible methodology for integrating climate risk into credit-risk estimation—one that can be adapted to different institutional contexts, modelling approaches, and estimation components. Specifically, climate risk can affect the three core parameters of credit risk assessment:

- **Probability of Default (PD)** — through the counterparty's exposure to physical climate risks;
- **Loss Given Default (LGD)** — through the impact of climate risks on collateral value and asset marketability;
- **Exposure at Default (EAD)** — through abnormal drawdown patterns on credit lines under adverse climate scenarios.

[314] European Central Bank, 'Guide on Climate-Related and Environmental Risks: Supervisory Expectations Relating to Risk Management and Disclosure' (European Central Bank 2020) and BCBS. *Climate-related financial risks – measurement methodologies*, April 2021 (d518, https://www.bis.org/bcbs/publ/d518.pdf); companion *Climate-related risk drivers and their transmission channels* (d517).

[315] https://www.ipcc.ch/site/assets/uploads/2021/01/The-concept-of-risk-in-the-IPCC-Sixth-Assessment-Report.pdf

This flexible design is intended to make the methodology applicable across a broad range of financial and investment entities. This methodology provides FIEs with an operational framework for systematically integrating climate adaptation factors into the creditworthiness assessment process. It offers a set of criteria and practical considerations that can serve as a starting point for implementation, functioning as a complement or corrective to the outputs of traditional credit risk models—without altering their methodological structure or requiring major changes to existing methodologies and models.

6.1 Background

The European prudential framework, as set out under the Capital Requirements Regulation (CRR)[316] and its subsequent amendments, establishes the regulatory architecture within which financial institutions measure and manage credit risk for capital adequacy purposes. Within this framework, institutions may adopt one of three principal approaches to credit risk measurement:

- the **Standardised Approach (SA)**, under which risk weights are assigned based on external credit assessments or supervisory-defined risk buckets;
- the **IRB Foundation Approach (F-IRB)**[317], under which institutions estimate the probability of default (PD) internally, while other risk parameters—such as LGD and EAD—are set by regulators;
- the **IRB Advanced Approach (A-IRB)**, under which institutions develop internal estimates for all relevant risk parameters (PD, LGD, EAD, and maturity), subject to supervisory approval.

A fourth approach is provided for **Specialised Lending** exposures, applicable to project finance, real estate finance, and object finance transactions, in recognition of the distinct risk profile and cash-flow structures that characterize these forms of financing.

The choice of approach adopted by a financial institution is not discretionary but is shaped by a combination of structural and operational factors. These include: the availability and depth of historical data, which determines the institution's ability to develop statistical models with robust predictive power (modelling capacity); the size, composition, and complexity of the credit portfolio, which influences the cost-benefit balance of adopting more sophisticated internal models; and the maturity of the institution's governance and validation infrastructure, including its capacity to independently assess, monitor, and challenge the methodologies used. Against this backdrop of regulatory heterogeneity, the methodology proposed in this document—the AACR approach—is designed to operate consistently across all three approaches, without requiring institutions to alter their existing modelling infrastructure.

[316] https://www.eba.europa.eu/regulation-and-policy/single-rulebook/interactive-single-rulebook/12674

[317] https://www.eba.europa.eu/activities/single-rulebook/regulatory-activities/model-validation/guidelines-credit-risk-mitigation-institutions-applying-irb-approach-own-estimates-lgds.

6.1.2 Objective and overall approach

This chapter summarizes the methodology developed to incorporate physical climate risk into the assessment of non-financial corporate creditworthiness, together with the results obtained on the study portfolio observing the consequences of a severe flood event (it can be used for any type of hazard provided return periods of the hazard are available). It covers the empirical basis of the exercise, the design of the PD climate adjustment and its effect on probabilities of default and rating classes.

The methodology addresses a practical need of lenders and risk managers: reflecting a borrower's exposure to physical climate hazards in the one-year probability of default (PD) produced by an existing credit scoring or rating model, using information that is observable, documented and available at scale[318].

The solution proposed is a climate adjustment factor that scales the credit PD upwards. The factor combines two components, each capturing a distinct dimension of physical risk. The hazard component measures how likely it is that a significant flood event affects the municipality where the firm is located. The vulnerability component measures how sensitive the firm's economic activity is to physical climate events. The adjustment is calibrated on the observed credit behaviour of firms located in areas hit by severe floods[319].

The work proceeds in two stages. The first is empirical and tests whether sectoral climate vulnerability is associated with credit deterioration after an extreme weather event. The second is operational and translates this evidence into a transparent, reproducible adjustment of the PD governed by a single calibration parameter.

6.2. Empirical setting and data

6.2.1 Case study and time horizon

The analysis is built around the floods that hit the provinces of Ravenna and Forlì-Cesena (Emilia-Romagna) in May 2023 and the provinces of Prato and Pistoia (Tuscany) in November 2023,[320] which are among the most destructive weather-related events recorded in Italy in recent decades. The observation period precedes the events and the performance period follows them. The quantitative analysis uses credit scores and default status for 2022–2025.

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[318] ECB/ESRB Project Team on climate risk. *Climate-related risk and financial stability* (July 2021, https://www.ecb.europa.eu/pub/pdf/other/ecb.climateriskfinancialstability202107~87822fae81.en.pdf); *The macroprudential challenge of climate change* (2022); *Towards macroprudential frameworks for managing climate risk* (December 2023, with Annex and Chartbook) and Meucci & Rinaldi (2022), *Bank exposure to climate-related physical risk in Italy: an assessment based on AnaCredit data on loans to non-financial corporations*, Occasional Paper No. 706 (https://www.bancaditalia.it/pubblicazioni/qef/2022-0706/; SSRN 4295424). NGFS. *Conceptual note on short-term climate scenarios*; *Leveraging physical climate risk data* (information note, 2025). ECB analytical/statistical indicators on physical risks (https://www.ecb.europa.eu/stats/all-key-statistics/horizontal-indicators/sustainability-indicators/).

[319] Autorita di bacino distrettuali, 'Piani Di Gestione Del Rischio Di Alluvioni (Flood Risk Management Plans): Low, Medium and High Probability Scenarios' (Autorita di bacino distrettuali 2021)

[320] ARPAT - Agenzia regionale per la protezione ambientale della Toscana, 'Alluvione Novembre 2023 in Toscana' (*ARPATnews*, 2023) https://www.arpat.toscana.it/notizie/arpatnews/2023/alluvione-novembre-2023-in-toscana>

6.2.2 Information sources

Four types of information are combined. Corporate registry and the geolocation data, economic activity and credit score/rating of each firm. Credit scores and one-year PDs are supplied by an international business information provider on an ordinal eight-class scale, ranging from a PD of 0.7% in class 1 to 28.2% in class 8. Physical hazard is measured with the AWARE© suite of indicators[321] at a municipal level, built by SustainAdvisory S.r.l. on public sources such as ISTAT[322], ISPRA[323] and the Civil Protection Department[324]. Sectoral vulnerability is measured with the Vulnerability Intensity Sector score (VIS), assigned to each NACE 2-digit sector under the Sector Vulnerability Framework. Firms are located by the municipality of their registered office, the only geographic attribute consistently available across the portfolio.

Default events are public defaults, namely bankruptcy, insolvency proceedings and compulsory liquidation. Because the reason for a default cannot be observed, voluntary liquidations are also tracked, since they may identify firms that chose, or were forced, to wind down after severe damage rather than borrow to restart operations.

6.2.3 Study portfolio

The portfolio includes corporations and equivalent legal forms, which provide the most complete and consistent information set[325]. Financial and insurance entities are excluded because the credit score applies to non-financial firms only. Starting from 32,855 companies, a structured data-cleaning process removed firms with missing identifiers or activity codes, firms without sufficient multi-year credit and financial data, unrated firms, and firms already in default or liquidation at the observation date, whose subsequent deterioration could not be attributed to the climate event (Table 10).

Table 10: Construction of the study portfolio

Step	Companies excluded	Companies remaining
Initial dataset	–	32,855
Missing registry or economic activity information	865	31,990
Insufficient multi-year credit and financial data	11,456	20,534
Credit score classified as unrated	1,376	19,158
Already in default or liquidation at the observation date	271	18,887
Total excluded and final portfolio	13,968	18,887

Source: annex, section on data quality checks and exclusions.

[321] Sustain Advisory, 'AWARE - Accident Weather Analytics Risk Events: Physical Climate Risk Indicators for Italian Administrative Units' <https://www.sustainadvisory.it/climate-risk-analytics/>

[322] ISTAT - Istituto Nazionale di Statistica, '

[323] ISPRA - Istituto Superiore per la Protezione e la Ricerca Ambientale, 'Alluvione in Emilia-Romagna: Reporting on the May 2023 Flood and National Hydrogeological Hazard Indicators' (ISPRA 2023) <https://www.isprambiente.gov.it/it/news/alluvione-in-emilia-romagna>

[324] Dipartimento della Protezione Civile, 'Documentation and Legal Measures Relating to the 2023 Severe Weather Events' (2023) <https://www.protezionecivile.gov.it/it/legal-measure/>

[325] InfoCamere - Unioncamere, 'Movimprese: Statistics on Registered and Active Enterprises by Province, Economic Sector, Legal Form and Status' <https://infocamere.it/movimprese>

The final portfolio of 18,887 companies covers 57.4% of the 32,899 active corporations in the four provinces, with coverage between 55% and 59% in each province. Its sectoral composition is broadly aligned with that of the local corporate population, except for a small number of thinly represented sectors.

6.3. Empirical evidence

6.3.1 Credit developments after the floods

Distress events (banking defaults are not included in the sample[326]) remained limited in number. Public defaults affected 25 firms in 2024 (0.13%) and 49 in 2025 (0.26%), for a cumulative rate of 0.39% over the two years, while 324 firms (1.72%) entered liquidation. Default rates were higher and more volatile in Prato and Pistoia, especially in 2025, which is consistent with the later timing of the November 2023 flood and with lagged transmission through supply chains and longer recovery periods.

Credit quality nonetheless deteriorated gradually[327]. The average portfolio PD rose from 3.66% in 2022 to 3.87% in 2023, 4.03% in 2024 and 4.26% in 2025, and the share of firms in the riskiest classes (6 to 8) increased from 17.7% to 19.3%. Transition matrices show annual stability rates (see Annex III) with downgrades exceeding upgrades in every window and deterioration concentrated in mid-risk classes (6 and 7). Two factors dampen the observed effect. Flood-related moratoria allowed borrowers to defer instalments without triggering a default, delaying or preventing the materialization of distress, and the slower growth of the average PD in 2024 is consistent with this. In addition, the 2023 credit scores partly reflect the post-pandemic recovery, which may reduce the apparent sensitivity of credit risk to climate shocks. The observed deterioration is therefore likely to understate the underlying impact of the events.

6.3.2 Relationship with sectoral vulnerability

Default rates are higher in more vulnerable sectors (Table 11). The cumulative 2024–2025 default rate rises from 0.23% for firms in sectors with negligible or very low vulnerability to 0.33% for moderate vulnerability and 0.51% for high vulnerability, more than twice the rate of the least vulnerable group. Firms in the most vulnerable group show a rate of 0.44%, still almost twice that of the least vulnerable group. Liquidation rates show no comparable pattern, suggesting that voluntary exits are driven mainly by factors unrelated to climate exposure. Results based on the water-related VIS are very similar. To provide a clearer, more intuitive view of the relationship, also the original seven classes of the vulnerability intensity score were reorganized into a simplified 4-groups risk scale, grouping VIS score classes 1 and 2 into "Negligible/Very low Vulnerability" (group 0) classes 3 and 4 into "Moderate vulnerability" (group 1), classes 5 and 6 into "High Vulnerability" (group 2) and class 7 into "Very High Vulnerability" (group 3).

[326] The default status available on the portfolio are relative to public defaults only (unlikely to pay and past due are not included in the sample of defaults. Garante per la protezione dei dati personali, 'Guidance on the Processing of and Access to Credit Information' <https://www.garanteprivacy.it>

[327] Banca d'Italia, 'TRI30633 - Quarterly Loan Deterioration Rate (Adjusted Default, Drawn Amounts), Non-Financial Corporations, by province'

Table 11: Default and liquidation rates by overall VIS group, 2024–2025

VIS Overall	Companies	Defaults 2024–2025	Default rate	Liquidation rate
0 – Negligible or very low	3,448	8	0.23%	1.91%
1 – Moderate	6,023	20	0.33%	1.56%
2 – High	6,915	35	0.51%	1.78%
3 – Very high	2,501	11	0.44%	1.64%
Total	18,887	74	0.39%	1.72%

Source: Annex III, Table on credit score relation to economic vulnerability.

Logistic regressions of default status on the VIS confirm a positive relationship in all six specifications, which cover the overall and water-related VIS and default in 2024, in 2025 and over the two years combined (see Statistical Evidence on Annex III). The coefficient is statistically significant at the 5% level for 2024 and for the two-year horizon, but not for 2025 taken alone, which the annex attributes to the effect of debt moratoria on the timing of defaults. The evidence indicates that climate vulnerability acts as an incremental stress factor that contributes to credit deterioration without being its primary driver (see Annex III).

6.4. Design of the PD climate adjustment

This section describes how the climate adjustment to the probability of default (PD) was designed. The adjustment combines the baseline credit PD with two climate-related components discussed in the previous sections: the vulnerability of each production model, measured through the VIS, and the physical hazard to which each firm is subject.

6.4.1 Model specification

Three approaches were considered: a multiplicative adjustment, in which the credit PD is scaled by a factor based on the product of vulnerability and hazard; a composite score, in which credit risk, vulnerability and hazard are combined through a weighted average and then mapped back to a PD; and a calibrated model with separate parameters for the overall intensity of the adjustment and for the interaction between vulnerability and hazard.

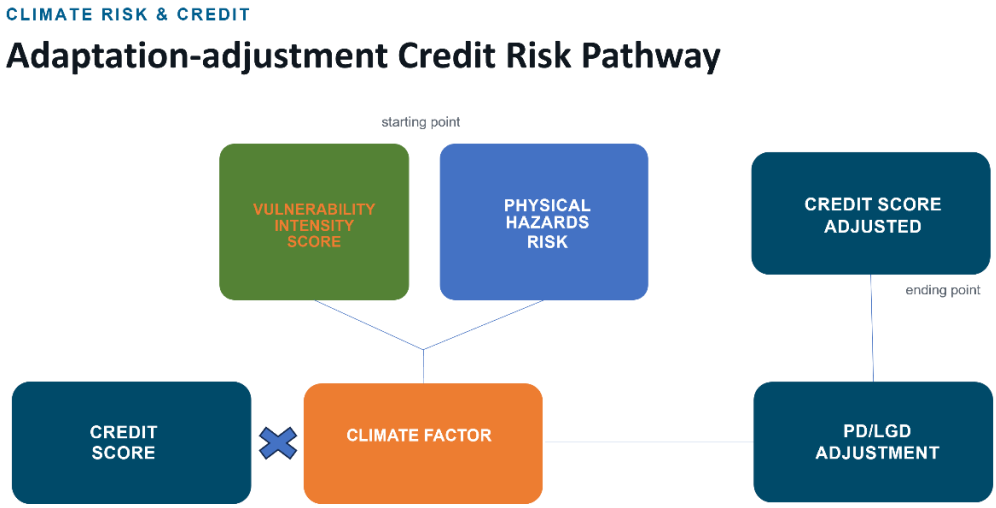
The multiplicative adjustment was selected because it preserves the calibration of the underlying credit model, requires a single parameter and produces a material uplift only when both components are high. For each firm i, operating in sector s and located in municipality m, the climate adjustment factor and the adjusted PD are defined as:

$$F_{climate} = 1 + \alpha \times v(s) \times p(m)$$

$$PD_{adjusted\ (i)} = PD_{(i)} \times F_{climate\,(i)}$$

where PD(i) is the one-year PD associated with the firm's credit score, v(s) is the overall VIS of the firm's sector divided by 100, p(m) is the annual flood probability of the firm's municipality expressed as a fraction, and α is the only free parameter. Because the factor is dimensionless, the adjusted PD is returned on the same scale as the input PD.

Figure 4: Adaptation-adjustment credit risk pathway



6.4.2 Hazard component

The AWARE© indicator classifies each Italian municipality on a five-level ordinal scale calibrated on the national distribution. Since the adjustment requires a probability rather than a ranking, each class is mapped to an annual probability of a significant flood event, calibrated on the return-period scenarios of the Flood Risk Management Plans and the related ISPRA reporting and interpolated to five levels (Table 12).

Table 12: Mapping of AWARE flood risk classes to annual event probabilities

AWARE flood risk class	Annual probability P	Implied return period	Normalised P
1 – Very low	0.20%	~500 years	0.0020
2 – Low	0.35%	~285 years	0.0035
3 – Medium	0.75%	~133 years	0.0075
4 – High	1.50%	~67 years	0.0150
5 – Very high	5.00%	~20 years	0.0500

Source: annex, hazard component.

6.4.3 Vulnerability component

The vulnerability component is the overall VIS, expressed on a 0–100 scale at NACE 2-digit level and normalized to the unit interval. The overall score is preferred to the water-related variant because the adjustment is intended to cover all physical climates. The water-related VIS is the most appropriate choice for exercises restricted to flood hazard and is retained as an alternative specification in the sensitivity analysis.

6.4.4 Design principles

Risk as the product of hazard and vulnerability. Consistent with the IPCC definition of risk, the two components interact rather than add up. A firm in a highly vulnerable sector located in a low-hazard municipality, or a firm in a high-hazard municipality operating in a resilient sector, receives only a limited uplift.

Incremental overlay. Creditworthiness remains driven by the financial, behavioural and public-record information underlying the credit score, and the climate factor adds a stress overlay in line with the empirical evidence.

One-sided and conservative. With a floor of 1, the factor maintains or increases each PD. Credit improvements continue to come from the credit scoring model, and the full climate uplift on exposed positions is retained at portfolio level.

Proportionality. The factor scales the PD rather than adding a fixed increment, so the same climate shock produces a larger absolute deterioration for a financially weaker borrower than for a sound one.

Transparency and reproducibility. The factor depends on two observable inputs and one parameter, with no estimated coefficients. Every value can be reconstructed from the municipality of the registered office, the NACE code and the published mapping tables.

6.4.5 Calibration

α is calibrated empirically on the portfolio and was set using the difference in credit deterioration between more and less vulnerable sectors over the observation and performance periods (α = 5). With α = 5 the factor is bounded in the interval [1, 1.25]: since the maximum attainable factor equals $1 + 0.05\alpha$ no position can have its PD increased by more than 25%, and the ceiling binds only for a company in the most vulnerable sector located in a Class 5 of hazard.

6.5. Results on the study portfolio

6.5.1 Distribution of the climate factor

The distribution of the factor across the 18,887 positions is strongly skewed (Table 13). Half of the positions receive an uplift below 2.8% and three quarters below 5.6%, while the top decile receives more than 16.5%. The maximum observed factor is 1.21, below the theoretical ceiling of 1.25, because no firm located reaching the maximum hazard class (5) and a sector with a max VIS above 84. Uplifts above 7.5% are possible only in class 5, so the upper tail of the distribution consists entirely of firms in very-high-hazard municipalities, as intended by the convex design of the hazard mapping.

Table 13: Distribution of the climate adjustment factor, 2023

Statistic	Climate factor	PD uplift
Minimum	1.0004	+0.04%
25th percentile	1.0131	+1.31%
Median	1.0278	+2.78%
Mean	1.0490	+4.9%
75th percentile	1.0555	+5.55%
90th percentile	1.1650	+16.5%
95th percentile	1.1850	+18.5%
Maximum	1.2100	+21.0%

Source: Annex III, results of the PD climate adjustment.

6.5.2 Impact on probabilities of default

Applying the factor raises the average portfolio PD by about 0.2 percentage points each year, a relative increase of about 5% (Table 14). The effect is stable over time because hazard and vulnerability are static inputs, so differences between years reflect changes in the underlying credit PDs. Positions already in default, with a PD of 100%, are left unchanged, and unrated positions are excluded, which explains the lower number of positions in 2024 and 2025.

Table 14: Average PD before and after the climate adjustment

Year	Positions	Average credit PD	Average adjusted PD	Increase (pp)	Relative increase
2023	18,887	3.87%	4.08%	+0.21	+5.4%
2024	18,758	4.03%	4.23%	+0.20	+5.1%
2025	18,563	4.26%	4.46%	+0.20	+4.8%

Source: Annex III, results of the PD climate adjustment.

At position level, the impact is modest for most firms. In 2023 the median increase is 0.06 percentage points and 90% of positions see an increase below 0.46 points. Larger increases are concentrated in companies that combine a high credit PD with high climate exposure: the 99th percentile is 2.47 points, and the maximum of 5.93 points corresponds to a class 8 firm whose PD rises from 28.22% to 34.15%. This concentration is the intended effect of the proportional design.

6.5.3 Impact on score/rating classes

When adjusted PDs are mapped back to the eight-class scale, the structure of the portfolio is largely preserved (Table 15). No firm moves by more than one class, and migrations occur only from class 3 to class 4, involving 280 firms in 2023, 306 in 2024 and 304 in 2025. These represent 11–13% of class 3 and 1.5–1.6% of the portfolio. In all other classes, the uplift is not large enough to

move firms into the next class. The adjustment therefore refines risk measurement within the existing rating structure, and its effect on the class distribution falls in the intermediate part of the scale, which the transition analysis identified as the segment most sensitive to climate events.

The limited score-class shifts mainly reflect the availability of a class-average PD (not a PD specific for the company), assigned to all the company belonging to the class. To better evaluate the measure of the adjustment, it was also estimated a company-level PD, using as a proxy the banking debt on EBITDA ratio. Applying the climate factor to these company-level PDs, the climate factor affects all classes and drives upward pressure precisely on firms positioned at the upper edge of their score band.

Table 15: Rating class migrations caused by the climate adjustment

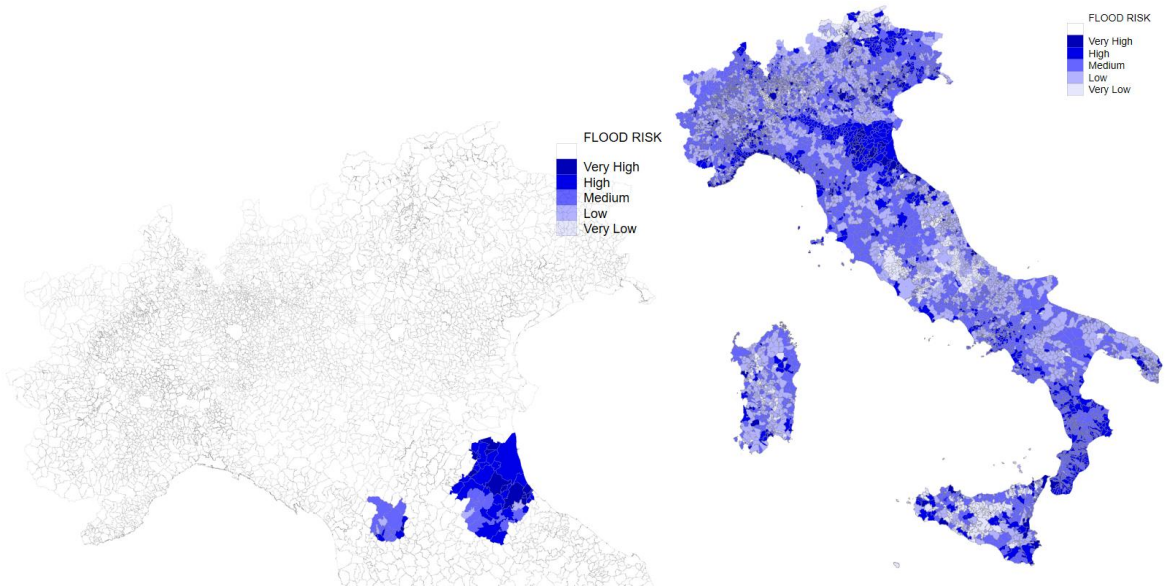
Year	Firms in class 3	Moved to class 4	Share of class 3	Share of portfolio
2023	2,560	280	10.9%	1.5%
2024	2,476	306	12.4%	1.6%
2025	2,309	304	13.2%	1.6%

Source: annex, comparison of original and adjusted rating classes.

6.5.4 Case Study

The total debt outstanding of the firms included in the portfolio amounted to EUR10.9 billion; the portfolio mean Probability of Default is 3.87%. The Adjusted PD is 4.08%. This PD adjustment generates a Delta Expected Losses of EUR7.1m.

Figure 5: Portfolio of municipalities by flood hazard



The portfolio is concentrated in the better classes. This asymmetry determines where the climate adjustment takes effect in monetary terms. The aggregate effect of the adjustment on the portfolio depends less on how many firms are affected than on the overlap between the high-vulnerability sectors, the high-hazard municipalities and the lower rating classes. See Annex III p.184 for full exercise description.

6.6. Scope of application

The adjustment requires only a PD, a NACE 2-digit code and the location of the borrower, and it uses no product, collateral or exposure information. It can therefore be applied to PDs from internal rating models, whether A-IRB or F-IRB, and to scores or PDs supplied by external providers or credit rating agencies, without access to the internals of the underlying model or its recalibration. Hazard data are equally interchangeable, since return-period probabilities are available from many climate data providers, including open sources such as EU Copernicus programme. Deciding which hazard is financially material for a given borrower remains a judgement for the credit analyst or risk manager.

The adjustment applies to every customer segment with a NACE classification, including corporates, SMEs, sole traders, public sector and non-profit entities, and to all lending products, from term loans and revolving facilities to trade finance and leasing. Consumer lending is out of scope, since private individuals have no economic activity classification.

Because it is applied downstream of the rating assignment, the adjustment does not alter the regulatory PD used for capital requirements unless it is explicitly incorporated into the rating system. In its present form, it is intended for risk management, portfolio steering, climate stress scenario analysis and disclosure. Each institution can set α according to its own portfolio composition, hazard mix and risk appetite, and document it as a discrete, auditable calibration choice. Where a PD over a longer horizon is not available, α can also be recalibrated to capture the higher cumulative exposure to climate events over the period of interest; this extends the horizon of the climate component only, while the underlying credit PD remains a one-year estimate.

6.7. Limitations and areas for development

Geographic proxy. The hazard class is assigned based on the municipality of the registered office. Where productive assets are located elsewhere, or spread across several sites, the hazard level used may not match the firm's actual exposure, in either direction.

Sectoral granularity. The VIS is constant within NACE 2-digit divisions and does not reflect firm-level adaptation, business continuity arrangements or insurance coverage.

Single-hazard calibration. The probability mapping covers flood hazard only. Extending the adjustment to drought, heat stress and wildfire requires an equivalent mapping for each hazard and a rule for aggregating multiple hazards, which has not yet been defined.

Gross exposure versus net credit impact. The VIS measures the gross physical exposure of an economic activity. It does not capture the net effect on creditworthiness, which can be of the opposite sign where the event generates demand for the sector.

Calibration sample. All firms are located in provinces affected by the 2023 floods, so no unaffected geographic control sample is available, and the calibration relies on the comparison between more and less vulnerable sectors. The calibration period was also affected by moratoria and by the post-pandemic recovery, and the number of default events is small, with 74 defaults over two years. α should therefore be reviewed as further evidence becomes available.

The main areas for development follow from these limitations: a VIS at NACE 3- or 4-digit level, the geolocation of productive assets, probability mappings and an aggregation rule for additional hazards, and periodic recalibration of α on new default and credit migration data.

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Annex I. Green Asset Ratio – survey commentary

1. Green Asset Ratio

Evidence from banks' disclosures. The pattern described by FIEs in the interviews is confirmed by banks' own regulatory reporting. To test it, we collected the Pillar 3 GAR disclosures of 25 banks in Belgium, France and Italy for the 2023 and 2024 reference dates, separating the climate change mitigation and climate change adaptation KPIs for both the stock and flow measures. The results are set out in full in Appendix 1 and summarised below.

Table 16. Composition of the GAR climate KPIs, sample of 25 Belgian, French and Italian banks

	2023		2024	
	Stock	Flow	Stock	Flow
Banks disclosing the KPI (of 25)	19	17	24	22
Average climate change mitigation KPI	2.71%	2.64%	2.75%	2.56%
Average climate change adaptation KPI	0.05%	0.05%	0.03%	0.06%
Adaptation as a share of the total climate KPI	1.8%	1.9%	1.1%	2.3%
Banks reporting adaptation of exactly 0.00%	15 of 19	15 of 17	16 of 24	17 of 22
Highest adaptation KPI in the sample	0.90%	0.88%	0.44%	0.67%

Simple averages across disclosing banks. Figures as reported by each institution; no adjustment has been made for differences in scope or coverage.

Across the 2024 stock measure, the average adaptation KPI is 0.03%, against 2.75% for mitigation. No bank in the sample, in either year and on either measure, reports an adaptation KPI above 1%; the highest figure recorded anywhere in the dataset is 0.90%. For the great majority of these institutions, adaptation does not round to a reportable number at all: 16 of the 24 banks disclosing a 2024 stock KPI report adaptation of exactly zero, as do 17 of the 22 reporting a flow KPI.

Adaptation accounts for 1.1% of the total climate KPI on the 2024 stock measure and 2.3% on the flow measure. Mitigation accounts for the rest. This is a difference of roughly two orders of magnitude, arising within the same balance sheets, under the same reporting framework and subject to the same regulatory incentives. Whatever the GAR is measuring, it is in practice a mitigation indicator with an adaptation column attached.

Between 2023 and 2024 the average mitigation KPI was broadly stable on the stock measure, moving from 2.71% to 2.75%, while the average adaptation KPI fell from 0.05% to 0.03%. More banks disclosed an adaptation figure in 2024 than in 2023, and more reported a non-zero one, so the fall reflects a lower level of exposure among those reporting rather than thinner disclosure. On the evidence of these two years, adaptation is not a small category growing from a low base; it is a small category that is not yet growing.

One pattern within the sample is worth isolating, because it points to the explanation. The largest adaptation exposures do not sit with the largest commercial lenders. They sit with public and promotional institutions: Bpi France reports the highest adaptation KPI in the dataset at 0.90% of stock in 2023 and 0.67% of flow in 2024, and SFIL, which finances French local authorities, reports

0.44% of stock in 2024. By contrast the large universal banks – those with the deepest corporate franchises and the widest sectoral reach – cluster at or just above zero: BNP Paribas at 0.02% of stock in 2024, UniCredit at 0.01%, Intesa Sanpaolo, Crédit Agricole, BPCE, Société Générale, Banco BPM and La Banque Postale at 0.00%. Adaptation currently registers on European balance sheets where the mandate is public and disappears where the mandate is commercial. That is the central finding of this survey.

Reasons for the gap - Alignment is demanding to prove. A company must run a climate risk and vulnerability assessment for the specific activity, identify which hazards are material to it, and support this with climate projections covering at least the next ten to thirty years. This evidence is expensive to produce, and the Commission expected from the outset that it would rarely be available for SME lending.

The ratio is asymmetric. Loans to counterparties outside the scope of the CSRD, such as SMEs and companies based outside the EU, are left out of the numerator but kept in the denominator. They are therefore counted as entirely unsustainable, whatever they actually finance. For most European banks these loans make up more than half of the denominator.[328, 329]

These design features do not, however, explain the size of the divergence, and treating the problem as a reporting artefact would miss what the data is actually showing. Mitigation has become a reportable asset class because it first became a bankable one. Over the past two decades, mitigation investment has acquired the features lenders require: an identifiable revenue stream (tariffs, PPAs, energy savings, carbon pricing), standardised project structures, an established track record of performance, comparable risk metrics, and sufficient volume and homogeneity to support origination at scale. The GAR simply records the outcome of that process.

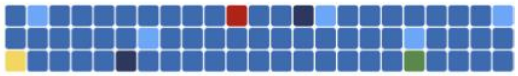
Adaptation has none of these features or has them only in fragments. Its returns typically take the form of avoided losses rather than incremental revenues – a cash flow that does not appear in a borrower's projections and cannot readily be pledged. Its benefits are frequently non-excludable, accruing to a catchment, a district or a supply chain rather than to the single counterparty carrying the debt. The timing of the benefit is contingent on hazard occurrence and therefore uncertain over the tenor of a loan. There are no widely accepted performance metrics against which resilience outcomes can be underwritten, priced or monitored. And the underlying needs are concentrated in small tickets and fragmented counterparties – farms, SMEs, local authorities, individual buildings – where origination costs are highest and

[328] The framework described above has since been rebuilt. The Omnibus Delegated Act, adopted on 4 July 2025, entered into force on 28 January 2026 and applies retrospectively from 1 January 2026. Its central change for banks is that exposures to entities outside the scope of sustainability reporting are excluded from the GAR denominator, with SME exposures excluded as a rule; a 10% materiality threshold now allows institutions to omit assessment of activities falling below that share, and the reporting templates have been consolidated, with the Commission estimating a reduction of roughly 89% in the data points required from credit institutions. The asymmetry described above has, in other words, largely been corrected.

[329] Commission Delegated Regulation amending the Disclosures and Climate Delegated Acts (Omnibus Delegated Act), adopted 4 July 2025, published in the Official Journal on 8 January 2026 and in force from 28 January 2026, applying retrospectively from 1 January 2026. See also Commission Notice on the interpretation and implementation of certain legal provisions of the Disclosures Delegated Act as amended by the Omnibus Delegated Act (fourth notice), OJ C/2026/2558, 30 April 2026.

standardization lowest. Adaptation, in short, is not absent from the GAR because it goes unfinanced; it is absent because it has not yet been rendered bankable, and what is not bankable does not become an asset class. The concentration of the sample's adaptation exposures in public and promotional lenders is precisely what one would expect of a category that can still only be financed where a return is not the binding constraint.

The consequence is that adaptation reaches banks almost exclusively through the risk function rather than the origination function. It is assessed as an exposure to be measured, provisioned for and, where possible, reduced or exited, but it is rarely structured as a transaction to be underwritten. This is consistent with what FIEs reported in the interviews, where the strongest motivation to act on adaptation was the vulnerability of the existing portfolio rather than the identification of a new market, and it is consistent with Table 16. A bank cannot report as aligned what it has not originated, and it will not originate what it cannot underwrite.



2 GAR Ratios

Pillar 3 GAR disclosures (Template 6) for 25 banks in Belgium, France and Italy. Figures are as reported by each institution. "n/a" indicates that the institution did not disclose the KPI for that reference date.

Table 17 Pillar 3 Data – KPI GAR (Template 6), 2023

Name	Country	Total assets class	KPI	Climate change mitigation	Climate change adaptation	Total (CCM + CCA)	% coverage (over total assets)
Belfius Banque SA ; Belfius Bank NV ; Belfius Bank SA	Belgium	150-300 bn	GAR Stock	0.11%	0.00%	n/a	37.1%
Belfius Banque SA ; Belfius Bank NV ; Belfius Bank SA	Belgium	150-300 bn	GAR Flow	0.89%	0.00%	n/a	23.0%
Crelan SA ; Crelan NV	Belgium	50-75 bn	GAR Stock	0.00%	0.00%	n/a	81.4%
Crelan SA ; Crelan NV	Belgium	50-75 bn	GAR Flow	0.00%	0.00%	n/a	0.0%
The Bank of New York Mellon SA/NV	Belgium	30-50 bn	GAR Stock	n/a	n/a	n/a	n/a
The Bank of New York Mellon SA/NV	Belgium	30-50 bn	GAR Flow	n/a	n/a	n/a	n/a
BNP Paribas S.A.	France	above EUR 1,000 bn	GAR Stock	0.77%	0.01%	0.78%	28.10%
BNP Paribas S.A.	France	above EUR 1,000 bn	GAR Flow	n/a	n/a	n/a	n/a
BPCE S.A.	France	500-1,000 bn	GAR Stock	3.98%	0.00%	n/a	66.16%
BPCE S.A.	France	500-1,000 bn	GAR Flow	n/a	n/a	n/a	n/a
Bpifrance	France	100-150 bn	GAR Stock	6.31%	0.90%	7.21%	14.12%
Bpifrance	France	100-150 bn	GAR Flow	0.15%	0.88%	1.04%	9.84%
Confédération Nationale du Crédit Mutuel	France	500-1,000 bn	GAR Stock	5.15%	0.00%	5.15%	76.21%
Confédération Nationale du Crédit Mutuel	France	500-1,000 bn	GAR Flow	0.51%	0.00%	0.51%	82.79%
Crédit Agricole S.A.	France	above EUR 1,000 bn	GAR Stock	n/a	n/a	n/a	n/a
Crédit Agricole S.A.	France	above EUR 1,000 bn	GAR Flow	n/a	n/a	n/a	n/a
HSBC Continental Europe	France	150-300 bn	GAR Stock	n/a	n/a	n/a	n/a

Name	Country	Total assets class	KPI	Climate change mitigation	Climate change adaptation	Total (CCM + CCA)	% coverage (over total assets)
HSBC Continental Europe	France	150-300 bn	GAR Flow	n/a	n/a	n/a	n/a
La Banque Postale	France	300-500 bn	GAR Stock	n/a	n/a	n/a	n/a
La Banque Postale	France	300-500 bn	GAR Flow	n/a	n/a	n/a	n/a
RCI Banque SA	France	50-75 bn	GAR Stock	5.20%	0.00%	5.20%	50.60%
RCI Banque SA	France	50-75 bn	GAR Flow	6.70%	0.00%	6.70%	75.20%
SFIL S.A.	France	50-75 bn	GAR Stock	12.61%	0.00%	12.61%	n/a
SFIL S.A.	France	50-75 bn	GAR Flow	31.44%	0.00%	31.44%	n/a
Société Générale S.A.	France	above EUR 1,000 bn	GAR Stock	n/a	n/a	n/a	n/a
Société Générale S.A.	France	above EUR 1,000 bn	GAR Flow	n/a	n/a	n/a	n/a
Banca Mediolanum S.p.A.	Italy	30-50 bn	GAR Stock	4.80%	0.00%	4.80%	31.00%
Banca Mediolanum S.p.A.	Italy	30-50 bn	GAR Flow	0.80%	0.00%	0.00%	4.40%
BANCA MONTE DEI PASCHI DI SIENA S.p.A.	Italy	100-150 bn	GAR Stock	0.50%	0.00%	0.50%	24.59%
BANCA MONTE DEI PASCHI DI SIENA S.p.A.	Italy	100-150 bn	GAR Flow	0.15%	0.00%	0.15%	3.11%
Banca Popolare di Sondrio, Società per Azioni (S.p.A.)	Italy	50-75 bn	GAR Stock	1.14%	0.00%	1.14%	69.32%
Banca Popolare di Sondrio, Società per Azioni (S.p.A.)	Italy	50-75 bn	GAR Flow	0.75%	0.00%	0.75%	76.97%
Banco BPM S.p.A.	Italy	150-300 bn	GAR Stock	2.02%	0.00%	2.02%	70.81%
Banco BPM S.p.A.	Italy	150-300 bn	GAR Flow	0.52%	0.00%	0.52%	51.26%
BPER Banca S.p.A.	Italy	100-150 bn	GAR Stock	1.50%	0.00%	1.50%	81.70%
BPER Banca S.p.A.	Italy	100-150 bn	GAR Flow	0.42%	0.00%	0.42%	81.70%
Cassa Centrale Banca - Credito Cooperativo Italiano S.p.A.	Italy	75-100 bn	GAR Stock	0.98%	0.00%	0.98%	61.60%
Cassa Centrale Banca - Credito Cooperativo Italiano S.p.A.	Italy	75-100 bn	GAR Flow	0.30%	0.00%	0.30%	45.62%
Credito Emiliano Holding S.p.A.	Italy	50-75 bn	GAR Stock	1.07%	0.00%	1.07%	71.93%
Credito Emiliano Holding S.p.A.	Italy	50-75 bn	GAR Flow	0.20%	0.00%	0.20%	71.93%
FinecoBank S.p.A.	Italy	30-50 bn	GAR Stock	0.00%	0.00%	0.00%	37.40%

Name	Country	Total assets class	KPI	Climate change mitigation	Climate change adaptation	Total (CCM + CCA)	% coverage (over total assets)
FinecoBank S.p.A.	Italy	30-50 bn	GAR Flow	0.00%	0.00%	0.00%	0.40%
ICCREA Banca S.p.A. - Istituto Centrale del Credito Cooperativo	Italy	150-300 bn	GAR Stock	n/a	n/a	n/a	n/a
ICCREA Banca S.p.A. - Istituto Centrale del Credito Cooperativo	Italy	150-300 bn	GAR Flow	n/a	n/a	n/a	n/a
Intesa Sanpaolo S.p.A.	Italy	500-1,000 bn	GAR Stock	2.65%	0.00%	2.65%	70.56%
Intesa Sanpaolo S.p.A.	Italy	500-1,000 bn	GAR Flow	0.67%	0.00%	0.67%	70.56%
Mediobanca - Banca di Credito Finanziario S.p.A.	Italy	75-100 bn	GAR Stock	1.60%	0.01%	1.61%	45.90%
Mediobanca - Banca di Credito Finanziario S.p.A.	Italy	75-100 bn	GAR Flow	0.86%	0.00%	0.87%	22.21%
UniCredit S.p.A.	Italy	500-1,000 bn	GAR Stock	1.06%	0.01%	1.16%	69.3%
UniCredit S.p.A.	Italy	500-1,000 bn	GAR Flow	0.60%	0.01%	0.83%	92.1%

Table 18. Pillar 3 Data – KPI GAR (Template 6), 2024

Name	Country	Total assets class	KPI	Climate change mitigation	Climate change adaptation	Total (CCM + CCA)	% coverage (over total assets)
Belfius Banque SA ; Belfius Bank NV ; Belfius Bank SA	Belgium	150-300 bn	GAR Stock	0.12%	0.00%	0.12%	78.6%
Belfius Banque SA ; Belfius Bank NV ; Belfius Bank SA	Belgium	150-300 bn	GAR Flow	0.08%	0.00%	0.08%	100.0%
Crelan SA ; Crelan NV	Belgium	50-75 bn	GAR Stock	0.03%	0.00%	0.03%	88.1%
Crelan SA ; Crelan NV	Belgium	50-75 bn	GAR Flow	n/a	n/a	n/a	n/a
The Bank of New York Mellon SA/NV	Belgium	30-50 bn	GAR Stock	n/a	n/a	n/a	n/a
The Bank of New York Mellon SA/NV	Belgium	30-50 bn	GAR Flow	n/a	n/a	n/a	n/a
BNP Paribas S.A.	France	above EUR 1,000 bn	GAR Stock	1.82%	0.02%	1.84%	11.21%
BNP Paribas S.A.	France	above EUR 1,000 bn	GAR Flow	11.50%	0.07%	11.56%	n/a

Name	Country	Total assets class	KPI	Climate change mitigation	Climate change adaptation	Total (CCM + CCA)	% coverage (over total assets)
BPCE S.A.	France	500-1,000 bn	GAR Stock	4.09%	0.00%	4.09%	66.18%
BPCE S.A.	France	500-1,000 bn	GAR Flow	2.70%	0.00%	2.70%	89.03%
Bpifrance	France	100-150 bn	GAR Stock	6.83%	0.09%	6.92%	11.84%
Bpifrance	France	100-150 bn	GAR Flow	1.61%	0.67%	2.28%	4.52%
Confédération Nationale du Crédit Mutuel	France	500-1,000 bn	GAR Stock	5.74%	0.00%	5.74%	76.90%
Confédération Nationale du Crédit Mutuel	France	500-1,000 bn	GAR Flow	2.25%	0.00%	2.25%	90.80%
Crédit Agricole S.A.	France	above EUR 1,000 bn	GAR Stock	4.26%	0.00%	4.26%	24.38%
Crédit Agricole S.A.	France	above EUR 1,000 bn	GAR Flow	3.23%	0.00%	3.23%	1.77%
HSBC Continental Europe	France	150-300 bn	GAR Stock	0.39%	0.01%	0.40%	45.28%
HSBC Continental Europe	France	150-300 bn	GAR Flow	0.01%	0.00%	0.01%	20.23%
La Banque Postale	France	300-500 bn	GAR Stock	5.70%	0.00%	5.70%	56.00%
La Banque Postale	France	300-500 bn	GAR Flow	1.70%	0.00%	1.70%	30.30%
RCI Banque SA	France	50-75 bn	GAR Stock	7.10%	0.00%	7.10%	59.10%
RCI Banque SA	France	50-75 bn	GAR Flow	7.10%	0.00%	7.10%	70.80%
SFIL S.A.	France	50-75 bn	GAR Stock	5.00%	0.44%	5.44%	80.02%
SFIL S.A.	France	50-75 bn	GAR Flow	n/a	n/a	n/a	n/a
Société Générale S.A.	France	above EUR 1,000 bn	GAR Stock	1.71%	0.00%	1.71%	9.88%
Société Générale S.A.	France	above EUR 1,000 bn	GAR Flow	0.96%	0.00%	0.96%	6.66%
Banca Mediolanum S.p.A.	Italy	30-50 bn	GAR Stock	6.52%	0.02%	6.53%	56.01%
Banca Mediolanum S.p.A.	Italy	30-50 bn	GAR Flow	1.00%	0.00%	1.00%	56.01%
BANCA MONTE DEI PASCHI DI SIENA S.p.A.	Italy	100-150 bn	GAR Stock	1.05%	0.00%	1.05%	49.00%
BANCA MONTE DEI PASCHI DI SIENA S.p.A.	Italy	100-150 bn	GAR Flow	0.60%	0.00%	0.60%	6.54%
Banca Popolare di Sondrio, Società per Azioni (S.p.A.)	Italy	50-75 bn	GAR Stock	1.58%	0.00%	1.58%	72.12%
Banca Popolare di Sondrio, Società per Azioni (S.p.A.)	Italy	50-75 bn	GAR Flow	1.72%	0.00%	1.72%	84.99%

Name	Country	Total assets class	KPI	Climate change mitigation	Climate change adaptation	Total (CCM + CCA)	% coverage (over total assets)
Banco BPM S.p.A.	Italy	150-300 bn	GAR Stock	2.52%	0.00%	2.52%	71.62%
Banco BPM S.p.A.	Italy	150-300 bn	GAR Flow	1.83%	0.00%	1.83%	53.13%
BPER Banca S.p.A.	Italy	100-150 bn	GAR Stock	2.70%	0.04%	2.74%	80.50%
BPER Banca S.p.A.	Italy	100-150 bn	GAR Flow	1.04%	0.00%	1.04%	80.50%
Cassa Centrale Banca - Credito Cooperativo Italiano S.p.A.	Italy	75-100 bn	GAR Stock	1.26%	0.00%	1.26%	63.92%
Cassa Centrale Banca - Credito Cooperativo Italiano S.p.A.	Italy	75-100 bn	GAR Flow	1.78%	0.00%	1.78%	49.51%
Credito Emiliano Holding S.p.A.	Italy	50-75 bn	GAR Stock	1.20%	0.00%	1.20%	74.40%
Credito Emiliano Holding S.p.A.	Italy	50-75 bn	GAR Flow	0.98%	0.00%	0.98%	90.62%
FinecoBank S.p.A.	Italy	30-50 bn	GAR Stock	1.68%	0.00%	1.68%	32.99%
FinecoBank S.p.A.	Italy	30-50 bn	GAR Flow	0.05%	0.00%	0.05%	0.27%
ICCREA Banca S.p.A. - Istituto Centrale del Credito Cooperativo	Italy	150-300 bn	GAR Stock	2.00%	0.00%	2.00%	67.25%
ICCREA Banca S.p.A. - Istituto Centrale del Credito Cooperativo	Italy	150-300 bn	GAR Flow	0.49%	0.00%	0.49%	7.35%
Intesa Sanpaolo S.p.A.	Italy	500-1,000 bn	GAR Stock	3.63%	0.00%	3.63%	73.80%
Intesa Sanpaolo S.p.A.	Italy	500-1,000 bn	GAR Flow	8.11%	0.00%	8.11%	9.43%
Mediobanca - Banca di Credito Finanziario S.p.A.	Italy	75-100 bn	GAR Stock	2.09%	0.05%	2.14%	44.82%
Mediobanca - Banca di Credito Finanziario S.p.A.	Italy	75-100 bn	GAR Flow	3.69%	0.29%	3.98%	87.49%
UniCredit S.p.A.	Italy	500-1,000 bn	GAR Stock	1.32%	0.01%	1.33%	69.0%
UniCredit S.p.A.	Italy	500-1,000 bn	GAR Flow	1.29%	0.03%	1.31%	80.4%

% coverage (over total assets): the share of assets covered by the GAR calculation as a proportion of total asset

Annex II. Sector Vulnerability Framework

This appendix sets out how the Sector Vulnerability Framework and the Vulnerability Intensity Sector score (VIS) were constructed. It produces, for each NACE 2-digit sector, an ordinal assessment of how severely a given physical climate hazard is expected to affect the sector through three transmission channels and an aggregate score to differentiate exposure across the portfolio. The assessment is at structural and sector level: it describes the susceptibility of a sector's production model to a hazard, expressed at an intensity level not a probability or an estimate of the damage caused by the event.

The Sector Vulnerability Framework defines how physical risks reach the three transmission channels — capital, human workforce and climate dependence — supported by quantitative analysis of a portfolio of corporate financial statements. Sectors were clustered by capital intensity and workforce intensity, and the resulting groupings were used as evidence in assigning the judgement-based vulnerability levels, corroborating them in most cases and prompting revision in others. The quantitative analysis is therefore an input to the assessment, not an independent validation of it.

Sectoral vulnerability for the climate-dependence driver was derived exclusively through expert judgement.

The methodology proceeds in these stages, each described in turn below:

1. Portfolio construction and information sources
2. Data quality checks and exclusions
3. Construction of intensity indicators
4. Portfolio segmentation and cluster analysis
5. Assignment of vulnerability levels
6. Vulnerability Matrix
7. Vulnerability Intensity Sector score and Vulnerability Scale
8. Limitations and improvements.

1 Portfolio construction and information sources

The analysis requires financial statement data together with the location and business activity classification of each entity. The portfolio supporting the Sector Vulnerability Framework therefore comprises corporations and equivalent legal forms, which report the necessary information consistently, and based in the Italian provinces of Ravenna and Forlì-Cesena (Emilia Romagna region) and Prato and Pistoia (Tuscany region), the same portfolio used in the Adaptation Adjustment Credit Risk Methodology (Annex III), ensuring methodological consistency between the two exercises[330].

[330] For details, see the Annex III 'Definition of the time horizon and performance (in bonis/default)'.

To ensure a clearer understanding of the companies' financial and operational structure, the portfolio excludes firms subject to negative public information—such as insolvency proceedings, protests, or other negative reports—as well as those undergoing liquidation procedures. By excluding firms that are in distress or undergoing liquidation, the analysis removes precisely those companies that have already experienced financial difficulties. This makes the resulting portfolio more representative for the intended purpose, as it is composed of firms that remain in stable operating and financial condition.

Moreover, the portfolio is constructed on companies' headquarters (registered office), which is used as a proxy for the location of activity; where a company's productive assets are situated elsewhere, the geographic attribution is approximate. This choice ensures methodological consistency between the two exercises, but it limits the coverage of the sector available for the framework: regional economies do not contain every NACE division in statistically significant numbers (see later the significance analysis for poorly represented or absent sectors).

2 Data quality checks and exclusions

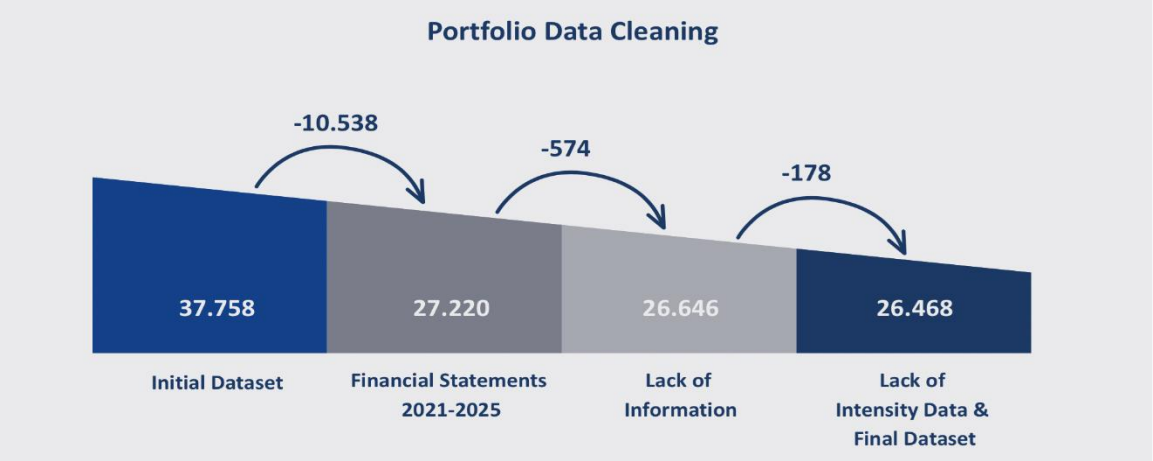
The initial dataset contains 37,758 companies established in the Italian provinces of Ravenna and Forlì-Cesena (Emilia Romagna region) and Prato and Pistoia (Tuscany region). Data cleaning is performed through a series of structured filters designed to ensure completeness, consistency and relevance. In line with market best practices, the following exclusions were made:

- missing registry information;
- only companies with financial statements available from the 2021 fiscal year are considered;
- companies without information on their economic activity or that cannot be classified under any sector[331];
- companies without sufficient data for the construction of the intensity indicators.

The final dataset contains 26,468 companies. Below is the impact on the portfolio of the rule-cleaning activities carried out.

[331] Information regarding the economic activities carried out by companies has been reclassified according to the new NACE classification (NACE Rev. 2.1-Nomenclature des Activités économiques dans la Communauté Européenne), which is used to classify economic activities in Europe and took effect in 2025. Therefore, the information available for the companies — which refers to the previous 2022 classification—has been mapped to the new classification based on the correspondence tables between the ATECO 2025 and ATECO 2022 classifications (ATECO-Italian economic activities classification) provided by statistical agencies (specifically Eurostat and, for Italy, ISTAT). The changes introduced by the new classification have not altered the structure and levels of the previous classification; however, since the correspondences between the codes have been revised, it has not always been possible to maintain a one-to-one correspondence. For some codes. the economic activities associated with a 2022 code are distributed across multiple 2025 codes at the same hierarchical level, without it being possible to identify a clearly prevalent or representative code. In these cases, since it was not possible to identify a reference code for the economic activity carried out by the company, the company was excluded from the portfolio perimeter. For details, see ec.europa.eu/eurostat/web/products-manuals-and-guidelines/w/ks-gq-24-007 and www.istat.it/classificazione/ateco-2025/.

Figure 6: Portfolio data cleaning



A coverage assessment was carried out to evaluate the representativeness of the selected portfolio. The analysis is based on a comparative approach between the portfolio size and the total number of active corporations (and equivalent legal forms) in the selected provinces using the Chamber of Commerce data on active corporate by province and sector activity (2-digit Nace code)[332]. The selected portfolio (consisting of 26,468 corporates) covers a substantial share of the territorial corporate population[333]. The share (equal to 80%) between the portfolio and the total number of active corporations in the selected areas indicates a high level of coverage, ensuring that the portfolio is sufficiently large to support sector-level inference.

Coverage is not the same as representativeness: because the exclusion rules are not random with respect to financial condition, high coverage does not by itself guarantee an unbiased sample. In addition to numerical representativeness, a sectoral significance check was performed. The sectoral distribution of the portfolio was compared with the sectoral composition of the active corporations in the selected provinces. The alignment observed across major economic sectors indicates that the portfolio is broadly representative from a sectoral point of view, thereby supporting the validity of sector-specific analyses and conclusions, except for a few sectors that are thinly represented, or absent also in the universe (for details, see the table 19 below) [334]:

[332] The relevance assessment was carried out using the Italian Business Registry statistics on the number of companies by geographic location of the registered office, sector of activity, legal type, and company status (registered, active). See https://infocamere.it/movimprese/.

[333] The Italian Business Registry figure refers exclusively to active entities in 2024. Within the selected provinces, the number of active corporations amounts to about 32,900, corresponding to roughly 2.1% of the national population of companies (at the national level, Italy counts approximately 1,550,900 companies). The initial portfolio is larger as it also comprises companies being wound up, inactive companies, and other non-operational units. Considering the total number of registered enterprises in the selected territories, the Business Registry would account for nearly 39,100 firms.

[334] The significance assessment was carried out considering different approaches: the coverage of the universe, the statistical error of the selected sample implicit in a very limited size. For coverage assessment, the following

- 07-Mining of metal ores,
- 08-Other mining and quarrying,
- 09-Mining support service activities,
- 19-Manufacture of coke and refined petroleum products,
- 21-Manufacture of basic pharmaceutical products and pharmaceutical preparations,
- 39-Remediation activities and other waste management service activities,
- 50-Water transport,
- 51-Air transport,
- 65-Insurance, reinsurance and pension funding, except compulsory social security,
- 78-Employment activities,
- 84-Public administration and defence; compulsory social security).

thresholds were defined: high when coverage is over 50%, medium when it is between 25% and 50%, and low when it is below 25%. For robustness, instead, a minimum threshold of 10 companies per sectoral group was set, with the following thresholds: high when the sector has more than 50 companies, medium when it is between 10 and 50, and low when the number is below 10. Since the portfolio coverage is numerically very high compared to the universe, it was not considered necessary to proceed with other approaches for assessing significance (e.g., the Cochran formula). It should also be noted that the data on the activities carried out, available for the universe from the Chambers of Commerce, show the classification of the economic activity carried out in the previous version (2022 instead of 2025). Comparing this with data from sectors that were most affected by the shifts could be influenced by the change in classification. For example, sector 45. Division 45 'Wholesale and retail trade and repair of motor vehicles and motorcycles' has been eliminated to achieve a consistent application of classification rules within section G. This means that the wholesale activities of motor vehicles and motorcycles have been moved to division 46 'Wholesale trade', the activities of retail trade of motor vehicles and motorcycles to division 47 'Retail trade' and the activities of maintenance and repair of motor vehicles and motorcycles to division 95 'Repair and maintenance of computers, personal and household goods, and motor vehicles and motorcycles' in section T. Since it's an aggregated figure by sector and province, it wasn't possible to align the data with the new classification.

Table 19: Selected portfolio by sector activity

NACE CODE 2-digit	NACE Description	PORTFOLIO N	PORTFOLIO %	UNIVERSE N. Corporates	UNIVERSE %	PORFTOLIO COVERAGE % Coverage	Robustness
01	Crop and animal production, hunting and related service activities	472	1,78	603	1,83	78,28	
02	Forestry and logging	30	0,11	43	0,13	69,77	
03	Fishing and aquaculture	22	0,08	21	0,06	104,76	
07	Mining of metal ores	0	0,00	0	0,00	0,00	na
08	Other mining and quarrying	8	0,03	8	0,02	100,00	
09	Mining support service activities	3	0,01	4	0,01	75,00	
10	Manufacture of food products	268	1,01	318	0,97	84,28	
11	Manufacture of beverages	22	0,08	23	0,07	95,65	
13	Manufacture of textiles	850	3,21	967	2,94	87,90	
14	Manufacture of wearing apparel	723	2,73	897	2,73	80,60	
15	Manufacture of leather and related products of other materials	184	0,70	205	0,62	89,76	
16	Manufacture of wood and of products of wood and cork, except furniture	94	0,36	112	0,34	83,93	
17	Manufacture of paper and paper products	79	0,30	89	0,27	88,76	
18	Printing and reproduction of recorded media	94	0,36	112	0,34	83,93	
19	Manufacture of coke and refined petroleum products	3	0,01	4	0,01	75,00	
20	Manufacture of chemicals and chemical products	114	0,43	132	0,40	86,36	
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	5	0,02	6	0,02	83,33	
22	Manufacture of rubber and plastic products	136	0,51	173	0,53	78,61	
23	Manufacture of other non-metallic mineral products	91	0,34	98	0,30	92,86	
24	Manufacture of basic metals	39	0,15	40	0,12	97,50	
25	Manufacture of fabricated metal products, except machinery and equipment	671	2,54	809	2,46	82,94	
26	Manufacture of computer, electronic and optical products	93	0,35	89	0,27	104,49	
27	Manufacture of electrical equipment	96	0,36	111	0,34	86,49	
28	Manufacture of machinery and equipment n.e.c.	365	1,38	425	1,29	85,88	
29	Manufacture of motor vehicles, trailers and semi-trailers	41	0,15	46	0,14	89,13	
30	Manufacture of other transport equipment	46	0,17	62	0,19	74,19	
31	Manufacture of furniture	222	0,84	280	0,85	79,29	
32	Other manufacturing	106	0,40	145	0,44	73,10	
33	Repair, maintenance and installation of machinery and equipment	267	1,01	310	0,94	86,13	
35	Electricity, gas, steam and air conditioning supply	283	1,07	271	0,82	104,43	
36	Water collection, treatment and supply	13	0,05	19	0,06	68,42	
37	Sewerage	30	0,11	27	0,08	111,11	
38	Waste collection, recovery and disposal activities	94	0,36	94	0,29	100,00	
39	Remediation activities and other waste management service activities	9	0,03	16	0,05	56,25	
41	Construction of residential and non-residential buildings	1.411	5,33	2164	6,58	65,20	
42	Civil engineering	94	0,36	102	0,31	92,16	
43	Specialised construction activities	1.546	5,84	2116	6,43	73,06	
45	*Wholesale and retail trade and repair of motor vehicles and motorcycles (eliminated)*	0	0,00	841	2,56	0,00	na
46	Wholesale trade	2.702	10,21	3047	9,26	88,68	
47	Retail trade	1.439	5,44	1782	5,42	80,75	
49	Land transport and transport via pipelines	401	1,52	452	1,37	88,72	
50	Water transport	8	0,03	11	0,03	72,73	
51	Air transport	1	0,00	4	0,01	25,00	
52	Warehousing, storage and support activities for transportation	337	1,27	407	1,24	82,80	
53	Postal and courier activities	10	0,04	15	0,05	66,67	
55	Accommodation	561	2,12	635	1,93	88,35	
56	Food and beverage service activities	1.194	4,51	1689	5,13	70,69	
58	Publishing activities	61	0,23	95	0,29	64,21	
59	Motion picture, video and television programme production, sound recording and music publishing activities	71	0,27	100	0,30	71,00	
60	Programming, broadcasting, news agency and other content distribution activities	16	0,06	17	0,05	94,12	
61	Telecommunication	34	0,13	47	0,14	72,34	
62	Computer programming, consultancy and related activities	440	1,66	517	1,57	85,11	
63	Computing infrastructure, data processing, hosting and other information service activities	387	1,46	488	1,48	79,30	
64	Financial service activities, except insurance and pension funding	427	1,61	430	1,31	99,30	
65	Insurance, reinsurance and pension funding, except compulsory social security	1	0,00	1	0,00	100,00	
66	Activities auxiliary to financial services and insurance activities	152	0,57	188	0,57	80,85	
68	Real estate activities	4.731	17,87	5012	15,23	94,39	
69	Legal and accounting activities	179	0,68	202	0,61	88,61	
70	Activities of head offices and management consultancy	743	2,81	954	2,90	77,88	
71	Architectural and engineering activities; technical testing and analysis	263	0,99	314	0,95	83,76	
72	Scientific research and development	91	0,34	109	0,33	83,49	
73	Activities of advertising, market research and public relations	159	0,60	240	0,73	66,25	
74	Other professional, scientific and technical activities	436	1,65	513	1,56	84,99	
75	Veterinary activities	16	0,06	13	0,04	123,08	ns
77	Rental and leasing activities	201	0,76	264	0,80	76,14	
78	Employment activities	8	0,03	10	0,03	80,00	
79	Travel agency, tour operator and other reservation service and related activities	76	0,29	133	0,40	57,14	
80	Investigation and security activities	26	0,10	28	0,09	92,86	
81	Services to buildings and landscape activities	222	0,84	275	0,84	80,73	
82	Office administrative, office support and other business support activities	448	1,69	605	1,84	74,05	
84	Public administration and defence; compulsory social security	0	0,00	3	0,01	0,00	
85	Education	201	0,76	319	0,97	63,01	
86	Human health activities	303	1,14	323	0,98	93,81	
87	Residential care activities	98	0,37	124	0,38	79,03	
88	Social work activities without accommodation	86	0,32	130	0,40	66,15	
90	Arts creation and performing arts activities	92	0,35	175	0,53	52,57	
91	Libraries, archives, museums and other cultural activities	10	0,04	26	0,08	38,46	
92	Gambling and betting activities	47	0,18	59	0,18	79,66	
93	Sports activities and amusement and recreation activities	548	2,07	911	2,77	60,15	
94	Activities of membership organisations	12	0,05	44	0,13	27,27	
95	Repair and maintenance of computers, personal and household goods, and motor vehicles and motorcycles	353	1,33	62	0,19	569,35	ns
96	Personal service activities	253	0,96	344	1,05	73,55	
Total		**26.468**	**100**	**32.899**	**100**	**80,45**	

3 Construction of intensity indicators

The framework assesses vulnerability through three risk transmission channels - capital intensity, human workforce and climate dependence - each capturing a distinct way in which a climate hazard translates into financial impact for a company operating in that sector.[335] [336]

Capital intensity - The extent to which a sector's value depends on fixed physical assets — plant, machinery, buildings, infrastructure — that are directly exposed to damage or business interruption from a hazard event. Where a large share of output depends on assets that can be physically damaged, impairment and repair or replacement costs follow directly from the event.

Human workforce - The degree to which a sector's productivity depends on labour performed under conditions that a hazard can render unsafe or unproductive — principally outdoor, on-site and physically demanding work, and work concentrated in narrow seasonal windows. Temperature-related hazards act through productivity and occupational health; acute events act through worker safety and site accessibility.

Climate dependence - The extent to which core inputs, processes or outputs of a sector rely directly on climate-conditioned natural resources — water availability, agricultural raw materials, temperature-controlled processes. Impact arises through the availability or quality of the input rather than through damage to the asset or to the workforce.

3.1 Vulnerability Intensity levels

Each risk channel is scored on a three-point ordinal scale. The same three levels are used throughout the framework, so that a level assigned on one risk channel is comparable in meaning to a level assigned on another.

Low [0] - Minimal sensitivity to physical climate risk. Low exposure of fixed assets, limited potential for operational disruption, and operations not materially affected by temperature, precipitation or extreme events. On the climate dependence channel, no significant reliance on climate-conditioned natural inputs (e.g., operations not materially affected by temperature, precipitation or extreme events).

Medium [1] - Intermediate sensitivity. Climate hazards may affect production processes, capital assets or workforce availability under specific conditions. Moderate capital intensity, a workforce structure that can amplify exposure in certain scenarios, and non-negligible reliance on stable environmental conditions or climate-sensitive inputs.

[335] See Schrapffer, A. and Bres, J., Assessing Economic Sector Vulnerability to Climate Physical and Transition Risks: A Comprehensive Methodological Framework, version 1.0 (17 May 2024), available at SSRN: https://ssrn.com/abstract=4831795.

[336] See Banca d'Italia - No. 77 - Hydrogeological and credit risk: the Italian firms' physical risk-adjusted probability of default

High [2] - Pronounced sensitivity to physical climate risks. Large fixed assets, including continuous-process plant (packaging line, refineries, infrastructure, reactors, storage systems, kilns, furnaces, and heavy equipment), located in exposed areas; labour-dependent operations requiring continuous on-site or outdoor presence; strong climate dependence (output or operational continuity directly shaped by temperature, hydrological variability or extreme weather events).

3.2 Vulnerability Intensity Indicators

To assess the first two risk channels of this approach, two quantitative indicators were developed[337]:

- **Capital Intensity (CI) ratio** — based on tangible fixed assets and total assets;
- **Human Workforce Intensity (HWI)** — based on employee headcount and personnel costs, with personnel costs used in the treatment of missing values.

To mitigate year-specific fluctuations, both indicators are computed as multi-year averages, drawing on data for the most recent available financial year (FY 2024) and the two preceding years. Where all three years are available, a three-year average is used; where one year is missing, a two-year average; and where only the most recent year is available, that value is used as a fallback. This hierarchical approach ensures that the most informative, complete and reliable indicator available is computed for each entity.

The Capital Intensity (CI) ratio is based on the total tangible fixed assets. Fixed assets provide a useful indicator for identifying economic activities that are more exposed to physical damage caused by adverse events. Sectors that heavily rely on long-term physical capital—like plants, machinery, infrastructure, and equipment—tend to be more vulnerable, since a larger part of their output depends on assets that can be directly damaged or disrupted. The indicator is computed as:

$$\mathrm{CI}_t = \frac{Tangible\ Fixed\ Assets_t}{Total\ Assets_t}\ x\ 100$$

for t =1, … 3 where 1 = last year, 2= last year–1, 3=last year–2

To enhance the understanding of potential adverse impacts, exposure could also be assessed by considering inventory levels, since losses of raw materials, semi-finished goods, or finished products may represent an additional channel through which physical events affect operational continuity and financial performance.

[337] The climate-dependence driver was not assessed through quantitative metrics or empirical modelling; its intensity level was determined exclusively through expert judgment, based on sectoral characteristics and qualitative evidence.

The Human Workforce Intensity (HWI) is measured using employee headcount and personnel costs. A conservative rule was applied to address missing values in the employment data[338].

It was decided to use the number of employees as the indicator, meaning a measure of scale rather than an index (as in the case of CI). This choice reflects the view that size is a more appropriate proxy for the factor we aim to capture: the extent to which production relies on work performed under hazardous conditions.

The definition of intensity could also be complemented with additional indicators such as personnel costs relative to revenue or personnel costs relative to total operating costs.

3.3 Vulnerability Intensity Development

Consistent with the three-level structure used for risk transmission channel vulnerability — Low [0], Medium [1], High [2]— a categorical variable was also constructed for each driver, classifying entities into three intensity groups. This classification supports interpretation of the characteristics of economic activities in terms of assets and employees. Thresholds for capital intensity were set by reference to the observed distribution of the data. The following table presents a set of descriptive statistics (CI ratio, employee data, and categorical variables distributions), intended to outline the main features of the portfolio.

Table 20. Vulnerability Intensity Indicators - Statistics

CAPITAL INTENSITY

TANGIBLEonTOTASSETS

	Percentiles	Smallest		
1%	0	0		
5%	0	0		
10%	0	0	Obs	26,468
25%	1.2	0	Sum of wgt.	26,468
50%	9.6		Mean	23.33355
		Largest	Std. dev.	29.06933
75%	35.7	100		
90%	77.1	100	Variance	845.0258
95%	89.8	100	Skewness	1.264309
99%	97.3	100	Kurtosis	3.324104

CI_class	Freq.	Percent	Cum.
0_LowTangibleAsset	10,674	40.33	40.33
1_MediumTangibleAsset	7,307	27.61	67.93
2_HighTangibleAsset	8,487	32.07	100.00
Total	26,468	100.00	

HUMAN WORKFORCE INTENSITY

EMPLOYEES

	Percentiles	Smallest		
1%	0	0		
5%	0	0		
10%	0	0	Obs	26,468
25%	0	0	Sum of wgt.	26,468
50%	2		Mean	8.840562
		Largest	Std. dev.	55.8571
75%	7	1875		
90%	16	1884	Variance	3120.015
95%	30	2484	Skewness	44.44774
99%	105	5192	Kurtosis	3224.248

DIP_class	Freq.	Percent	Cum.
0_LowHumanWF	21,672	81.88	81.88
1_MediumHumanWF	4,123	15.58	97.46
2_HighHumanWF	673	2.54	100.00
Total	26,468	100.00	

[338] Employee data was missing for about 2.8% of the portfolios' balance sheets. The following rule was applied: when employment data was missing but personnel costs were present, the missing value was considered not available, and the entity was excluded from the portfolio. When both were missing, it was assumed that the entity had no employees: entities in this category were included in the portfolio, since it's plausible that companies of this size don't have employees beyond the owners. Otherwise, the companies were excluded.

To classify corporate tangible fixed assets, the following thresholds are applied:

- Low Tangible Assets — representing a low intensity level: CI indicator ≤ 5%
- Medium Tangible Assets — representing a medium intensity level: CI indicator above 5% and up to 25%
- High Tangible Assets — representing a high intensity level: CI indicator > 25%.

Workforce thresholds follow European Commission Recommendation 2003/361/EC. To classify corporate workforce size [339], the following thresholds are applied:

- Low Workforce Intensity — representing a low intensity level: HWI indicator < 10 employees (micro-enterprises according to the employees thresholds),
- Medium Workforce Intensity — representing a medium intensity level: HWI indicator from 10 to 49 employees (small enterprises),
- High Workforce Intensity — representing a high intensity level: HWI indicator > 50 employees (medium and large enterprises),

This classification provides a structural segmentation of corporates based on labour intensity[340].

3.4 Portfolio segmentation and cluster analysis

The CI and HW indicators represent the quantitative input for the carrying out of the next activities: segmentation analysis.

Segmentation analysis seeks to determine whether a population contains sub-groups displaying a degree of homogeneity with respect to key variables, such that the population can be divided into distinct segments. Applied to a portfolio of financial statements, it makes explicit the differences in balance-sheet structure and business activity across industries.

For the purpose of the framework, a hybrid approach was adopted[341]. The empirical component rests on two complementary elements: cluster analysis, which provides a statistically grounded and reproducible grouping of sectors, and expert judgement, which captures the aspects of sectoral vulnerability that the data cannot express. Combining the two yields a more reliable identification of capital intensity and workforce intensity than either element would provide separately.

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[339] The workforce thresholds follow European Commission Recommendation 2003/361/EC, under which micro-enterprises have fewer than 10 employees, small enterprises fewer than 50, and medium-sized enterprises fewer than 250. These thresholds apply uniformly across Member States and determine eligibility for EU and national support programmes.

[340] For the HWI, it was decided to use the number of employees as the indicator, meaning a measure of scale rather than an index (as in the case of CI). This choice reflects the view that size is a more appropriate proxy for the factor we aim to capture: the extent to which production relies on work performed under hazardous conditions. The definition of intensity could also be complemented with additional indicators, such as personnel costs relative to revenue or personnel costs relative to total operating costs.

[341] Two approaches are generally used to identify an appropriate segmentation. Under the heuristic approach, groups are identified on the basis of experience and knowledge of the portfolio (judgemental segmentation). Under the empirical approach, statistical methods such as decision trees or cluster analysis identify the most homogeneous groups within the portfolio, using key variables or deterministic information on specific characteristics — for instance, the presence or absence of financial statement data.

To ensure that entities can be meaningfully compared and grouped, the two continuous indicators are first standardised through a z-score transformation, placing all observations on a common scale. Given the size of the dataset, a preliminary segmentation is then performed using k-means with 250 centroids, reducing dimensionality and producing a more tractable structure for the subsequent hierarchical stage[342]. The choice of 250 centroids reflects the need to substantially reduce the dataset's complexity while still preserving enough granularity to capture meaningful heterogeneity across entities[343]. The resulting pre-clusters serve as inputs to Ward clustering, applied to the collapsed dataset.

The methodology applies a hierarchical cluster analysis (Ward's method) on the standardised variables. Ward's method is the most stable approach for corporate financial data because it systematically minimises within‑cluster variance, producing compact and homogeneous groups even when financial ratios are noisy or skewed[344]. It was decided to apply cluster analysis to the indicators of each individual company rather than to the sector average data in order to have a more accurate analysis and better assess the concentration and variability of situations within the sectors. The results of the cluster analysis were evaluated not to determine the optimal number of clusters, but to help decide which of the three predefined vulnerability levels each economic activity should be assigned to[345]. Below are some results of the cluster and categorical analyses: dendrograms at 15 and 3 cuts, descriptive statistics of the three groupings (cluster distribution for each group), and breakdown by 2-digit NACE code.

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[342] Cluster analysis aims to identify similarities and differences among entities, producing clusters with two complementary properties: maximum similarity within each cluster and maximum difference between clusters. Methods fall into two families. Hierarchical methods reconstruct the full hierarchy of the objects under analysis — the dendrogram — in either ascending or descending order. Partitioning methods require the number of clusters to be specified in advance. Within hierarchical methods, the similarity between clusters can be computed in several ways: *single link* (nearest neighbor) takes the minimum distance between any pair of observations in the two clusters; *complete link* (farthest neighbor) takes the maximum such distance; *average link* takes the mean pairwise distance across all observations in the two clusters; and *Ward's method* merges clusters so as to minimise the increase in total within-cluster variance.

[343] With a large sample, a smaller number of centroids would oversimplify the underlying structure, whereas a much larger number it might not handle the computational load of the next hierarchical clustering phase. Using 250 centroids therefore strikes a practical balance: it produces a tractable intermediate representation that stabilises the hierarchical procedure without losing the variability needed for meaningful group differentiation.

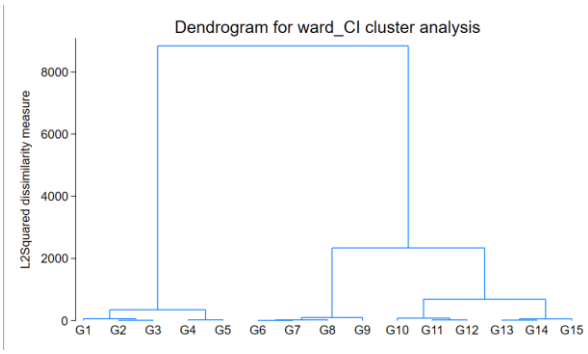
[344] Ward's method was selected because it is particularly well suited to corporate financial data. The algorithm merges clusters by choosing the combination producing the smallest increase in the sum of squared differences, so that groupings are internally coherent and companies with genuinely similar financial profiles are grouped together. This variance-minimising criterion handles the wide dispersion in ratios typical of balance-sheet and income-statement data more effectively than linkage rules based on single pairwise distances. Empirical applications to banks and corporate financial statements report that the resulting clusters are economically interpretable and stable under financial data conditions. See Bank for International Settlements, 'Using statistical clustering to identify business models', BIS Quarterly Review, December 2014 (www.bis.org/publ/qtrpdf/r_qt1412.htm) and Anna Bieniasz & Anna Majchrzak (2011) "Applying The Ward Method in the Analysis of Financial Situation of Commercial Banks," "e-Finanse", University of Information Technology and Management, Institute of Financial Research and Analysis (https://ideas.repec.org/a/rze/efinan/v7y2011i3p1-12.html).

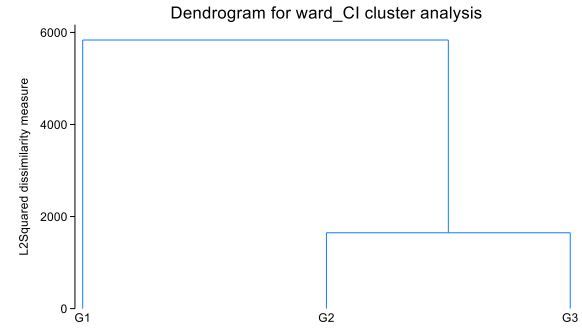
345 The results of the cluster analysis were evaluated by looking at the Calinski–Harabasz rule, checking the dendrogram at 15, 7, 5, and 3 cuts, the distribution of the 2-digit NACE codes.

Regarding human workforce-intensity assessments, the results may be influenced by the specific characteristics of the Italian business structure, which is predominantly composed of small and micro enterprises with labor-driven operational models. Since the portfolio under analysis is entirely represented by Italian companies, its human workforce-intensity profile may therefore reflect structural features that could be less representative of other European contexts, where firm size, capital endowment and production organisation differ substantially.

Table 21: Vulnerability Intensity Indicators – Cluster results

CAPITAL INTENSITY

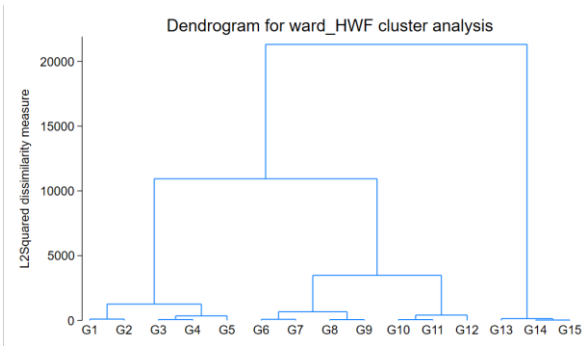


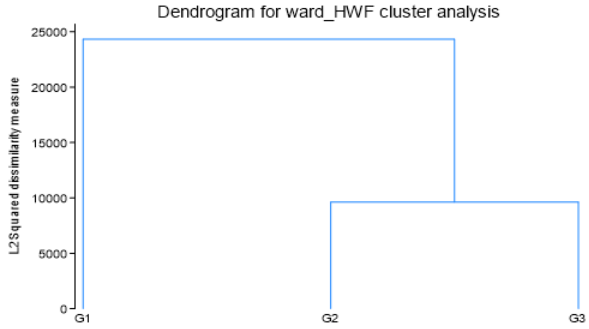


group3_CI	Freq.	Percent	Cum.
1	5,277	73.49	73.49
2	1,109	15.44	88.93
3	795	11.07	100.00
Total	7,181	100.00	

group3_CI	Mean	SD	Min	Max
1	12.48837	10.2551	0	37
2	48.53986	7.522606	37.1	64.3
3	81.41173	9.892878	64.6	100
Total	25.68641	25.48251	0	100

HUMAN WORKFORCE INTENSITY





group3_HWF	Freq.	Percent	Cum.
1	2,390	96.68	96.68
2	70	2.83	99.51
3	12	0.49	100.00
Total	2,472	100.00	

group3_HWF	Mean	SD	Min	Max
1	36.12971	42.69825	0	261
2	437.7857	158.7023	268	883
3	1382	129.0004	1101	1500
Total	54.03681	124.844	0	1500

Table 22: Vulnerability Intensity Indicator - Capital Intensity Assessment by sector

CAPITAL INTENSITY - TANGIBLE FIXED ASSETS											
2-digit NACE CODE	DESCRIPTION	CATEGORIAL RESULTS					CLUSTER RESULTS				
		Total n. Companies	0_Low %	1_Medium %	2_High %	Total %	N. Clusters	0_Low %	1_Medium %	2_High %	Total %
01	Crop and animal production, hunting and related service activities	472	17,2	15,0	67,8	100,0	170	51,2	21,2	27,6	100,0
02	Forestry and logging	30	26,7	26,7	46,7	100,0	24	58,3	8,3	33,3	100,0
03	Fishing and aquaculture	22	27,3	22,7	50,0	100,0	18	50,0	16,7	33,3	100,0
08	Other mining and quarrying	8	12,5	0,0	87,5	100,0	8	37,5	37,5	25,0	100,0
09	Mining support service activities	3	33,3	0,0	66,7	100,0	3	33,3	66,7	0,0	100,0
10	Manufacture of food products	268	13,8	42,5	43,7	100,0	146	72,6	19,2	8,2	100,0
11	Manufacture of beverages	22	18,2	45,5	36,4	100,0	20	85,0	15,0	0,0	100,0
13	Manufacture of textiles	850	29,2	34,8	36,0	100,0	216	69,9	18,5	11,6	100,0
14	Manufacture of wearing apparel	723	56,4	34,3	9,3	100,0	165	83,6	13,3	3,0	100,0
15	Manufacture of leather and related products of other materials	184	33,2	41,8	25,0	100,0	114	80,7	12,3	7,0	100,0
16	Manufacture of wood and of products of wood and cork, except furniture	94	26,6	39,4	34,0	100,0	74	77,0	18,9	4,1	100,0
17	Manufacture of paper and paper products	79	15,2	40,5	44,3	100,0	63	74,6	17,5	7,9	100,0
18	Printing and reproduction of recorded media	94	24,5	37,2	38,3	100,0	71	78,9	16,9	4,2	100,0
19	Manufacture of coke and refined petroleum products	3	33,3	0,0	66,7	100,0	3	66,7	33,3	0,0	100,0
20	Manufacture of chemicals and chemical products	114	24,6	42,1	33,3	100,0	81	80,2	18,5	1,2	100,0
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	5	80,0	20,0	0,0	100,0	4	100,0	0,0	0,0	100,0
22	Manufacture of rubber and plastic products	136	16,9	49,3	33,8	100,0	99	76,8	19,2	4,0	100,0
23	Manufacture of other non-metallic mineral products	91	25,3	45,1	29,7	100,0	71	83,1	15,5	1,4	100,0
24	Manufacture of basic metals	39	17,9	46,2	35,9	100,0	35	74,3	17,1	8,6	100,0
25	Manufacture of fabricated metal products, except machinery and equipment	671	21,6	47,7	30,7	100,0	203	74,4	17,2	8,4	100,0
26	Manufacture of computer, electronic and optical products	93	50,5	33,3	16,1	100,0	66	87,9	12,1	0,0	100,0
27	Manufacture of electrical equipment	96	38,5	45,8	15,6	100,0	66	86,4	10,6	3,0	100,0
28	Manufacture of machinery and equipment n.e.c.	365	34,5	48,5	17,0	100,0	151	89,4	7,9	2,6	100,0
29	Manufacture of motor vehicles, trailers and semi-trailers	41	14,6	46,3	39,0	100,0	36	72,2	25,0	2,8	100,0
30	Manufacture of other transport equipment	46	43,5	34,8	21,7	100,0	35	80,0	11,4	8,6	100,0
31	Manufacture of furniture	222	35,1	40,1	24,8	100,0	127	81,1	14,2	4,7	100,0
32	Other manufacturing	106	29,2	39,6	31,1	100,0	80	81,3	16,3	2,5	100,0
33	Repair, maintenance and installation of machinery and equipment	267	33,3	53,6	13,1	100,0	122	86,9	10,7	2,5	100,0
35	Electricity, gas, steam and air conditioning supply	283	30,4	11,3	58,3	100,0	117	47,9	25,6	26,5	100,0
36	Water collection, treatment and supply	13	15,4	15,4	69,2	100,0	11	36,4	0,0	63,6	100,0
37	Sewerage	30	26,7	46,7	26,7	100,0	26	80,8	15,4	3,8	100,0
38	Waste collection, recovery and disposal activities	94	22,3	35,1	42,6	100,0	67	73,1	20,9	6,0	100,0
39	Remediation activities and other waste management service activities	9	55,6	33,3	11,1	100,0	9	88,9	11,1	0,0	100,0
41	Construction of residential and non-residential buildings	1.411	58,9	24,9	16,2	100,0	226	66,4	13,3	20,4	100,0
42	Civil engineering	94	51,1	35,1	13,8	100,0	50	90,0	8,0	2,0	100,0
43	Specialised construction activities	1.546	47,7	39,9	12,4	100,0	203	77,8	16,3	5,9	100,0
46	Wholesale trade	2.702	56,9	29,2	14,0	100,0	231	69,7	16,9	13,4	100,0
47	Retail trade	1.439	53,4	32,5	14,1	100,0	216	72,2	17,6	10,2	100,0
49	Land transport and transport via pipelines	401	25,2	43,4	31,4	100,0	168	76,8	16,1	7,1	100,0
50	Water transport	8	12,5	25,0	62,5	100,0	8	50,0	25,0	25,0	100,0
51	Air transport	1	0,0	0,0	100,0	100,0	1	0,0	100,0	0,0	100,0
52	Warehousing, storage and support activities for transportation	337	49,9	25,2	24,9	100,0	146	71,9	13,0	15,1	100,0
53	Postal and courier activities	10	60,0	40,0	0,0	100,0	9	100,0	0,0	0,0	100,0
55	Accommodation	561	19,1	28,3	52,6	100,0	209	62,7	14,8	22,5	100,0
56	Food and beverage service activities	1.194	16,7	39,4	44,0	100,0	227	67,8	17,6	14,5	100,0
58	Publishing activities	61	77,0	11,5	11,5	100,0	31	83,9	9,7	6,5	100,0
59	Motion picture, video and television programme production, sound recording and music publishing activities	71	50,7	25,4	23,9	100,0	50	80,0	8,0	12,0	100,0
60	Programming, broadcasting, news agency and other content distribution activities	16	31,3	37,5	31,3	100,0	13	69,2	30,8	0,0	100,0
61	Telecommunication	34	38,2	41,2	20,6	100,0	32	84,4	9,4	6,3	100,0
62	Computer programming, consultancy and related activities	440	62,5	25,7	11,8	100,0	138	81,9	13,8	4,3	100,0
63	Computing infrastructure, data processing, hosting and other information service activities	387	59,9	24,0	16,0	100,0	144	75,7	10,4	13,9	100,0
64	Financial service activities, except insurance and pension funding	427	79,4	9,4	11,2	100,0	88	69,3	19,3	11,4	100,0
65	Insurance, reinsurance and pension funding, except compulsory social security	1	0,0	0,0	100,0	100,0	1	0,0	100,0	0,0	100,0
66	Activities auxiliary to financial services and insurance activities	152	64,5	27,6	7,9	100,0	80	92,5	5,0	2,5	100,0
68	Real estate activities	4.731	25,4	8,8	65,8	100,0	241	63,1	16,6	20,3	100,0
69	Legal and accounting activities	179	57,5	20,1	22,3	100,0	92	72,8	14,1	13,0	100,0
70	Activities of head offices and management consultancy	743	67,2	16,4	16,4	100,0	175	70,9	13,1	16,0	100,0
71	Architectural and engineering activities; technical testing and analysis	263	46,0	29,3	24,7	100,0	129	76,7	17,1	6,2	100,0
72	Scientific research and development	91	63,7	27,5	8,8	100,0	48	91,7	4,2	4,2	100,0
73	Activities of advertising, market research and public relations	159	58,5	27,7	13,8	100,0	90	85,6	6,7	7,8	100,0
74	Other professional, scientific and technical activities	436	56,7	27,8	15,6	100,0	154	78,6	13,0	8,4	100,0
75	Veterinary activities	16	12,5	31,3	56,3	100,0	15	66,7	26,7	6,7	100,0
77	Rental and leasing activities	201	30,3	19,4	50,2	100,0	108	64,8	21,3	13,9	100,0
78	Employment activities	8	75,0	12,5	12,5	100,0	7	100,0	0,0	0,0	100,0
79	Travel agency, tour operator and other reservation service and related activities	76	63,2	21,1	15,8	100,0	45	82,2	13,3	4,4	100,0
80	Investigation and security activities	26	53,8	26,9	19,2	100,0	19	78,9	15,8	5,3	100,0
81	Services to buildings and landscape activities	222	45,5	37,4	17,1	100,0	108	84,3	11,1	4,6	100,0
82	Office administrative, office support and other business support activities	448	56,3	23,7	20,1	100,0	158	73,4	12,7	13,9	100,0
85	Education	201	55,2	24,4	20,4	100,0	103	75,7	15,5	8,7	100,0
86	Human health activities	303	21,1	37,3	41,6	100,0	155	70,3	18,7	11,0	100,0
87	Residential care activities	98	22,4	41,8	35,7	100,0	79	70,9	16,5	12,7	100,0
88	Social work activities without accommodation	86	53,5	29,1	17,4	100,0	62	79,0	16,1	4,8	100,0
90	Arts creation and performing arts activities	92	42,4	21,7	35,9	100,0	64	62,5	15,6	21,9	100,0
91	Libraries, archives, museums and other cultural activities	10	0,0	30,0	70,0	100,0	9	44,4	22,2	33,3	100,0
92	Gambling and betting activities	47	51,1	29,8	19,1	100,0	36	88,9	2,8	8,3	100,0
93	Sports activities and amusement and recreation activities	548	25,5	27,4	47,1	100,0	202	61,9	17,3	20,8	100,0
94	Activities of membership organisations	12	33,3	0,0	66,7	100,0	9	44,4	33,3	22,2	100,0
95	Repair and maintenance of computers, personal and household goods, and motor vehicles and motorcycles	353	26,9	44,8	28,3	100,0	163	77,3	13,5	9,2	100,0
96	Personal service activities	253	28,9	30,8	40,3	100,0	138	62,3	21,7	15,9	100,0
Total		**26.468**	**40,3**	**27,6**	**32,1**	**100,0**	**7.181**	**73,5**	**15,4**	**11,1**	**100,0**

Table 23: Vulnerability Intensity Indicator - Human Workforce Intensity Assessment by sector

2-digit NACE CODE	DESCRIPTION	HUMAN WORKFORCE INTENSITY									
		CATEGORIAL RESULTS					CLUSTER RESULTS				
		Total n. Companies	0_Low %	1_Medium %	2_High %	Total %	N. Clusters	0_Low %	1_Medium %	2_High %	Total %
01	Crop and animal production, hunting and related service activities	472	80,5	12,5	7,0	100,0	64	90,6	7,8	1,6	100,0
02	Forestry and logging	30	80,0	16,7	3,3	100,0	10	100,0	0,0	0,0	100,0
03	Fishing and aquaculture	22	86,4	13,6	0,0	100,0	7	100,0	0,0	0,0	100,0
08	Other mining and quarrying	8	75,0	25,0	0,0	100,0	5	100,0	0,0	0,0	100,0
09	Mining support service activities	3	66,7	0,0	33,3	100,0	3	100,0	0,0	0,0	100,0
10	Manufacture of food products	268	56,7	31,3	11,9	100,0	67	91,0	7,5	1,5	100,0
11	Manufacture of beverages	22	72,7	22,7	4,5	100,0	12	91,7	8,3	0,0	100,0
13	Manufacture of textiles	850	55,3	39,2	5,5	100,0	88	97,7	2,3	0,0	100,0
14	Manufacture of wearing apparel	723	81,1	18,3	0,7	100,0	42	100,0	0,0	0,0	100,0
15	Manufacture of leather and related products of other materials	184	45,1	41,8	13,0	100,0	61	96,7	3,3	0,0	100,0
16	Manufacture of wood and of products of wood and cork, except furniture	94	64,9	27,7	7,4	100,0	29	93,1	6,9	0,0	100,0
17	Manufacture of paper and paper products	79	44,3	45,6	10,1	100,0	36	100,0	0,0	0,0	100,0
18	Printing and reproduction of recorded media	94	71,3	27,7	1,1	100,0	27	100,0	0,0	0,0	100,0
19	Manufacture of coke and refined petroleum products	3	66,7	0,0	33,3	100,0	3	100,0	0,0	0,0	100,0
20	Manufacture of chemicals and chemical products	114	53,5	35,1	11,4	100,0	43	100,0	0,0	0,0	100,0
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	5	80,0	20,0	0,0	100,0	3	100,0	0,0	0,0	100,0
22	Manufacture of rubber and plastic products	136	44,9	44,1	11,0	100,0	48	97,9	2,1	0,0	100,0
23	Manufacture of other non-metallic mineral products	91	68,1	27,5	4,4	100,0	31	100,0	0,0	0,0	100,0
24	Manufacture of basic metals	39	38,5	46,2	15,4	100,0	25	100,0	0,0	0,0	100,0
25	Manufacture of fabricated metal products, except machinery and equipment	671	51,6	43,2	5,2	100,0	77	97,4	2,6	0,0	100,0
26	Manufacture of computer, electronic and optical products	93	59,1	35,5	5,4	100,0	32	96,9	3,1	0,0	100,0
27	Manufacture of electrical equipment	96	64,6	25,0	10,4	100,0	34	97,1	2,9	0,0	100,0
28	Manufacture of machinery and equipment n.e.c.	365	49,9	36,7	13,4	100,0	89	91,0	9,0	0,0	100,0
29	Manufacture of motor vehicles, trailers and semi-trailers	41	48,8	43,9	7,3	100,0	24	100,0	0,0	0,0	100,0
30	Manufacture of other transport equipment	46	50,0	37,0	13,0	100,0	31	96,8	3,2	0,0	100,0
31	Manufacture of furniture	222	61,3	32,9	5,9	100,0	45	93,3	6,7	0,0	100,0
32	Other manufacturing	106	72,6	27,4	0,0	100,0	25	100,0	0,0	0,0	100,0
33	Repair, maintenance and installation of machinery and equipment	267	70,8	25,1	4,1	100,0	41	95,1	4,9	0,0	100,0
35	Electricity, gas, steam and air conditioning supply	283	96,1	3,2	0,7	100,0	19	100,0	0,0	0,0	100,0
36	Water collection, treatment and supply	13	92,3	0,0	7,7	100,0	3	100,0	0,0	0,0	100,0
37	Sewerage	30	60,0	33,3	6,7	100,0	13	100,0	0,0	0,0	100,0
38	Waste collection, recovery and disposal activities	94	62,8	27,7	9,6	100,0	38	97,4	0,0	2,6	100,0
39	Remediation activities and other waste management service activities	9	100,0	0,0	0,0	100,0	7	100,0	0,0	0,0	100,0
41	Construction of residential and non-residential buildings	1.411	92,1	7,6	0,4	100,0	41	100,0	0,0	0,0	100,0
42	Civil engineering	94	67,0	24,5	8,5	100,0	35	97,1	2,9	0,0	100,0
43	Specialised construction activities	1.546	82,0	16,6	1,4	100,0	67	100,0	0,0	0,0	100,0
46	Wholesale trade	2.702	82,8	15,2	2,0	100,0	90	90,0	10,0	0,0	100,0
47	Retail trade	1.439	85,2	12,7	2,1	100,0	67	95,5	3,0	1,5	100,0
49	Land transport and transport via pipelines	401	71,8	24,4	3,7	100,0	59	96,6	1,7	1,7	100,0
50	Water transport	8	62,5	12,5	25,0	100,0	7	100,0	0,0	0,0	100,0
51	Air transport	1	100,0	0,0	0,0	100,0	1	100,0	0,0	0,0	100,0
52	Warehousing, storage and support activities for transportation	337	69,7	24,3	5,9	100,0	62	96,8	3,2	0,0	100,0
53	Postal and courier activities	10	80,0	20,0	0,0	100,0	8	100,0	0,0	0,0	100,0
55	Accommodation	561	66,1	32,1	1,8	100,0	52	100,0	0,0	0,0	100,0
56	Food and beverage service activities	1.194	71,7	27,2	1,1	100,0	58	96,6	1,7	1,7	100,0
58	Publishing activities	61	93,4	6,6	0,0	100,0	12	100,0	0,0	0,0	100,0
59	Motion picture, video and television programme production, sound recording and music publishing activities	71	95,8	4,2	0,0	100,0	12	100,0	0,0	0,0	100,0
60	Programming, broadcasting, news agency and other content distribution activities	16	75,0	25,0	0,0	100,0	10	100,0	0,0	0,0	100,0
61	Telecommunication	34	79,4	20,6	0,0	100,0	14	100,0	0,0	0,0	100,0
62	Computer programming, consultancy and related activities	440	81,1	16,6	2,3	100,0	48	100,0	0,0	0,0	100,0
63	Computing infrastructure, data processing, hosting and other information service activities	387	92,2	6,2	1,6	100,0	29	100,0	0,0	0,0	100,0
64	Financial service activities, except insurance and pension funding	427	99,3	0,7	0,0	100,0	10	100,0	0,0	0,0	100,0
65	Insurance, reinsurance and pension funding, except compulsory social security	1	100,0	0,0	0,0	100,0	1	100,0	0,0	0,0	100,0
66	Activities auxiliary to financial services and insurance activities	152	87,5	11,8	0,7	100,0	23	100,0	0,0	0,0	100,0
68	Real estate activities	4.731	99,3	0,6	0,0	100,0	27	100,0	0,0	0,0	100,0
69	Legal and accounting activities	179	79,9	16,8	3,4	100,0	35	100,0	0,0	0,0	100,0
70	Activities of head offices and management consultancy	743	95,6	3,6	0,8	100,0	31	96,8	3,2	0,0	100,0
71	Architectural and engineering activities; technical testing and analysis	263	83,7	14,4	1,9	100,0	33	97,0	3,0	0,0	100,0
72	Scientific research and development	91	90,1	8,8	1,1	100,0	18	100,0	0,0	0,0	100,0
73	Activities of advertising, market research and public relations	159	92,5	6,9	0,6	100,0	21	100,0	0,0	0,0	100,0
74	Other professional, scientific and technical activities	436	92,4	6,9	0,7	100,0	27	100,0	0,0	0,0	100,0
75	Veterinary activities	16	93,8	6,3	0,0	100,0	8	100,0	0,0	0,0	100,0
77	Rental and leasing activities	201	85,6	13,9	0,5	100,0	26	100,0	0,0	0,0	100,0
78	Employment activities	8	87,5	12,5	0,0	100,0	5	100,0	0,0	0,0	100,0
79	Travel agency, tour operator and other reservation service and related activities	76	92,1	7,9	0,0	100,0	13	100,0	0,0	0,0	100,0
80	Investigation and security activities	26	46,2	30,8	23,1	100,0	19	89,5	10,5	0,0	100,0
81	Services to buildings and landscape activities	222	61,7	24,8	13,5	100,0	70	94,3	2,9	2,9	100,0
82	Office administrative, office support and other business support activities	448	86,4	12,3	1,3	100,0	39	97,4	2,6	0,0	100,0
85	Education	201	87,6	11,4	1,0	100,0	22	100,0	0,0	0,0	100,0
86	Human health activities	303	84,5	12,9	2,6	100,0	38	94,7	5,3	0,0	100,0
87	Residential care activities	98	41,8	37,8	20,4	100,0	52	90,4	3,8	5,8	100,0
88	Social work activities without accommodation	86	50,0	33,7	16,3	100,0	43	90,7	9,3	0,0	100,0
90	Arts creation and performing arts activities	92	90,2	7,6	2,2	100,0	18	100,0	0,0	0,0	100,0
91	Libraries, archives, museums and other cultural activities	10	70,0	30,0	0,0	100,0	7	100,0	0,0	0,0	100,0
92	Gambling and betting activities	47	74,5	23,4	2,1	100,0	20	95,0	5,0	0,0	100,0
93	Sports activities and amusement and recreation activities	548	85,0	12,8	2,2	100,0	45	95,6	4,4	0,0	100,0
94	Activities of membership organisations	12	100,0	0,0	0,0	100,0	1	100,0	0,0	0,0	100,0
95	Repair and maintenance of computers, personal and household goods, and motor vehicles and motorcycles	353	78,5	21,5	0,0	100,0	30	100,0	0,0	0,0	100,0
96	Personal service activities	253	84,6	13,4	2,0	100,0	36	97,2	0,0	2,8	100,0
Total		**26.468**	**81,9**	**15,6**	**2,5**	**100,0**	**2.472**	**96,7**	**2,8**	**0,5**	**100,0**

3.5 Assignment of vulnerability levels

The combined use of cluster analysis and categorical grouping allows the assessment of capital tangible assets and labour intensity from both an absolute and a relative perspective. The continuous indicator included in the clustering procedure captures the intensity of physical assets and workforce with greater accuracy at the level of each individual company and sectors with similar structural characteristics, reflecting how heavily operations depend on these production factors. At the same time, the categorical segmentation introduces a comparative dimension, positioning each entity relative to other firms. This dual approach ensures that vulnerability is evaluated not only in terms of a company's own exposure, but also in relation to the broader distribution of intensity across the portfolio and the economic sectors considered.

In details, the assignment of each NACE 2-digit sector to a specific intensity level driver by driver was carried out through a combined methodological approach. The process relied on existing studies and research[346], domain knowledge and expert judgement, together with the evidence emerging from both the cluster analysis and the categorical grouping. Sector classification was checked by assessing the significance and robustness of each group in terms of sample size and within-sector variability, ensuring that the segmentation reflected stable and meaningful structural patterns[347]. In addition, the final attribution incorporated qualitative elements not fully captured by the quantitative indicators, such as the relevance of inventory and the potential loss of raw materials, semi-finished or finished goods, as well as operational characteristics like whether activities are performed predominantly indoors within dedicated facilities or outdoors in more exposed environments. This integrated approach ensures that the intensity level assigned to each sector reflects both quantitative evidence and operational realities that influence vulnerability.

Take the sector 01 - Crop and Animal Production as an example of the vulnerability level assessment. The number of companies in this sector (472) shows a good representation of the portfolio across the universe (covers 78%) and ensures sufficient robustness of sector data. The sector's capital intensity was assessed by combining quantitative evidence from the cluster analysis with qualitative operational insights. The quantitative analysis results in a high tangible fixed assets according to the categorical indicator, but a bipolar distribution according to cluster analysis, which reflects the presence of small farms with a more flexible structure and large farms with significant fixed assets. In both analyses, the data indicate that agricultural and livestock activities require substantial investment in machinery, irrigation systems, land, storage facilities, and animal housing. These structural elements create a stable pattern of medium-to-high capital intensity across the sector. Expert judgement further confirmed that even

[346] See Schrapffer, Anthony and Bres, Julia, Assessing Economic Sector Vulnerability to Climate Physical and Transition Risks: A Comprehensive Methodological Framework- version 1.0 (May 17, 2024). Available at SSRN: https://ssrn.com/abstract=4831795 or http://dx.doi.org/10.2139/ssrn.4831795.

[347] In sectors where the number of corporates was not sufficiently robust—either due to limited coverage of the reference universe or to the inherently small number of companies operating in this activity —the vulnerability assessment relied more heavily on expert judgment. The reduced statistical representativeness has constrained the use of quantitative evidence, making qualitative, domain-specific expertise the primary basis for determining the intensity level.

smallholder farms—although less mechanised—still rely on essential physical assets and infrastructure, reinforcing the sector's placement at intensity level 2 for Capital Intensity.

Although the quantitative indicators show a low reliance on manual labor, this sector heavily depends on hands-on work mostly done outdoors, especially in small and medium-sized farms, which, due to less mechanisation, show high labor intensity, particularly for tasks like planting, harvesting, taking care of animals, and maintaining the fields. Expert knowledge confirms that many tasks cannot be fully automated due to biological cycles, terrain constraints, and the need for manual supervision. Seasonal peaks further increase a high human-work intensity. Therefore, the predominance of outdoor, physically demanding tasks supports the assignment of intensity level 2 for Work Force Intensity.

The sector's climate dependence emerged clearly from sensitivity to temperature, precipitation, water availability, and extreme weather events. Expert knowledge confirmed that production cycles are intrinsically tied to environmental conditions, and exposure cannot be fully mitigated even with technological improvements. Agricultural output and livestock productivity are directly shaped by environmental conditions. Variations in temperature, precipitation patterns, soil moisture and hydrological availability can materially affect yields, animal health and operational continuity. The risk of crop failure, livestock stress, water scarcity and disruptions in irrigation supply reflects an intrinsic exposure to climate variability and extreme events. These dynamics justify the assignment of intensity level 2 for Climate Dependency, since the sector's performance is tightly coupled with climatic factors that cannot be fully mitigated through technology or management practices.

Figure 7: Sector intensity assessment – worked example (sector 01)

SECTOR

01-Crop and animal production, hunting and related service activities

	DRIVERS	RATIONALE	INTENSITY LEVEL
RISK TRANSMISSION DRIVERS	CAPITAL INTENSITY	Relies on high investment in mechanised farming, land use livestock facilities, irrigation systems, storage structures for feeds and/or cultivated agricultural products (smallholder and labor-intensive crops can be less capital but even more workforce-intensive)	2
	HUMAN WORKFORCE INTENSITY	Highly dependent of manual and outdoor work, especially in small and medium farms (smallholder and labor-intensive crops can be less capital but even more workforce-intensive)	2
	CLIMATE DEPENDENCE	Production strongly depends on temperature, precipitation, water availability, and extreme events	2

The result of this assessment for each 2-digit Nace code is a table mapping relevant physical hazards against three risk transmission channels. Below is the resulting matrix with the level assessment and related rationale for each sector and grouped by homogeneous intensity levels.

Table 24: Sector intensity assessment

RISK TRANSMISSION CHANNELS – INTENSITY LEVEL (IL)								
VIS NACE Grouping	NACE Description	IL	CAPITAL INTENSITY	IL	HUMAN WORKFORCE INTENSITY	IL	CLIMATE DEPENDENCE
A (01)	01-Crop and animal production, hunting and related service activities	2	Relies on high investment in mechanised farming, land use livestock facilities, irrigation systems, storage structures for feeds and/or cultivated agricultural products (smallholder and labor-intensive crops can be less capital but even more workforce-intensive)	2	Highly dependent of manual and outdoor work, especially in small and medium farms (smallholder and labor-intensive crops can be less capital but even more workforce-intensive)	2	Production strongly depends on temperature, precipitation, water availability, and extreme events
A (02,03)	02-Forestry and logging 03-Fishing and aquaculture	1	Capital investment could be required in heavy harvesting machinery, vessels and onboard equipment, storage and processing facilities, and land or water concessions	2	Large share of manual and outdoor work forestry, and fishing activities	2	Production depends directly on fishing condition, temperature, precipitation and extreme events
B (05,06,07,08,09)	05-Mining of coal and lignite 06-Extraction of crude petroleum and natural gas 07-Mining of metal ores 08-Other mining and quarrying 09-Mining support service activities	1	Requires extraction equipment, pits, shafts, and processing plants with long-lived capital	2	Operational labor (usually outdoor) in hazardous and remote environments despite mechanization	1	Operations and supply chains are sensitive to heat, heavy rainfall, landslides, water stress, and disruptions in remote sites.
C (10,11,12,13,14,15)	10-Manufacture of food products 11-Manufacture of beverages 12-Manufacture of tobacco products 13-Manufacture of textiles 14-Manufacture of wearing apparel 15-Manufacture of leather and related products of other materials	1	Depends on processing plants, machinery, cold chains, and storage infrastructure, but less heavy plant compared to other industries; significant volumes of products and materials warehouses	2	Labor-intensive production lines, especially in smaller facilities and in cutting, sewing and finishing	2	Highly dependent on climate-sensitive agricultural or forestry resources and cold-chain stability and exposed to hydrological and heat-related risks; climate affects feedstocks and water use for dyes and processing
C (16,17,19,20,23)	16-Manufacture of wood and of products of wood and cork 17-Manufacture of paper and paper products 19-Manufacture of coke and refined petroleum products 20-Manufacture of chemicals and chemical products 23-Manufacture of other non-metallic mineral products	2	Complex and large continuous-process plants (packaging line, refineries, infrastructure, reactors, storage systems, kilns, furnaces, and heavy equipment) and significant volumes of products and materials warehouses make these sectors highly capital-intensive	1	Moderately staffed due to high automation (low employment density) and usually indoor work	2	Highly dependent on agricultural or forestry resources and cold-chain stability; sensitive to heat, cooling needs and exposed to hydrological and heat-related risks
C (18,31)	18-Printing and reproduction of recorded media 31-Manufacture of furniture	0	Uses specialized equipment but not heavy industrial assets; moderate capital needs for workshops and machinery	2	Highly labor-intensive with many manual and semi-automated stages, craftsmanship and assembly activities	1	Low direct climate dependence, mainly through supply chains, inputs and logistics
C (25,29,30)	25-Manufacture of fabricated metal products, except machinery and equipment 29-Manufacture of motor vehicles, trailers and semi-trailers 30-Manufacture of other transport equipment	1	Uses machinery and plants with robotics, but not very high capital assets	1	Low or medium labor density due to automation and usually indoor work; need for labor for processing, assembly, welding and finishing	1	Moderate climate dependence through supply chains and energy

RISK TRANSMISSION CHANNELS – INTENSITY LEVEL (IL)								
VIS NACE Grouping	NACE Description	IL	CAPITAL INTENSITY	IL	HUMAN WORKFORCE INTENSITY	IL	CLIMATE DEPENDENCE
C (26,27,32)	26-Manufacture of computer, electronic and optical products 27-Manufacture of electrical equipment 32-Other manufacturing	0	Moderate capital needs workshops and machinery, cleanrooms and precision equipment	1	Skilled indoor work with low density, for for processing, assembly and finishing	0	Limited climate dependence, with some exposure through global supply chains and energy
C (21)	21-Manufacture of basic pharmaceutical products and pharmaceutical preparations	2	Specialized, controlled environments with significant capital requirements	0	Skilled but sparse labor force, employed in indoor activities	0	Limited climate dependence; climate impacts arise through supply chains
C (22,24)	22-Manufacture of rubber and plastic products 24-Manufacture of basic metals	1	Uses presses, molds, and continuous production lines, but not very high capital assets and large plants (expect capital needs for blast furnaces and smelters)	1	Low labor needs with mixed manual handling and heavy automation	1	Climate impacts arise through supply chains; strongly affected by energy and commodity exposure
C (28,33)	28-Manufacture of machinery and equipment n.e.c. 33-Repair, maintenance and installation of machinery and equipment	0	Requires plant and tooling but a moderate capital investment	1	Skilled labor with low density	1	Mostly indirect climate exposure via supply chains
D (35)	35-Electricity, gas, steam and air conditioning supply	2	Very high capital intensity due to generation assets, grids, and pipelines	1	Low labor density relative to asset base	2	Strong climate dependence through generation mix, peak loads, and exposure of infrastructure to hazards
E (36)	36-Water collection, treatment and supply	2	Very high capital needs for networks and treatment plants	2	Moderate staffing for operations and supervision, but operations need outdoor labor	2	Strongly affected by rainfall patterns, droughts, floods, and stormwater surges
E (37)	37-Sewerage	2	Very high capital needs for networks and treatment plants	0	Low labor density for operations and supervision	2	Strongly affected by rainfall patterns, droughts, floods, and stormwater surges
E (38)	38-Waste collection, recovery and disposal activities	1	Require fleets of specialized vehicles, compactors, containers, transfer stations, sorting lines, recycling plants, incinerators, and engineered landfills	2	Labor intensity is significant, with a large operational workforce staffed in outdoor activities (collection crews, plant operators, technicians, maintenance staff, environmental specialists, and safety personnel; while mechanization and automated sorting systems reduce some manual tasks, human labor remains essential for collection operations, facility management, monitoring, and compliance	2	Climate dependence is strong: heatwaves increase odors, accelerate decomposition, stress workers, and affect plant efficiency, floods and storms can damage landfills, overwhelm drainage systems, disrupt collection routes, and spread contaminants, extreme rainfall affects leachate management and landfill stability, climate-driven disasters generate surges in waste volumes (debris, hazardous materials)
E (39)	39-Remediation activities and other waste management service activities	1	Requires fixed assets, infrastructures and continuous investment in safety and compliance, such as specialized machinery, treatment plants, containment systems, hazardous-waste handling technologies, monitoring instruments, and dedicated vehicles	1	Relies on a skilled technical workforce: environmental engineers, chemists, technicians, machine operators, field workers, and safety specialists; while mechanization and automated systems support operations, human expertise remains essential for assessment, monitoring, and safe execution of remediation activities.	1	Climate volatility directly affects operational risks: floods, storms, and landslides can damage contaminated sites and spread pollutants, extreme rainfall can overwhelm treatment plants and containment structures, heatwaves reduce worker productivity and stress treatment systems, climate-driven disasters generate additional hazardous waste and increase emergency remediation needs
F (41)	41-Construction of residential and non-residential buildings	2	High capital-intensive and significant capital investments in buildings, lands, equipement and materials used in construction activities; building	2	Highly labor-intensive with on-site and ourdoor work, with large and diverse workforce: architects, engineers, project	2	Strongly climate-dependent; weather affects productivity, safety, scheduling, and damage risk: extreme weather (storms, heatwaves, heavy rainfall)

VIS NACE Grouping	NACE Description	IL	CAPITAL INTENSITY	IL	HUMAN WORKFORCE INTENSITY	IL	CLIMATE DEPENDENCE
			RISK TRANSMISSION CHANNELS – INTENSITY LEVEL (IL)				
			construction requires significant investment in materials (concrete, steel, insulation, fixtures), heavy machinery, scaffolding, specialized equipment		managers, skilled construction workers, electricians, plumbers, carpenters, machine operators, and safety specialists; many tasks require manual execution, on-site supervision, and specialized craftsmanship		disrupts construction schedules and increases safety risks, floods, landslides, and soil instability affect project feasibility and structural integrity, heatwaves reduce worker productivity and stress machinery, long-term climate trends influence design standards and maintenance requirements
F (42)	42-Civil engineering	2	Fixed assets are substantial: heavy machinery, specialized equipment, large volumes of construction materials, engineered structures, and long-duration projects such as roads, bridges, tunnels, railways, ports, and water systems	1	Labor intensity is significant, with large and technically diverse workforce staffed in indoor and outdoor activities: civil engineers, project managers, surveyors, skilled construction workers, machine operators, and safety specialists; while mechanization reduces some manual labor, on-site operations, supervision, and technical expertise remain essential	1	Strongly climate-dependent; weather affects productivity, safety, scheduling, and damage risk: extreme weather (storms, heatwaves, heavy rainfall) disrupts construction schedules and increases safety risks, floods, landslides, and soil instability affect project feasibility and structural integrity, heatwaves reduce worker productivity and stress machinery, long-term climate trends influence design standards and maintenance requirements
F (43)	43-Specialised construction activities	1	Require investments in equipment and materials used in specialized construction activities	2	Highly labor-intensive with on-site and outdoor work	2	Strongly climate-dependent: weather affects productivity, safety, scheduling, and damage risk.
G (46-47)	46-Wholesale trade 47-Retail trade	1	Capital needs for stores, products and materials warehouses, equipment and IT systems; the sector depends on the transport infrastructure	1	Moderate staffing labor, with indoor and outdoor work; retail is usually run by small business owners and requires more labor, but low investments, unlike wholesale or retail in large supermarkets which need buildings and infrastructures	1	Climate impacts arise through supply chains; climate affects supply chains, logistics, and customer flows
H (49,51,53)	49-Land transport and transport via pipelines 51-Air transport 53-Postal and courier activities	1	Capital needs for tracks and business vehicles, planes, terminals, logistics hubs and equipment	1	Labor needs for drivers, operators, and logistics personnel with indoor and outdoor work	1	Climate dependence due to exposure of networks and hubs to storms, floods, landslides, heat and frost
H (50)	50-Water transport	1	Capital needs ships, terminals, and logistics hubs	1	Labor needs for drivers, operators, and logistics personnel with indoor and outdoor work	2	Highly climate-dependent due to exposure of networks and hubs to sea-level rise and of river navigation to droughts
H (52)	52-Warehousing, storage and support activities for transportation	2	Capital needs for trucks and commercial vehicles, ports, terminals and logistics hubs, but significant investments in warehouse products and materials	1	Labor needs for drivers, operators, and logistics personnel with indoor and outdoor work	1	Climate dependence due to exposure of networks and hubs to storms, floods, heat and frost
I (55,56)	55-Accomodation 56-Food and beverage service activities	2	Require investments in buildings (hotels and restaurants), kitchens, and fit-outs	2	Highly labor-driven services with indoor and outdoor activities	2	Climate affects tourism demand, seasonality, and operational conditions
J (58)	58-Publishing activities	0	Mostly asset-light (usually buildings, offices, ...)	0	Skilled usually indoor labor with low workforce intensity	0	Climate impacts are indirect through power supply, cooling needs, and physical site risks
J (59,60)	59-Motion picture, video and television programme production, sound recording and music publishing activities 60-Programming, broadcasting, news agency and other content distribution activities	1	Limited fixed assets, with capital needs driven mainly by project-based production cycles: technical equipment (cameras, lighting, audio systems, editing suites, post-production software), intellectual property rights, broadcasting infrastructure, digital transformation and editorial infrastructure; most investments are intangible and projects specific rather than structural	0	Usually indoor labor, with specialized labour (actors, directors, screenwriters, technical crews, editors)	0	Climate impacts are indirect through power supply, cooling needs, and physical site risks

RISK TRANSMISSION CHANNELS – INTENSITY LEVEL (IL)							
VIS NACE Grouping	NACE Description	IL	CAPITAL INTENSITY	IL	HUMAN WORKFORCE INTENSITY	IL	CLIMATE DEPENDENCE
K (61)	61-Telecommunication	2	Telcoms require massive investments in physical infrastructure (mobile networks, fiber, towers, data centers, radio spectrum), which need to be built, maintained, and periodically upgraded	0	Skilled personnel usually indoor labor with low workforce intensity	1	Climate dependence due to vulnerability of networks telecommunications networks -both fixed and mobile- to storms, floods, landslides, which can damage towers, underground cables, and distribution nodes, causing service interruptions cables, and distribution nodes, causing service interruptions
K (62)	62-Computer programming, consultancy and related activities	0	Low capital-intensity industry dominated by human capital, digital tools, and intangible investments rather than physical infrastructure and fixed assets (usually buildings, offices, IT equipment, cloud platforms)	0	Skilled personnel usually indoor labor with low workforce intensity	0	Climate impacts are indirect through power supply, cooling needs, and physical site risks
K (63)	63-Computing infrastructure, data processing, hosting and other information service activities	1	Not significant capital needs compared the most other industries, but the sector's investment structure is dominated by physical and digital infrastructure driven by large-scale investment in data centers, computing hardware, energy and refreshing systems and network infrastructure	0	Skilled technical labour is essential, but usually indoor labor with low workforce intensity	1	Climate dependence in digital infrastructure is significant, driven by the physical exposure of communication networks and data-processing facilities to extreme weather (storms, floods), rising temperatures and heatwaves
L (64,66)	64-Financial service activities, except insurance and pension funding 66-Activities auxiliary to financial services and insurance activities	0	Mostly asset-light (usually buildings, offices and IT); asset base is mostly financial, not physical	0	Skilled usually indoor labor with workforce intensity	0	Climate impacts are indirect via client portfolios and risk exposure
L (65)	65-Insurance, reinsurance and pension funding, except compulsory social security	0	Mostly asset-light (usually buildings, offices, and IT)	0	Skilled usually indoor labor with moderate workforce intensity	1	Climate impacts are indirect via client portfolios, significant risk exposure for the effects of extreme events on the coverage insurance
M (68)	68-Real estate activities	2	Very high capital intensity because physical assets (land, buildings, and long-term property assets) are the core business	0	Skilled usually indoor labor with low workforce intensity	2	Strong climate dependence due to direct exposure of buildings and land to physical hazards and retrofit needs
N (69,70,71,72,73, 74,75)	69-Legal and accounting activities 70-Activities of head offices and management consultancy 71-Architectural and engineering activities; technical testing and analysis 72-Scientific research and development 73-Activities of advertising, market research and public relations 74-Other professional, scientific and technical activities 75-Veterinary activities	0	Capital needs (these sectors are labour-intensive, not high fixed asset-intensive) for office infrastructure and IT systems (compliance software, case management platforms, cybersecurity, data protection tools, analytics and specialized tools, labs, medical equipment, clinics, ...) ; investments are mainly intangible (expertise, compliance, software)	1	Skilled usually indoor labor with moderate workforce intensity	0	Climate impacts are indirect and depend on client sectors and locations
O (77)	77-Rental and leasing activities	1	Capital-intensity industry driven by the need to acquire, maintain, and replace large portfolios of physical assets such as vehicles, machinery, and equipment, storage and logistics infrastructure, and asset management systems	0	Skilled usually indoor labor with low workforce intensity	0	Climate impacts are indirect and depend on client sectors, type and location of the rented property

RISK TRANSMISSION CHANNELS – INTENSITY LEVEL (IL)								
VIS NACE Grouping	NACE Description	IL	CAPITAL INTENSITY	IL	HUMAN WORKFORCE INTENSITY	IL	CLIMATE DEPENDENCE
O (78, 80, 81,82)	78-Employment activities 80-Investigation and security activities 81-Services to buildings and landscape activities 82-Office administrative, office support and other business support activities	0	Activities driven primarily by labour with low-capital-intensity and limited physical assets: investments in equipment, vehicles and IT systems	0	Skilled usually indoor labor with low workforce intensity	0	Climate impacts are indirect and depend on the customer's sector and the physical risks from the location of the assets
O (79)	79-Travel agency, tour operator and other reservation services and related activities	0	Low capital intensity, driven primarily by technology platforms (online travel platforms and digital systems) and marketing investments rather than fixed assets	1	Skilled usually indoor labor with moderate workforce intensity	2	Climate affects the demand for tourist services, seasonality and operational conditions
P (84)	84-Public administration and defense; compulsory social security	2	Significant capital intensity driven by physical infrastructure, long-term public assets, defense systems, administrative facilities and nationwide digital platforms (buildings, transportation fleets, defense equipment, secure IT systems, and large-scale public service networks)	1	Highly labor-intensive service sectors, with indoor and outdoor work	0	Limited climate dependence; climate could affect operational conditions
Q (85)	85-Education	1	Requires investment in physical infrastructure, buildings (schools, universities, laboratories, training facilities), equipment, and digital learning platforms and in human capital; capital intensity varies by level of education: higher education and research institutions tend to be more asset-heavy, while primary and secondary education remain more labour-intensive	1	Labour-intensive sector, above all in primary and secondary education, with skilled labour (teachers, researchers, administrative staff)	1	Climate affects operational conditions and extreme events effects educational structures
R (86,87)	86-Human health activities 87-Residential care activities	1	Hospitals, clinics, diagnostic centers and residential care facilities require substantial investment in medical equipment, imaging technologies, surgical systems and continuous investment in buildings, safety systems, medical and assistive equipment	1	Labor-intensive sectors, relying on large numbers of highly skilled professionals (physicians, nurses, technicians, large teams of caregivers, support staff) whose availability and specialization are essential for service continuity	1	Healthcare infrastructure and residential care facilities are increasingly exposed to climate-driven disruptions (storms and floods) and to heatwaves, which threaten building integrity, compromise residence safety, disrupt energy supply, and strain cooling systems essential for medical devices and pharmaceuticals
R (88)	88-Social work activities without accommodation	0	Low capital intensity because social work without accommodation relies primarily on professional services, counselling, community outreach, and support programs rather than physical asset (mainly offices, digital case-management systems)	0	Significant labor intensity: the sector depends on large numbers of social workers, educators, mediators, psychologists, and support staff, working usually in indoor	0	Indirect climate exposure, linked to the populations it serves and the continuity of operations
S (90, 92,93)	90-Arts creation and performing arts activities 92-Gambling and betting activities 93-Sports activities and amusement and recreation activities	1	Capital needs driven by investment in physical assets (theatres, rehearsal spaces, stage equipment, lighting, sound systems, production materials, casinos, betting halls, sports facilities (stadiums, gyms, pools, amusement parks, and specialized equipment)	1	Labor-intensive sectors, relying on specialised personnel, such as artists, performers, technicians, creative professionals, security, and compliance personnel, coaching, fitness instruction, event management, recreation services, and facility operations	1	Indoor venues are relatively protected, but outdoor activities (festivals, performances, cultural events, sports, recreation, amusement parks) are vulnerable to extreme weather (storms, heatwaves, heavy rainfall) and floods, damaging infrastructure, and compromising safety and health

RISK TRANSMISSION CHANNELS – INTENSITY LEVEL (IL)							
VIS NACE Grouping	NACE Description	IL	CAPITAL INTENSITY	IL	HUMAN WORKFORCE INTENSITY	IL	CLIMATE DEPENDENCE
S (91)	91-Libraries, archives, museums and other cultural activities	1	Activities require fixed assets and investments in dedicated buildings (libraries, archives, museums, climate-controlled storage areas, exhibition spaces, preservation laboratories, and specialized equipment for conservation and digitization)	1	Significant labor intensity and dependence on skilled labor and specialized human expertise in cataloguing, preservation, curation (librarians, archivists, curators, conservators, educators, researchers, and cultural mediators)	1	Cultural institutions are increasingly exposed to heatwaves, humidity shifts, storms, and flooding, which can damage buildings, threaten collections, and disrupt visitor access. Archives and museums are particularly sensitive to temperature and humidity variations, and outdoor cultural sites and events face higher exposure to extreme weather.
T (94,95,96)	94-Activities of membership organisations 95-Repair and maintenance of computers, personal and household goods, and motor vehicles and motorcycles 96-Personal service activities	0	Not significant capital intensity, light in fixed assets with minimal physical infrastructure: activities rely on offices, communication tools, and administrative systems, diagnostic tools, machinery, specialized equipment, inventory of spare parts, industrial laundry machines	0	Labor is the dominant production factor with skilled personnells (technicians, mechanics, electronics specialists, hairdressers, beauticians, wellness operators, laundry staff, and other personal care professionals) essential for service delivery, but usually indoor work	0	Climate dependence is generally moderate and indirect, affecting service continuity rather than physical infrastructure; **workshops are indoor but vulnerable to heatwaves, floods, and power outages that disrupt operations or damage facilities**
U (97)	97-Activities of households as employers of domestic personnel	0	Minimal capital intensity, as households employing domestic workers do not require infrastructures or significant fixed assets (production facilities, specialized equipment); assets are limited to basic household tools or appliances already present for domestic use	2	High labor-intensive sectors: domestic personnel (cleaners, caregivers, nannies, gardeners, drivers) provide services entirely based on human labor; generally, most domestic work occurs indoors, except for certain activities (gardening, outdoor maintenance, household transport, caregiving for vulnerable individuals)	0	Climate impacts are indirect and relate mainly to worker safety, mobility, and continuity of service rather than infrastructure vulnerability, affected by heatwaves, storms, or heavy rainfall
U (98)	98-Undifferentiated goods and service-producing activities of private households for own use	0	Minimal capital intensity, as households produce goods and services exclusively for their own consumption using basic household tools, appliances, or manual labor (no business infrastructure, specialized equipment, and fixed assets)	2	Extremely labor-intensive, entirely generated through human labor; most activities occur indoors, except for certain household tasks (gardening, outdoor maintenance)	0	Climate impacts are indirect and relate mainly to household comfort, safety, and the feasibility of outdoor tasks rather than infrastructure vulnerability, affected by heatwaves, storms, or heavy rainfall
V (99)	99-Activities of extraterritorial organisations and bodies	1	Capital intensity for embassies, consulates, international organisations, and diplomatic missions not relied on heavy physical assets or production equipment, but rather on controlled facilities (administrative buildings, offices, and diplomatic compounds), communication systems, and security infrastructure	0	Activities revolve around very skilled labor, driven almost entirely by human expertise relying on diplomats, administrative staff, policy experts, analysts, interpreters, and security personnel; most activities occur indoors within secure facilities	0	Despite diplomatic compounds and international offices can be affected by heatwaves, storms, floods, or disruptions to local infrastructure, climate risks are indirect and relate mainly to operational continuity, staff safety, and resilience of host country utilities rather than vulnerability of the organisations' own assets

3.6 Vulnerability Matrix

Not every risk transmission channel is structurally relevant to every hazard. Flooding damages fixed installations, interrupts logistics and affects workforce, so it impacts heavily on all three risk transmission channels. Chronic heat reduces labour productivity and raises occupational health costs, impacting mainly on workforce intensity, with a secondary capital impacting through cooling demand and equipment operating below rated capacity[348]. To capture these differences, a vulnerability matrix was built to map each physical risk area, broken down by event, against the relevant transmission channels. The matrix below identifies the risk transmission channels that are material for each event. Risk transmission channels that are not significant for a given hazard are treated as having a low intensity level.

Figure 8: Vulnerability matrix

PHYSICAL RISK AREAS		TRASMISSION CHANNELS: CAPITAL INTENSITY	HUMAN WORK INTENSITY	CLIMATE DEPENDENCE
WATER-RELATED	Flood	✓	✓	✓
	Drought		✓	✓
	Heavy precipitation		✓	✓
	Changing precipitation patterns		✓	✓
	Sea level rise	✓		
TEMPERATURE RELATED	Heat wave	✓	✓	✓
	Cold wave/frost	✓	✓	✓
	Changing temperature		✓	✓
SOLID MASS-RELATED	Landslide/Subsidence	✓		
	Coastal erosion	✓		
	Soil erosion /degradation		✓	✓
WIND-RELATED	Cyclone/Storm/Tornado	✓	✓	✓
	Changing wind patterns	✓		✓

The physical climate hazards included in the matrix are those listed in the Appendix to the Taxonomy Regulation (EU) 2020/852. For assessment purposes, closely related hazards that reach a business through the same channels have been consolidated, giving thirteen events grouped into four physical risk areas.

Water-related - Flood; drought; heavy precipitation; sea level rise; changing precipitation patterns / precipitation variability.

Temperature-related - Heat wave; cold wave/frost; changing temperature patterns / temperature variability.

Solid mass-related - Landslide / subsidence; coastal erosion; soil erosion/degradation.

Wind-related - Cyclone / storm / tornado; changing wind patterns.

[348] https://www.eea.europa.eu/en/analysis/publications/european-climate-risk-assessment

This structure allows to produce vulnerability scores at three levels of aggregation: Event Score for a single event, Area Score for each of the four physical risk areas, and the Overall Score for the 13 risk events combined.

3.7 Vulnerability Intensity Sector score and Vulnerability Scale

The methodological approach for developing the vulnerability intensity sector score (VIS) is structured into sequential activities, combining the result of the attribution of the intensity level (0-Low, 1-Medium, 2-High) for each physical risk event to each of the 87 economic sectors of activities (NACE), where material, according to the vulnerability matrix described above.

The score is constructed in three stages, and each stage produces a vulnerability assessment:

- **VIS Event** score — the score for each sector against a single type of hazard, derived from the combination of its three channel levels (example: VIS for heat wave);
- **VIS Area** score — the score for each sector across all hazards within a physical risk area, obtained as the arithmetic mean of the constituent event scores (example: VIS for water-related area).
- **VIS Overall** score — the score for each sector across all thirteen hazards, obtained as the arithmetic mean of all event scores (example: VIS for all combined 13 physical events together).

3.7.1 VIS Event Score

To obtain a synthetic measure of the combined effect of the three vulnerability risk transmission channel on the single event, a matrix-based approach was adopted. Each risk transmission channel takes one of three intensity levels (0, 1, 2), resulting in 27 possible combinations. Where a risk transmission channel is not material for a given hazard, it is assigned a value of 0, so the assessment reflects only the channels through which that hazard actually operates.

The 27 combinations were then consolidated into seven vulnerability classes, grouping configurations with similar structural profiles and comparable overall intensity. The consolidation follows two rules. First, the drivers are equally weighted and interchangeable, so (2,0,0) and (0,0,2) fall in the same class. Second, the criterion is conservative in the sense that concentration matters more than breadth: a hazard reaching a sector through one channel at maximum intensity is assessed as more severe than one reaching it through three channels at mild intensity.

The table below sets out the approach for the vulnerability intensity scale: how the intensity level combinations are mapped in into vulnerability classes.

Table 25: VIS Event Score and Class Grouping

VIS-Event Class	Risk Channels Combinations	Description
1-Non intensive	0–0–0	All channels at level 0. Overall vulnerability is negligible
2-Very Low Intensity	1–0–0; 0–1–0; 0–0–1	Only one channel at level 1. Very limited vulnerability
3-Low Intensity	1–1–0; 1–0–1; 0–1–1	Two channels at level 1. Low but non-negligible vulnerability
4-Medium Intensity	1–1–1	All channels at level 1. Structurally medium vulnerability
5-High Intensity	2–0–0; 0–2–0; 0–0–2; 2–1–0; 2–0–1; 1–2–0; 0–2–1; 1–0–2; 0–1–2; 2–1–1; 1–2–1; 1–1–2	One channel at level 2 and others at level 1 or 0. Elevated vulnerability across single or multiple dimensions
6-Very High Intensity	2–2–0; 2–0–2; 0–2–2; 2–2–1; 2–1–2; 1–2–2	Two channels at level 2 and one at level 1 or 0. Very high vulnerability with broader structural intensity
7-Extreme Intensity	2–2–2	Maximum intensity across all dimensions. Vulnerability is extreme

Take the sector 01 - Crop and Animal Production as an example of the intensity class assignment. Sector 01 is characterised by the maximum intensity level (2) across all three vulnerability risk transmission channels at the sector level. As a result, the event‑level configuration for floods (VIS Event Score) corresponds to a combination where three risk transmission channels retain intensity level 2. This configuration maps into the '7-Extreme Intensity' class, reflecting the maximum sensitivity of agricultural activities to flood-related disruptions through the relevant risk transmission channels.

3.7.2 VIS Area Score

The second stage aggregates the VIS Event Scores into a VIS Area Score for each physical risk area, combining the contributions of all events material to that area. For the water-related area, these are flood, drought, heavy precipitation, changing precipitation patterns and sea level rise.

Each event-level intensity class was first converted into a normalised score on a 1–100 scale, where 1 denotes the absence of vulnerability and 100 the maximum. The conversion maps the class number directly onto the scale, so that higher classes correspond proportionally to higher scores:

$$N_e = 1 + (Ce - 1) * \frac{(100 - 1)}{(C_{max} - 1)}$$

where:

N_e = normalised score of climate-related event e on a 1–100 scale

C_e = intensity class of event e (corresponding to the class number of event intensity scale), with $C_e \in \{1, \dots, 7\}$

C_{max} = maximum class of event intensity scale (value=7).

Because the value assigned to each class corresponds to the upper bound of that class, the first class would otherwise have no defined lower reference. Its cut-off was therefore set at half the cut-off of the second class, preserving consistency across the classification. The resulting normalised scores for the seven classes are shown in the table below.

Table 26: Intensity Class Normalisation

INTENSITY CLASS	C_e	N_e
1-Non intensive	1	9
2-Very Low Intensity	2	18
3-Low Intensity	3	34
4-Medium Intensity	4	51
5-High Intensity	5	67
6-Very High Intensity	6	84
7-Extreme Intensity	7	100

The VIS Area score is then obtained as a weighted average of the normalised scores of the events belonging to the area. A simple average was not used: it would allow a severe vulnerability to a single event to be offset by low vulnerability to the others, understating the exposure of the sector. The weighting is prudential and gives greater weight to the more severe events, using each event's own class number as its weight, so that the weights adjust automatically to the distribution of scores within the area:

$$VIS_{\text{area}} = \frac{\sum_e C_e * N_e}{\sum_e C_e}$$

where

C_e = intensity class of event e

N_e = normalised score of event e

This aggregate score ensures comparability across areas and sectors, thereby generating the final VIS Area Score.

Take the Water-related risk area for sector 01 - Crop and animal production. Applying the methodology outlined above, the VIS Event belonging to this sector range from the class 5-High Intensity to 7-Extreme Intensity. The sum of all standardised event score is 419 across five events, corresponding to the weighted score 85 and the extreme value of the class 7-Extreme Intensity.

Table 27: VIS Area - Water-related events - example

WATER-RELATED EVENTS	VIS Event	Ne	Weight	%	Ne Weighted	VIS Area
Flood	7-Extreme Intensity	100	7	23,3	23	
Drought	6-Very High Intensity	84	6	20,0	17	
Heavy Precipitation	6-Very High Intensity	84	6	20,0	17	
Sea Level Rise	5-High Intensity	67	5	16,7	11	
Changing Precipitation Patterns	6-Very High Intensity	84	6	20,0	17	
Total Event Normalised Scores (num)		**419**				
Total Weights (den)			**30**	**100**		
Total Area Score					**85**	**7-Extreme Intensity**

Below the VIS Area Score for the other physical risk areas.

Table 28: VIS Area – Temperature-related, solid mass-related, wind-related events - example

TEMPERATURE-RELATED EVENTS	VIS Event	Ne	Weight	%	Ne Weighted	VIS Area
Heat Waves	7-Extreme Intensity	100	7	35,0	35	
Cold Waves/Frost	7-Extreme Intensity	100	7	35,0	35	
Changing Temperature Patterns	6-Very High Intensity	84	6	30,0	25	
Total Event Normalised Scores (num)		**284**				
Total Weights (den)			**20**	**100**		
Total VIS Area Score					**95**	**7-Extreme Intensity**

SOLID MASS-RELATED EVENTS	VIS Event	Ne	Weight	%	Ne Weighted	VIS Area
Landslide/Subsidence	5-High Intensity	67	5	31,3	21	
Coastal Erosion	5-High Intensity	67	5	31,3	21	
Soil Erosion/Degradation	6-Very High Intensity	84	6	37,5	32	
Total Event Normalised Scores (num)		**218**				
Total Weights (den)			**16**	**100**		
Total VIS Area Score					**73**	**6-Very High Intensity**

WIND-RELATED EVENTS	VIS Event	Ne	Weight	%	Ne Weighted	VIS Area
Cyclone/Storm/Tornado	7-Extreme Intensity	100	7	53,8	54	
Changing Wind Patterns	6-Very High Intensity	84	6	46,2	39	
Total Event Normalised Scores (num)		**184**				
Total Weights (den)			**13**	**100**		
Total VIS Area Score					**93**	**7-Extreme Intensity**

3.7.3 VIS Overall

The final stage produces a single overall vulnerability profile for each sector (VIS Overall). Rather than combining the four area scores, the overall VIS is computed directly from the normalised scores of all thirteen events, using the same prudential weighting scheme applied at area level. Aggregating from the events avoids a second round of averaging, so each event contributes to the overall score exactly as it was assessed, without the loss of information that intermediate aggregation would introduce.

Because all levels of assessment share the same 1–100 normalisation, event, area and overall scores are expressed on a single comparable scale. The same Vulnerability Intensity Sector score scale therefore applies throughout, which keeps the classification consistent across levels and allows an institution to apply the framework at whichever level of granularity and materiality suits the portfolio it is analysing.

One consequence of aggregating from events follows directly from this design. Each area contributes to the overall VIS in proportion to the number of events it contains, so the hazard taxonomy, rather than a judgement about materiality, determines the relative influence of each area. With five water-related events, three temperature-related, three solid-mass-related and two wind-related, the water-related area accounts for about 38% of the event set and the wind-related area for about 15%. This is an accepted feature of the present specification rather than a calibrated choice; where an institution has evidence that a particular area is more material to its portfolio, the weighting can be adjusted at this stage without affecting the event- or area-level scores.

Take the VIS Overall Score for sector 01 - Crop and animal production. Applying the methodology outlined above, the VIS Events belonging to this sector range from class 5-High Intensity to class 7-Extreme Intensity. The sum of all standardised event score is 1105 across thirteen events, corresponding the weighted score 86 and to the class 7-Extreme Intensity.

Table 29: VIS Overall events – example

Event	VIS Event	Ne	Weight	%	Ne Weighted	VIS Overall
Flood	7-Extreme Intensity	100	7	8,9	9	
Drought	6-Very High Intensity	84	6	7,6	6	
Heavy Precipitation	6-Very High Intensity	84	6	7,6	6	
Sea Level Rise	5-High Intensity	67	5	6,3	4	
Changing Precipitation Patterns	6-Very High Intensity	84	6	7,6	6	
Heat Waves	7-Extreme Intensity	100	7	8,9	9	
Cold Waves/Frost	7-Extreme Intensity	100	7	8,9	9	
Changing Temperature Patterns	6-Very High Intensity	84	6	7,6	6	
Landslide/Subsidence	5-High Intensity	67	5	6,3	4	
Coastal Erosion	5-High Intensity	67	5	6,3	4	
Soil Erosion/Degradation	6-Very High Intensity	84	6	7,6	6	
Cyclone/Storm/Tornado	7-Extreme Intensity	100	7	8,9	9	
Changing Wind Patterns	6-Very High Intensity	84	6	7,6	6	
Total Event Normalised Scores		**1105**				
Total Weights (den)			**79**	**100**		
Total VIS Overall Score					**86**	**7-Extreme Intensity**

The VIS Overall score is mapped onto an ordinal seven-class scale, which provides a synthetic framework for reading how vulnerability to climate hazards increases in intensity. The cut-offs were set judgmentally so that each class captures a comparable portion of the underlying distribution of event-level configurations, balancing granularity against interpretability. Each class is accompanied by a definition of the vulnerability profile it represents, ranging from negligible to extreme intensity.

Figure 9: Vulnerability Intensity Sector score (VIS) scale

SCORE min	SCORE max	Vulnerability Intensity	Description
1	9	1 – Negligible	The economic activity exhibits negligible or very low vulnerability to climate risk
10	18	2 – Very Low	
19	34	3 – Low	The economic activity exhibits moderate vulnerability to climate risk, reflecting a combination of sectoral characteristics and driver interactions that generate a non-negligible but still contained sensitivity to physical hazards
35	51	4 – Medium	
52	67	5 – High	The economic activity presents an high vulnerability to climate risk, with multiple drivers contributing meaningfully to sensitivity, a structural dependencies and significant exposure to relevant hazards, resulting in a higher likelihood of disruption and damages under adverse physical events
68	84	6 – Very High	
85	100	7 – Extreme	The economic activity exhibits strong and simultaneous vulnerabilities to climate risk from all relevant drivers, placing the sector among those most exposed and sensitive to climate-related damages and disruptions

Table 30: VIS Area and Overall by group of sub-sectors

NACE Description	VIS AREA				VIS OVERALL
	WATER-RELATED EVENTS	TEMPERATURE-RELATED EVENTS	SOLID MASS-RELATED EVENTS	WIND-RELATED EVENTS EVENTS	ALL EVENTS
01-Crop and animal production, hunting and related service activities	7-Extreme Intensity	7-Extreme Intensity	6-Very High Intensity	7-Extreme Intensity	7-Extreme Intensity
02-Forestry and logging 03-Fishing and aquaculture	6-Very High Intensity	6-Very High Intensity	5-High Intensity	6-Very High Intensity	6-Very High Intensity
05-Mining of coal and lignite 06-Extraction of crude petroleum and natural gas 07-Mining of metal ores 08-Other mining and quarrying 09-Mining support service activities	5-High Intensity	5-High Intensity	4-Medium Intensity	5-High Intensity	5-High Intensity
10-Manufacture of food products 11-Manufacture of beverages 12-Manufacture of tobacco products 13-Manufacture of textiles 14-Manufacture of wearing apparel 15-Manufacture of leather and related products of other materials	6-Very High Intensity	6-Very High Intensity	5-High Intensity	6-Very High Intensity	6-Very High Intensity
16-Manufacture of wood and of products of wood and cork 17-Manufacture of paper and paper products 19-Manufacture of coke and refined petroleum products 20-Manufacture of chemicals and chemical products 23-Manufacture of other non-metallic mineral products	6-Very High Intensity	6-Very High Intensity	5-High Intensity	6-Very High Intensity	6-Very High Intensity
18-Printing and reproduction of recorded media 31-Manufacture of furniture	5-High Intensity	5-High Intensity	4-Medium Intensity	5-High Intensity	5-High Intensity
25-Manufacture of fabricated metal products, except machinery and equipment 29-Manufacture of motor vehicles, trailers and semi-trailers 30-Manufacture of other transport equipment	4-Medium Intensity	4-Medium Intensity	3-Low Intensity	4-Medium Intensity	4-Medium Intensity
26-Manufacture of computer, electronic and optical products 27-Manufacture of electrical equipment 32-Other manufacturing	2-Very Low Intensity	2-Very Low Intensity	2-Very Low Intensity	2-Very Low Intensity	2-Very Low Intensity
21-Manufacture of basic pharmaceutical products and pharmaceutical preparations	5-High Intensity	5-High Intensity	5-High Intensity	5-High Intensity	5-High Intensity
22-Manufacture of rubber and plastic products 24-Manufacture of basic metals	4-Medium Intensity	4-Medium Intensity	3-Low Intensity	4-Medium Intensity	4-Medium Intensity
28-Manufacture of machinery and equipment n.e.c. 33-Repair, maintenance and installation of machinery and equipment	3-Low Intensity	3-Low Intensity	3-Low Intensity	3-Low Intensity	3-Low Intensity

NACE Description	VIS AREA				VIS OVERALL
	WATER-RELATED EVENTS	TEMPERATURE-RELATED EVENTS	SOLID MASS-RELATED EVENTS	WIND-RELATED EVENTS EVENTS	ALL EVENTS
35-Electricity, gas, steam and air conditioning supply	6-Very High Intensity	6-Very High Intensity	5-High Intensity	6-Very High Intensity	6-Very High Intensity
36-Water collection, treatment and supply	7-Extreme Intensity	7-Extreme Intensity	6-Very High Intensity	7-Extreme Intensity	7-Extreme Intensity
37-Sewerage	6-Very High Intensity	6-Very High Intensity	5-High Intensity	6-Very High Intensity	6-Very High Intensity
38-Waste collection, recovery and disposal activities	6-Very High Intensity	6-Very High Intensity	5-High Intensity	6-Very High Intensity	6-Very High Intensity
39-Remediation activities and other waste management service activities	4-Medium Intensity	4-Medium Intensity	3-Low Intensity	4-Medium Intensity	4-Medium Intensity
41-Construction of residential and non-residential buildings	7-Extreme Intensity	7-Extreme Intensity	6-Very High Intensity	7-Extreme Intensity	7-Extreme Intensity
42-Civil engineering	4-Medium Intensity	5-High Intensity	5-High Intensity	5-High Intensity	5-High Intensity
43-Specialised construction activities	6-Very High Intensity	6-Very High Intensity	5-High Intensity	6-Very High Intensity	6-Very High Intensity
46-Wholesale trade 47-Retail trade	4-Medium Intensity	4-Medium Intensity	3-Low Intensity	4-Medium Intensity	4-Medium Intensity
49-Land transport and transport via pipelines 51-Air transport 53-Postal and courier activities	4-Medium Intensity	4-Medium Intensity	3-Low Intensity	4-Medium Intensity	4-Medium Intensity
50-Water transport	5-High Intensity	5-High Intensity	4-Medium Intensity	5-High Intensity	5-High Intensity
52-Warehousing, storage and support activities for transportation	4-Medium Intensity	5-High Intensity	5-High Intensity	5-High Intensity	5-High Intensity
55-Accomodation 56-Food and beverage service activities	7-Extreme Intensity	7-Extreme Intensity	6-Very High Intensity	7-Extreme Intensity	7-Extreme Intensity
58-Publishing activities	1-Non intensive	1-Non intensive	1-Non intensive	1-Non intensive	1-Non intensive
59-Motion picture, video and television programme production, sound recording and music publishing activities 60-Programming, broadcasting, news agency and other content distribution activities	2-Very Low Intensity	2-Very Low Intensity	2-Very Low Intensity	3-Low Intensity	2-Very Low Intensity
61-Telecommunication	4-Medium Intensity	5-High Intensity	5-High Intensity	5-High Intensity	5-High Intensity
62-Computer programming, consultancy and related activities	1-Non intensive	1-Non intensive	1-Non intensive	1-Non intensive	1-Non intensive
63-Computing infrastructure, data processing, hosting and other information service activities	3-Low Intensity	3-Low Intensity	2-Very Low Intensity	4-Medium Intensity	3-Low Intensity
64-Financial service activities, except insurance and pension funding 66-Activities auxiliary to financial services and insurance activities	1-Non intensive	1-Non intensive	1-Non intensive	1-Non intensive	1-Non intensive
65-Insurance, reinsurance and pension funding, except compulsory social security	2-Very Low Intensity	2-Very Low Intensity	2-Very Low Intensity	3-Low Intensity	2-Very Low Intensity

NACE Description	VIS AREA				VIS OVERALL
	WATER-RELATED EVENTS	TEMPERATURE-RELATED EVENTS	SOLID MASS-RELATED EVENTS	WIND-RELATED EVENTS EVENTS	ALL EVENTS
68-Real estate activities	6-Very High Intensity	6-Very High Intensity	5-High Intensity	6-Very High Intensity	6-Very High Intensity
69-Legal and accounting activities 70-Activities of head offices and management consultancy 71-Architectural and engineering activities; technical testing and analysis 72-Scientific research and development 73-Activities of advertising, market research and public relations 74-Other professional, scientific and technical activities 75-Veterinary activities	2-Very Low Intensity	2-Very Low Intensity	2-Very Low Intensity	2-Very Low Intensity	2-Very Low Intensity
77-Rental and leasing activities	2-Very Low Intensity	2-Very Low Intensity	2-Very Low Intensity	3-Low Intensity	2-Very Low Intensity
78-Employment activities 80-Investigation and security activities 81-Services to buildings and landscape activities 82-Office administrative, office support and other business support activities	1-Non intensive	1-Non intensive	1-Non intensive	1-Non intensive	1-Non intensive
79-Travel agency, tour operator and other reservation services and related activities	5-High Intensity	5-High Intensity	4-Medium Intensity	5-High Intensity	5-High Intensity
84-Public administration and defence; compulsory social security	4-Medium Intensity	5-High Intensity	5-High Intensity	5-High Intensity	5-High Intensity
85-Education	4-Medium Intensity	4-Medium Intensity	3-Low Intensity	4-Medium Intensity	4-Medium Intensity
86-Human health activities 87-Residential care activities	4-Medium Intensity	4-Medium Intensity	3-Low Intensity	4-Medium Intensity	4-Medium Intensity
88-Social work activities without accommodation	1-Non intensive	1-Non intensive	1-Non intensive	1-Non intensive	1-Non intensive
90-Arts creation and performing arts activities 92-Gambling and betting activities 93-Sports activities and amusement and recreation activities	4-Medium Intensity	4-Medium Intensity	3-Low Intensity	4-Medium Intensity	4-Medium Intensity
91-Libraries, archives, museums and other cultural activities	4-Medium Intensity	4-Medium Intensity	3-Low Intensity	4-Medium Intensity	4-Medium Intensity
94-Activities of membership organisations 95-Repair and maintenance of computers, personal and household goods, and motor vehicles and motorcycles 96-Personal service activities	1-Non intensive	1-Non intensive	1-Non intensive	1-Non intensive	1-Non intensive
97-Activities of households as employers of domestic personnel	5-High Intensity	5-High Intensity	4-Medium Intensity	5-High Intensity	5-High Intensity
98-Undifferentiated goods and service-producing activities of private households for own use	5-High Intensity	5-High Intensity	4-Medium Intensity	5-High Intensity	5-High Intensity
99-Activities of extraterritorial organisations and bodies	2-Very Low Intensity	2-Very Low Intensity	2-Very Low Intensity	3-Low Intensity	2-Very Low Intensity

3.8 Limitations and methodological improvements

The following limitations qualify the results presented above and should be read alongside them. The assessment has not been validated against realised outcomes. No back-testing against observed damage has been performed. The reference provinces include areas affected by the 2023 Emilia-Romagna flood, which offers a natural setting for such a test should loss or performance data become available.

The workforce indicator is a measure of scale rather than of intensity. Human Workforce Intensity is measured as employee headcount, whereas Capital Intensity is a ratio. Headcount is an imperfect proxy for the extent to which production depends on labour performed in hazardous conditions, and the asymmetry between the two indicators is acknowledged. A complementary ratio — personnel costs to revenue, or personnel costs to total operating costs — is envisaged as a robustness check.

The climate-dependence risk transmission channel rests entirely on expert judgement. No quantitative indicator or empirical model underpins it.

Coverage of the reference universe is measured against Chamber of Commerce data classified under the previous (2022) nomenclature, while the portfolio is mapped to NACE Rev. 2.1. The comparison is approximate for the divisions most affected by the remapping.

Methodological improvements: Extension of the capital-intensity indicator to include inventory, so as to capture losses of raw materials and of semi-finished and finished goods; addition of a workforce-intensity ratio alongside headcount; a sensitivity analysis of the sector assignments to the threshold values and to the clustering specification; a kernel analysis and, based on the resulting evidence, refining or adjusting the judgmental thresholds; and, subject to data availability, back-testing against realised loss experience.

Annex III. Adaptation Adjustment Credit Rating Methodology

This annex provides a comprehensive description of the methodological framework proposed for the integration of the impact of physical climate risks on the evaluation of non-financial corporate creditworthiness. The methodology proceeds through the following sections, each described in turn below:

1. Portfolio definition
2. Selection of information sources
3. Definition of the time horizon and performance
4. Data quality, checks and exclusions
5. Analysis of the relationship and identification of the impact on solvency
6. Integration of the impact into the credit risk measure.

1. Portfolio definition

The portfolio used to develop and test the approach comprises corporations and equivalent legal forms, selected because they offer fuller and more consistent data — financial statements above all — for examining how physical climate events affect credit risk and for tracing the transmission channels involved. Since the analysis also requires a credit rating or score and a probability of default for each entity, and these were available only for non-financial companies, banking and insurance entities were excluded, along with firms in certain other sectors.

2. Selection of information sources

The climate-related credit risk assessment and the integration of the impact of physical climate risks on the evaluation of non-financial corporate creditworthiness needs of multiple data sources, including corporate information on the location and business activity of the entity, financial statements, credit score/ratings, sectoral climate indicators, detailed climate risk metrics at the local level, and acute climate event data. The AACR approach draws on four macro-types of information:

- corporate registry information, such as location and business activity of the entity, and financial statement data
- corporate credit scores/ ratings, providing annual creditworthiness assessments (score/rating class) and one-year probability of default (PD),
- climate hazard data on physical risks, such as floods, droughts, wildfires and heat stress in the municipality where the company's strategic assets are located or its activities carried out,
- economic activities vulnerability assessment (Vulnerability Intensity Score-VIS): 2-digit NACE-based sectoral vulnerability score[349].

[349] For details on the Vulnerability Intensity Score, see the chapter 6.

Corporate information and credit ratings are sourced from an international business information provider. Equivalent data is available from other business information providers and credit rating agencies. The creditworthiness assessment supplied by the provider used here draws on a range of public sources:

- company registers held by the Italian Business Register ('Camera di Commercio');
- financial statements filed with the Italian Business Register;
- adverse public records (bankruptcy proceedings, prejudicial filings, protests and settlements) from public registers;
- commercial payment behavior;
- territorial and sectoral banking credit risk data.

These inputs feed a suite of statistical models that assess creditworthiness on an ordinal eight-class scale. Class 1 corresponds to sound financial and economic balance with a very low default risk (0.7%); class 8 denotes an unstable, unbalanced financial profile with a very high default risk (28.2%).

2.1 Climate hazard data

Physical climate hazard is assessed using the AWARE© (Accident Weather Analytics Risk Events) suite of indicators[350].The AWARE indicators are built through an expert-led approach supported by statistical analysis. They draw on thematic public sources — principally ISTAT (the Italian Statistical National Institute) [351], ISPRA (the Italian Agency for Environmental Protection and Research)[352], and the Civil Protection Department[353] — selected according to the weather event in question. These data are checked for quality and consistency and combined with further datasets, including proprietary ones such as emergency measures decrees and orders. The inputs are integrated through successive aggregation steps, using algorithms that produce partial thematic risk indicators (for instance flood risk or heatwave risk) and combined risk indicators (for instance hydrogeological risk or extreme temperature risk).

Each AWARE indicator returns a score, mapped onto an ordinal five-level risk scale. The scale is calibrated to the relative distribution across Italian municipalities, so classes express relative standing within the national distribution rather than absolute hazard thresholds. The scale provides a synthetic framework for evaluating how exposed a given area is to flood hazards, distinguishing stable contexts with limited vulnerability from territories where extreme events are recurrent and risk levels are high. The table below presents the five classes of the flood risk assessment scale, ranging from *Very Low* to *Very*

[350] See www.sustainadvisory.it/climate-risk-analytics/. AWARE provides a set of indicators for assessing the physical caused by climate change and by extreme events such as extreme weather events and related incidents by event type (i.e. intense and frequent rainfall, floods, temperature increase, hot and cold waves, landslides) and combined events (i.e. hydrogeological risk, temperature extreme risk). AWARE is available throughout the Italian territory and within administrative units (municipalities, provinces, regions).

[351] www.istat.it

[352] ISPRA Istituto Superiore per la Protezione e la Ricerca Ambientale

[353] https://www.protezionecivile.gov.it/it/

High. Each class combines three core elements: the extent of the territory potentially affected, and the intensity, recurrence of extreme rainfall phenomena and the probability of flood events (expressed through return periods P1–P3 defined in the ISPRA framework). As the scale progresses, both the likelihood of flooding and the severity of associated hydrological conditions increase, moving from rare, low-intensity events to frequent floods with significant territorial impact.

Table 31: AWARE flood risk scale

RISK CLASS		FLOOD RISK		
Definition: temporary flooding of areas that are normally not covered by water, caused by lakes, rivers, streams, and possibly artificial drainage networks; any other surface water body, including those with temporary, natural, or artificial flow regimes; coastal marine inundation; and flooding attributable to meteorological events.			**Probability FLOOD HAZARD (1/Tr)**	
	VERY LOW	The hydraulic risk is usually absent and the territory has a low probability of floods and extreme events (hazard P1). Intense and abundant rainfall extreme phenomena are generally limited.	P1 – rare floods of extreme intensity: return period up to 500 years (low probability)	0,20%
	LOW	The probability of floods (hazard P1) is generally low, offsetting the greater hazard in terms of surface at risk. Intense and abundant rainfall extreme phenomena are quite limited.		0,35%
	MEDIUM	The territory could be affected by not very frequent floods (P2, with return period between 100 and 200 years) involving a small portion of the surface and by intense and abundant rainfall sometimes. The flood probability is still moderate.	P2 – infrequent floods: return period between 100 and 200 years (medium probability)	0,75%
	HIGH	The territory could be affected by not very frequent floods (P2, with return period between 100 and 200 years) involving a significant portion of the surface or by frequent floods (P3 with return time between 20 and 50 years). Rainfalls often result in extreme phenomena for concentration and intensity. The flood probability is high.		1,50%
	VERY HIGH	The territory could be affected by frequent floods (P3, with return period between 20 and 50 years) involving a large portion of surface and by extreme rainfall phenomena for concentration and intensity. The flood probability is high and/or the territory have areas already involved in recent flood events.	P3 – frequent floods: return period between 20 and 50 years (high probability)	5,00%

2.2 Conversion of Flood Return Periods into Annual Probabilities and Construction of Risk Scale

In the ISPRA framework, flood hazard is classified into three categories (P1, P2, P3), each associated with a specific range of return periods (Tr). High hazard areas (P3) correspond to return periods between 20 and 50 years; medium hazard areas (P2) to return periods between 100 and 200 years; and low hazard areas (P1) to return periods exceeding 200 years, typically around 500 years.

To integrate these hazard classes within a risk modelling environment, return periods are converted into annual probabilities of occurrence. The conversion relies on the standard hydraulic engineering formula :

$$P = 1 - (1 - \frac{1}{Tr})^{N}$$

where Tr is the return period and N = 1, reflecting the probability that the event occurs at least once within the current year.

For each ISPRA class, the mean return period (arithmetic average of the interval bounds) is used to derive representative annual probabilities. This yields approximate probability ranges of 2–5% for P3, 0.5–1% for P2, and 0.2–0.5% for P1.

Table 32: ISPRA hazard classes, return periods and annual probabilities

Hazard		Tr			Probability		
P1	Low	500	>	200	0,2%	<	0,5%
P2	Medium	100	-	200	1,0%	-	0,5%
P3	High	20	-	50	5,0%	-	2,0%

Since the risk evaluation requires a more granular representation of hydraulic risk, the three ISPRA classes are mapped onto a five-level probability scale.

The selected probability values correspond to meaningful lower bounds, mid-points, and upper bounds of the ISPRA-derived ranges:

Table 33: AWARE flood risk classes and implied return periods

AWARE flood risk class	Annual probability P	Implied return period	Methodological Reference
1 – very low	0.20%	~500 years	Lower bound P1 – Tr ≈ 500 years
2 – low	0.35%	~285 years	Intermediate value within P1
3 – medium	0.75%	~135 years	Mean P2 – Tr ≈ 100–200 years
4 – high	1.50%	~65 years	Intermediate value within P2
5 – very high	5.00%	~20 years	Upper bound P3 – Tr ≈ 20 years

Because the analysis of the relationship between physical climate risk and credit deterioration focused on a portfolio of corporates located in areas affected by acute flood events, this exercise used the hydrogeological risk indicator at municipal level, taking the location of the company's registered office as the reference point. The hydrogeological indicator combines events related to flooding from inundation and overflow with those related to extreme rainfall, including flash floods, heavy precipitation and consecutive days of high rainfall. AWARE probabilities relied on ISPRA hazard maps, that are derived from historical observations until 2021.

Using the registered office location as the geographic reference as a proxy for the location of activity is a known limitation, since a company's legal seat need not coincide with the location of its productive assets, and a single reference point cannot capture exposure distributed across multiple sites. It was adopted here because it is the only geographic attribute consistently available across the portfolio and the reference used in the financial statements and the underlying credit information sources. This choice ensures methodological consistency between the two exercises (the credit score adjustment and the vulnerability sector matrix), but it could limit the climate-related risk assessment: when a company's productive assets are situated elsewhere, the geographic attribution based on company headquarter could be approximate and not ensure the real risk level of hazards of the other strategic and operational sites where the company operates.

3. Definition of the time horizon and performance

The exercise was structured around the flood events occurred in 2023 in the Italian provinces of Ravenna and Forlì-Cesena (Emilia Romagna region) and Prato and Pistoia (Tuscany region)[354].

To ensure a proper timing for observing the relationship between the climatic physical event and any impact on the company's economic and financial situation, the observation window used covered the period before the 2023 events (observation date) and the following period (performance date). Therefore, in coherence with the observation and performance periods, the following information was used for the quantitative analysis:

- full year financial statements from 2021 to 2024,
- corporate credit score from 2022 to 2025,
- default and in bonis status from 2022 to 2025,

according to the following scheme:

[354] The floods in Emilia-Romagna and Tuscany are among the most destructive weather-related events that Italy has faced in recent decades. Both regions were hit by exceptionally heavy rainfall events, with return periods of over a century in several basins, in areas that are highly vulnerable due to densely populated settlements and rich industrial infrastructure, but also with significant geomorphological sensitivity, especially in the Apennine areas. In Emilia-Romagna, the disaster unfolded through two consecutive events at the beginning and mid-May 2023 (1-3 May and 16-17 May), with an exceptional sequence of storms that dumped rain on the region with intensity rarely seen in historical records. According to ISPRA and the Civil Protection, the total rainfall reached amounts comparable to several months of rain concentrated in just a few days, with over 300 millimeters in 48 hours. The ground, saturated and unable to absorb any more water, and the region's rivers started to swell quickly, and twenty-one of them overflowed. The slopes of the Apennines reacted violently with thousands of landslides that erupted almost simultaneously, ranging from small surface slips to large deep movements that cut off roads, isolated villages, and damaged houses and public infrastructure. Cities like Faenza, Forlì, Cesena, and Ravenna experienced widespread flooding, with neighbourhoods submerged, farmland ruined, and essential services disrupted. Tuscany experienced an equally intense event of heavy rainfall in November 2023 (November 1-3). Civil Protection reports describe a series of storms that caused local flooding, road landslides, and widespread slope failures, especially in areas already prone to geological instability. Rivers like the Arno and its tributaries rose quickly, and several municipalities faced damage to public works, businesses, and residential areas. The events didn't reach the same overall magnitude as those in Emilia-Romagna, but they still reached high intensity in just a few hours (almost 200 millimetres of rain in 6 hours). The estimated resources needed to repair the damage caused in the provinces of Emilia-Romagna amount to about 10 billion euros, while for the provinces of Tuscany it's about 2 billion euros. For details, see ISPRA's official reports on the May 2023 Emilia-Romagna floods (www.isprambiente.gov.it/it/news/alluvione-in-emilia-romagna), the Italian Civil Protection Department's documentation on the 2023 severe weather events (www.protezionecivile.gov.it/it/), and the Tuscany Region's and ARPAT's official pages on the November 2023 flood emergency (www.regione.toscana.it/alluvione-2023 and www.arpat.toscana.it/notizie/arpatnews/2023/alluvione-novembre-2023-in-toscana).

Figure 10: Observation and performance periods



The timing mismatch between financial statement information and data on solvency and default reflects the deadlines and requirements for presenting financial statements and the timing of when financial information becomes available or is published. Usually, there's a time lag of 3 to 9 months for financial statements, shorter for publicly traded companies and longer for other companies.

The definition of the performance applied in the scores provided by the source of the creditworthiness assessment, according to banking regulations on default[355], considers the following events of non-performing exposure: Distress, Past-due, Unlikely to pay (UTP).

In addition to the Basel definition, the occurrence of a default event during the performance period also considers negative public information due to insolvency proceedings, protests, and other negative reports.

4. Data quality checks and exclusions

The initial dataset consists of 32,855 companies established (registered office location) in the same provinces as those used in the creditworthiness analysis[356]: Italian provinces of Ravenna and Forlì-Cesena (Emilia-Romagna region) and Prato and Pistoia (Tuscany region) with financial statements available from the 2021 fiscal year to 2024 and credit risk

[355] The definition of default status follows Article 178 of Regulation (EU) No. 575/2013 (CRR), which sets out the conditions under which an obligor is considered to be in default. Operational application of the materiality threshold for past-due amounts is based on Commission Delegated Regulation (EU) 2018/171. Further interpretative guidance is provided in the EBA Guidelines on the application of the definition of default (EBA/GL/2016/07). See Regulation - 575/2013 - EN - Capital Requirements Regulation - EUR-Lex, Delegated regulation - 2018/171 - EN - EUR-Lex and Guidelines on the application of the definition of default | European Banking Authority.

[356] This approach ensuring methodological consistency between the two exercises: vulnerability indicator score development and credit risk profile (PD) adjustment.

profile from the 2022 year to 2025)[357]. The table below summarises the consistency and completeness of information by information/source area.

Table 34: Number of companies for information source

	Companies (n.)		
Year	Company Information	Financial Statement	Credit Risk Score
2021	32.849	29.064	
2022	32.850	29.195	26.836
2023	32.851	28.929	27.995
2024	32.855	26.444	28.893
2025			29.817

In line with market best practices, to ensure consistency, completeness, and reliability across database supporting the climate-related credit risk assessment a structured data cleaning activity was applied. The following exclusion criteria were implemented:

- missing registry or economic activity information: a total of 865 companies were excluded due to missing identifiers or economic activity codes (companies without information on their industry or that cannot be classified under any industry and associated to a physical risk localisation or to the climate vulnerability[358]),
- no sufficient information for multi-year analysis with complete risk assessment and financial information (almost financial statements from 2022 to 2024 and credit risk score from 2023 to 2025): for 11,456 companies, no credit risk assessment or financial statements were available, not assuring a consistent company profile,
- credit risk score classified as 'unrated'[359]: an additional 1,376 companies were excluded due to non-rated credit profiles.

[357] For details on the timing mismatch between financial statement information and credit score, see the paragraph dedicated to definition of the time horizon and performance (in bonis/default).

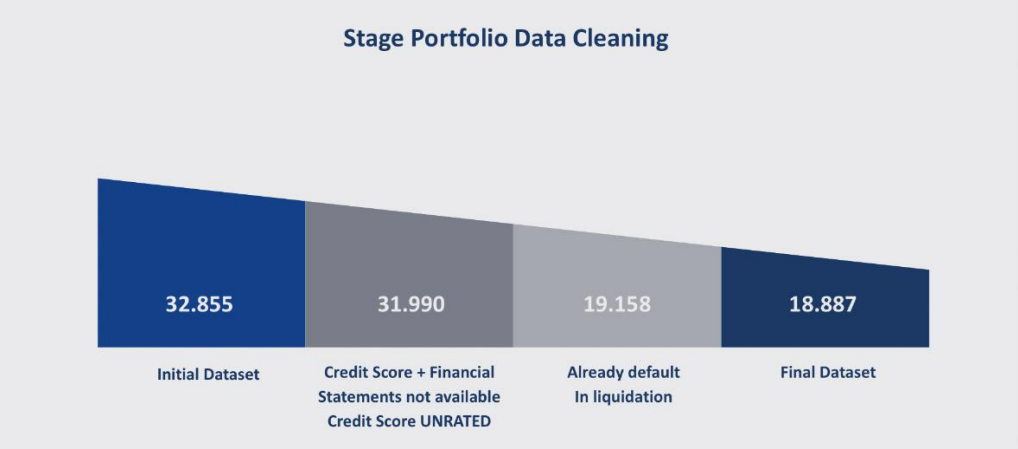
[358] Information regarding the economic activities carried out by companies has been reclassified according to the new NACE classification (NACE Rev. 2.1-Nomenclature des Activités économiques dans la Communauté Européenne), which is used to classify economic activities in Europe and took effect in 2025. Therefore, the information available for the companies — which refers to the previous 2022 classification—has been mapped to the new classification based on the correspondence tables between the ATECO 2025 and ATECO 2022 classifications (ATECO-Italian economic activities classification) provided by statistical agencies (specifically Eurostat and, for Italy, ISTAT). The changes introduced by the new classification have not altered the structure and levels of the previous classification; however, since the correspondences between the codes have been revised, it has not always been possible to maintain a one-to-one correspondence. For some codes. the economic activities associated with a 2022 code are distributed across multiple 2025 codes at the same hierarchical level, without it being possible to identify a clearly prevalent or representative code. In these cases, since it was not possible to identify a reference code for the economic activity carried out by the company, the company was excluded from the portfolio perimeter. For details, see ec.europa.eu/eurostat/web/products-manuals-and-guidelines/w/ks-gq-24-007 and www.istat.it/classificazione/ateco-2025/.

[359] A corporate score/rating is 'Unrated' when a credit rating cannot be assigned, typically due to missing or insufficient relevant information, or because the company is undergoing voluntary liquidation, which prevents a meaningful assessment of its future creditworthiness.

The resulting intermediate portfolio includes 19,158 companies, all of which with a consistent set of information. To properly observe the relationship between the climate event and the evolution of credit risk, all companies that were already defaulted in the observation period (credit risk score assign to 'Default' in the 2023) or in a status of liquidation were excluded from the portfolio: 233 defaulted companies, of which 38 also involved in a liquidation procedure. These entities were experiencing preexisting financial distress, making it impossible to attribute any subsequent credit risk changes to the climate shock itself. This ensures that any subsequent change in credit profile can be attributed to the impact of the climate shock rather than to pre‑existing distress.

The resulting final portfolio includes 18,887 companies, all of which with a consistent data for subsequent modelling and portfolio-risk assessments. Below is the impact on the portfolio of the cleaning activities carried out.

Figure 11: Stage portfolio data cleaning



A coverage assessment was carried out to evaluate the representativeness of the selected portfolio. The analysis is based on a comparative approach between the portfolio size and the total number of active corporations (and equivalent legal forms) in the selected provinces using the Chamber of Commerce data on active corporate by province and sector activity (2-digit Nace code)[360]. At the national level, Italy counts approximately 1,550,900 active companies. Within the selected provinces, the number of active corporations amounts to about 32,900[361], corresponding to roughly, 2.1% of the national stock. The selected portfolio (consisting of 18,887 corporates) covers a substantial share of the territorial corporate population. The share (approximately 57%) between the portfolio and the total number of active corporations in the selected areas indicates a good level of coverage, ensuring that the portfolio is sufficiently large to support sector-

[360] The relevance assessment was carried out using the Italian Business Registry statistics on the number of companies by geographic location of the registered office, sector of activity, legal type, and company status (registered, active.). See https://infocamere.it/movimprese/.

[361] The Italian Business Registry figure refers exclusively to active entities in 2024. The initial portfolio is larger as it also comprises companies being wound up, inactive companies, and other non-operational units. Considering the total number of registered enterprises in the selected territories, the Business Registry would account for nearly 39,100 firms.

level inference. Coverage is not the same as representativeness: because the exclusion rules are not random with respect to financial condition, high coverage does not by itself guarantee an unbiased sample. In addition to numerical representativeness, a sectoral significance check was performed. The sectoral distribution of the portfolio was compared with the sectoral composition of the active corporations in the selected provinces. The alignment observed across major economic sectors indicates that the portfolio is broadly representative from a sectoral point of view [362], thereby supporting the validity of sector-specific analyses and conclusions, except for a few sectors that are thinly represented, or absent also in the universe (for details, see the table 35):

- 07-Mining of metal ores,
- 08-Other mining and quarrying,
- 09-Mining support service activities,
- 19-Manufacture of coke and refined petroleum products,
- 21-Manufacture of basic pharmaceutical products and pharmaceutical preparations,
- 36-Water collection, treatment and supply,
- 39-Remediation activities and other waste management service activities,
- 50-Water transport,
- 51-Air transport,
- 53-Postal and courier activities,
- 75-Veterinary activities,
- 78-Employment activities,
- 84-Public administration and defence; compulsory social security).

Since the credit-risk score is specific for the assessment of non-financial firms and is therefore not applicable to entities in the financial or insurance sectors, the selected portfolio is focused on non-financial corporations and does not include entities operating in the financial or insurance sectors (sectors 64-Financial service activities and 65-Insurance, reinsurance and pension funding).

[362] The significance assessment was carried out considering different approaches: the coverage of the universe, the statistical error of the selected sample implicit in a very limited size. For coverage assessment, the following thresholds were defined: high when coverage is over 50%, medium when it is between 25% and 50%, and low when it is below 25%. For robustness, instead, a minimum threshold of 10 companies per sectoral group was set, with the following thresholds: high when the sector has more than 50 companies, medium when it is between 10 and 50, and low when the number is below 10. Since the portfolio coverage is numerically very high compared to the universe, it was not considered necessary to proceed with other approaches for assessing significance (e.g., the Cochran formula). It should also be noted that the data on the activities carried out, available for the universe from the Chambers of Commerce, show the classification of the economic activity carried out in the previous version (2022 instead of 2025). Comparing this with data from sectors that were most affected by the shifts could be influenced by the change in classification. For example, sector 45. Division 45 'Wholesale and retail trade and repair of motor vehicles and motorcycles' has been eliminated to achieve a consistent application of classification rules within section G. This means that the wholesale activities of motor vehicles and motorcycles have been moved to division 46 'Wholesale trade', the activities of retail trade of motor vehicles and motorcycles to division 47 'Retail trade' and the activities of maintenance and repair of motor vehicles and motorcycles to division 95 'Repair and maintenance of computers, personal and household goods, and motor vehicles and motorcycles' in section T. Since it's an aggregated figure by sector and province, it wasn't possible to align the data with the new classification.

Table 35: Selected portfolio by sector activity

NACE CODE 2-digit	NACE Description	PORTFOLIO		UNIVERSE		PORFTOLIO COVERAGE	
		N	%	N. Corporates	%	% Coverage	Robustness
01	Crop and animal production, hunting and related service activities	398	2,11	603	1,83	66,00	
02	Forestry and logging	26	0,14	43	0,13	60,47	
03	Fishing and aquaculture	16	0,08	21	0,06	76,19	
07	Mining of metal ores	0	0,00	0	0,00	0,00	na
08	Other mining and quarrying	7	0,04	8	0,02	87,50	
09	Mining support service activities	2	0,01	4	0,01	50,00	
10	Manufacture of food products	213	1,13	318	0,97	66,98	
11	Manufacture of beverages	14	0,07	23	0,07	60,87	
13	Manufacture of textiles	736	3,90	967	2,94	76,11	
14	Manufacture of wearing apparel	476	2,52	897	2,73	53,07	
15	Manufacture of leather and related products of other materials	118	0,62	205	0,62	57,56	
16	Manufacture of wood and of products of wood and cork, except furniture	78	0,41	112	0,34	69,64	
17	Manufacture of paper and paper products	64	0,34	89	0,27	71,91	
18	Printing and reproduction of recorded media	83	0,44	112	0,34	74,11	
19	Manufacture of coke and refined petroleum products	3	0,02	4	0,01	75,00	
20	Manufacture of chemicals and chemical products	107	0,57	132	0,40	81,06	
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	5	0,03	6	0,02	83,33	
22	Manufacture of rubber and plastic products	133	0,70	173	0,53	76,88	
23	Manufacture of other non-metallic mineral products	74	0,39	98	0,30	75,51	
24	Manufacture of basic metals	33	0,17	40	0,12	82,50	
25	Manufacture of fabricated metal products, except machinery and equipment	565	2,99	809	2,46	69,84	
26	Manufacture of computer, electronic and optical products	72	0,38	89	0,27	80,90	
27	Manufacture of electrical equipment	86	0,46	111	0,34	77,48	
28	Manufacture of machinery and equipment n.e.c.	344	1,82	425	1,29	80,94	
29	Manufacture of motor vehicles, trailers and semi-trailers	35	0,19	46	0,14	76,09	
30	Manufacture of other transport equipment	37	0,20	62	0,19	59,68	
31	Manufacture of furniture	175	0,93	280	0,85	62,50	
32	Other manufacturing	80	0,42	145	0,44	55,17	
33	Repair, maintenance and installation of machinery and equipment	202	1,07	310	0,94	65,16	
35	Electricity, gas, steam and air conditioning supply	158	0,84	271	0,82	58,30	
36	Water collection, treatment and supply	8	0,04	19	0,06	42,11	
37	Sewerage	23	0,12	27	0,08	85,19	
38	Waste collection, recovery and disposal activities	67	0,35	94	0,29	71,28	
39	Remediation activities and other waste management service activities	9	0,05	16	0,05	56,25	
41	Construction of residential and non-residential buildings	1.082	5,73	2164	6,58	50,00	
42	Civil engineering	66	0,35	102	0,31	64,71	
43	Specialised construction activities	985	5,22	2116	6,43	46,55	
45	*Wholesale and retail trade and repair of motor vehicles and motorcycles (eliminated)*	0	0,00	841	2,56	0,00	na
46	Wholesale trade	1.838	9,73	3047	9,26	60,32	
47	Retail trade	921	4,88	1782	5,42	51,68	
49	Land transport and transport via pipelines	258	1,37	452	1,37	57,08	
50	Water transport	8	0,04	11	0,03	72,73	
51	Air transport	0	0,00	4	0,01	0,00	
52	Warehousing, storage and support activities for transportation	256	1,36	407	1,24	62,90	
53	Postal and courier activities	7	0,04	15	0,05	46,67	
55	Accommodation	345	1,83	635	1,93	54,33	
56	Food and beverage service activities	668	3,54	1689	5,13	39,55	
58	Publishing activities	42	0,22	95	0,29	44,21	
59	Motion picture, video and television programme production, sound recording and music publishing activities	43	0,23	100	0,30	43,00	
60	Programming, broadcasting, news agency and other content distribution activities	11	0,06	17	0,05	64,71	
61	Telecommunication	30	0,16	47	0,14	63,83	
62	Computer programming, consultancy and related activities	318	1,68	517	1,57	61,51	
63	Computing infrastructure, data processing, hosting and other information service activities	309	1,64	488	1,48	63,32	
64	Financial service activities, except insurance and pension funding	0	0,00	430	1,31	0,00	
65	Insurance, reinsurance and pension funding, except compulsory social security	0	0,00	1	0,00	0,00	
66	Activities auxiliary to financial services and insurance activities	103	0,55	188	0,57	54,79	
68	Real estate activities	3.427	18,14	5012	15,23	68,38	
69	Legal and accounting activities	158	0,84	202	0,61	78,22	
70	Activities of head offices and management consultancy	428	2,27	954	2,90	44,86	
71	Architectural and engineering activities; technical testing and analysis	218	1,15	314	0,95	69,43	
72	Scientific research and development	66	0,35	109	0,33	60,55	
73	Activities of advertising, market research and public relations	94	0,50	240	0,73	39,17	
74	Other professional, scientific and technical activities	293	1,55	513	1,56	57,12	
75	Veterinary activities	8	0,04	13	0,04	61,54	ns
77	Rental and leasing activities	130	0,69	264	0,80	49,24	
78	Employment activities	5	0,03	10	0,03	50,00	
79	Travel agency, tour operator and other reservation service and related activities	77	0,41	133	0,40	57,89	
80	Investigation and security activities	20	0,11	28	0,09	71,43	
81	Services to buildings and landscape activities	162	0,86	275	0,84	58,91	
82	Office administrative, office support and other business support activities	342	1,81	605	1,84	56,53	
84	Public administration and defence; compulsory social security	0	0,00	3	0,01	0,00	
85	Education	151	0,80	319	0,97	47,34	
86	Human health activities	217	1,15	323	0,98	67,18	
87	Residential care activities	77	0,41	124	0,38	62,10	
88	Social work activities without accommodation	91	0,48	130	0,40	70,00	
90	Arts creation and performing arts activities	76	0,40	175	0,53	43,43	
91	Libraries, archives, museums and other cultural activities	12	0,06	26	0,08	46,15	
92	Gambling and betting activities	28	0,15	59	0,18	47,46	
93	Sports activities and amusement and recreation activities	392	2,08	911	2,77	43,03	
94	Activities of membership organisations	14	0,07	44	0,13	31,82	
95	Repair and maintenance of computers, personal and household goods, and motor vehicles and motorcycles	518	2,74	62	0,19	835,48	ns
96	Personal service activities	146	0,77	344	1,05	42,44	
Total		**18.887**	**100**	**32.899**	**100**	**57,41**	

The same analysis was performed for evaluating the geographical coverage of the selected portfolio (see table below).

Table 36: Selected portfolio by geographical zone

PROVINCE	PORTFOLIO		UNIVERSE		PORFTOLIO COVERAGE	
	N	%	N. Corporates	%	% Coverage	Robustness
FORLI' - CESENA	5.098	26,99	8.741	26,57	58,32	
PISTOIA	3.908	20,69	7.071	21,49	55,27	
PRATO	5.247	27,78	9.193	27,94	57,08	
RAVENNA	4.634	24,54	7.894	23,99	58,70	na
Total	**18.887**	**100,00**	**32.899**	**100,00**	**57,41**	

5. Analysis of the relationship and identification of the impact on solvency

To explore how credit risk behaves in relation to climate related events, a series of analytical steps were carried out to better understand the condition of the portfolio and the dynamics that emerge over time. The first part of the work focused on identifying situations of severe financial distress. A specific flag was created to capture all companies that entered default after the flooding events happened (in the performance period), allowing the analysis to quantify how many companies experienced a deterioration in their credit standing after climate events.

Moreover, to analyse the relationship between economic-financial impacts and physical climate events, cases of voluntary liquidation that do not result in formal insolvency proceedings have also been taking into consideration. Their inclusion strengthens the robustness of the analysis by expanding the set of companies affected not only by a negative legal but also by voluntary event and reflects a more realistic scenario in which the firm has suffered damage so severe that it either chooses—or is forced—to wind down its business rather than take on new debt to restart operations. In such circumstances, access to credit or additional borrowing may be constrained by a weakened credit profile, insufficient collateral, the firm's size, the nature of its business, or other limiting factors, involving the voluntary closure of the business.

The relationship between physical climate risk events and their impacts on a company's solvency is constrained by the lack of specific information on the underlying reasons that triggered the default. Identifying whether a default was caused by a physical climate event is rarely possible, as such information is generally unavailable even within the internal datasets of Financial Institutions. Moreover, even if these details existed, access to company specific information would not be permitted for regulatory provisions[363]. Just as

[363] Access to granular banking data—including information on the specific reasons behind a default event and the severity of credit exposures—is restricted by several regulatory frameworks. The General Data Protection Regulation (Regulation (EU) 2016/679 - GDPR (Regulation - 2016/679 - EN - gdpr - EUR-Lex) imposes strict requirements on the protection of personal and credit-related data, prohibiting disclosure to unauthorised parties. Similarly, Regulation (EU) 2018/1725 (Regulation - EU - 2018/1725 - EN - EUDPR - EUR-Lex) governs the processing of personal data by the ECB and supervisory authorities, limiting the use of such information

non-financial entities cannot access credit-behaviour data or obtain information on the underlying reason for a default event, nor on the severity of the default or its specific regulatory status, access to such granular credit-risk information remains strictly restricted to Regulators and FIEs. Since there is neither specific information for individual companies nor detailed information, defaults directly attributable to climate-related physical impacts cannot be precisely isolated. As a result, the set of detected default events could also include situations caused by other non-climate related factors, such as the non-performing status may be related to the impact of a climate shock that did not directly affect the company itself, but that propagated indirectly through strategic suppliers or key customers.

The default status available on the portfolio are relative to public defaults only (unlikely to pay and past due are not included in the sample of defaults).[364] The data revealed a distress situation (default status) for 25 companies defaulted in 2024, followed by 49 in 2025 and liquidation procedures underway for 324 companies. These negative events were also combined into a single annual status that reflected whether each company was either in default or in liquidation. This consolidated measure provided a clearer view of the portfolio's overall health and made it possible to trace how distress evolved year by year, especially in the period surrounding the climate shock. The following tables present the results in term of default status and liquidation procedures and geographical location of the companies.

Table 37: Company distribution by status and province

status	Freq.	Percent	Cum.
DEF24	25	0.13	0.13
DEF25	49	0.26	0.39
IN LIQUIDATION	324	1.72	2.11
INBONIS	18,489	97.89	100.00
Total	18,887	100.00	

	stato				
Province	DEF24	DEF25	IN LIQU..	INBONIS	Total
Forlì-Cesena	6	8	85	4,999	5,098
	0.12	0.16	1.67	98.06	100.00
Pistoia	9	12	86	3,801	3,908
	0.23	0.31	2.20	97.26	100.00
Prato	3	19	89	5,136	5,247
	0.06	0.36	1.70	97.88	100.00
Ravenna	7	10	64	4,553	4,634
	0.15	0.22	1.38	98.25	100.00
Total	25	49	324	18,489	18,887
	0.13	0.26	1.72	97.89	100.00

The annual default rate amounted to 0,13% in 2024 and 0,26% in 2025, i.e. twice the previous year's level. Overall, cumulative defaults over the two-year period reached 0,4%, while

exclusively to institutional purposes. The European prudential framework, defined by the Capital Requirements Regulation (Regulation (EU) No 575/2013 - CRR (Regulation - 575/2013 - EN - Capital Requirements Regulation - EUR-Lex) and the Capital Requirements Directive (Directive 2013/36/EU - CRD IV (Directive - 2013/36 - EN - Capital Requirements Directive - EUR-Lex), establishes that supervisory reporting and default-related information are confidential and accessible only to competent authorities, reinforcing restrictions on the dissemination of credit risk information. Furthermore, the Single Supervisory Mechanism Regulation (Regulation (EU) No 1024/2013 (Regulation - 1024/2013 - EN - ssm regulation - EUR-Lex) confirms that data collected for prudential supervision cannot be disclosed to non-supervised entities. At the national level, banking secrecy provisions and guidance from national data protection authorities reinforce the prohibition on granting third-party access to credit information (e.g., Italy's Garante Privacy Home - Garante Privacy) further restrict access to credit information and prohibit third party access to granular banking data.

[364] Public defaults are bankruptcy, insolvency procedures, compulsory liquidations.

liquidations had a significantly larger impact, accounting for 1,7%. Within the observed portfolio, liquidation procedures contribute more markedly to firm attrition than credit-related defaults.

The four provinces show heterogeneous patterns in default and liquidation rates, and these differences align with the timing and severity of the flood events that affected the territories in 2023. These values suggest that the May 2023 flood did not translate into an immediate spike in credit defaults, possibly due to mitigation measures, temporary support schemes, or delayed transmission of financial stress. Prato and Pistoia show higher and more volatile default rates, especially in 2025. The sharper rise in 2025 is consistent with the later timing of the November 2023 flood, which may have produced lagged financial effects, particularly through supply chain disruptions or prolonged recovery periods. Liquidation rates are also higher (2,20% in Pistoia and 1,70% in Prato), suggesting that firm attrition was more pronounced in these territories.

The trend in default rates, and more generally the impact of the climate event on the economic and financial profile, must be read considering the distorting effect of the support measures introduced in emergency situations such as floods. Flood related banking moratoria allow borrowers to defer instalments[365] — on principal, interest or both — without triggering a deterioration in credit quality or a regulatory default, provided that the underlying financial position remains sound. By stabilising short-term liquidity and preventing technical arrears caused by the disruption of business operations, they delay the materialisation of financial distress and contain the number of defaults recorded in the territories hit by the floods.

Moreover, for a more detailed view of the credit profile evolution, the mean probabilities of default (PDs) for each score class in the period 2022-2025 was analysed and transition matrices (one-year, two years and three years) are constructed. The results seem to confirm that the negative impacts of climate events on company credit profiles have been mitigated by the extraordinary measures put in place, even by FIEs, delaying the onset of default/insolvency or even preventing it.[366]

The analysis of score distributions and mean PD values indicate that the portfolio shows a progressive decline in the upper classes (except for class 1) and an expanding share of the higher risk score classes (6–8) that exhibit a gradual rise, contributing to a higher overall portfolio PD. This trend even is more clearly comparing the 2025 distribution with 2022's.

[365] Ocdpc n. 992 dell'8 maggio 2023 | Dipartimento della Protezione Civile

[366] We analysed the financial statements (full years 2023-2025) of a small local bank operating in the provinces affected by the 2023 floods in Emilia Romagna. The flood affected 60 out of the 63 municipalities where the bank operates, impacting almost the entire area served by the bank. The 2023 floods had a significant impact on bank's credit risk, with increased provisions and temporary pressure on insolvencies, but bank implemented extraordinary measures to support affected families, businesses, and members, such as suspension of mortgages (principal and interest), disbursement of new loans for flood emergencies, participation in social and productive microcredit agreements, and charity initiatives. Despite the severity of the event, the quality of the loan portfolio remained solid, even in improvement. The bank expected a possible rise in bad loans in 2024, since the 2023 flood was an extraordinary event that severely tested the local economic fabric and the bank's customers, but the floods led to a temporary increase in requests for renegotiation and moratoria but did not cause a structural rise in defaults The first signs of potential deterioration in credit quality only appear in 2025, with overdue installments increasing by 3%. The agricultural sector and small businesses were among the hardest hit by the floods, with a rise in requests for debt restructuring and access to subsidised loans. See Bilanci — BCC ravennate forlivese e imolese.

The portfolio-level probability of default (PD) shows a progressive increase over the period 2022–2025, rising from 3,66% in 2022 to 4,26% in 2025. The year-on-year evolution is broadly monotonic, but the 2024 value (4,03%) indicates a temporary attenuation of the upward trend, consistent with the presence of extraordinary support measures implemented during 2024, which contributed to stabilising credit conditions and mitigating the deterioration that would otherwise have emerged more sharply.

The analysis of the transition matrices across successive scoring years shows results consistent with typical rating migration dynamics, with persistence that weakens as the time horizon lengthens (the scores mobility increases when the observation window is extended) and a strong polarisation: extreme classes exhibit substantial persistence, while intermediate classes show significant bidirectional mobility:

- annual stable rates remain close to 46% in the transitions 2023 vs 2024 and 2024 vs 2025, while they decrease to 36–40% in the multi-year matrices (2023 vs 2025 and 2022 vs 2025),
- the upgrade component is moderate and predominantly concentrated in the upper score classes (1–3), with an overall improvement in these classes over the medium term, despite short-term fluctuations,
- conversely, downgrade rates show a gradual increase, with a deterioration particularly concentrated in the mid-high score classes (6–7), which display the highest probabilities of migrating to worse categories.

The credit risk profile shows more weakness in the mid-score classes. This segment is the most sensitive part of the portfolio and the one most affected by climate events.

Table 38: Company distribution by score/rating class, PD mean and transition matrix 2022-2025

	COMPANY (n.)				COMPANY (%)			
	2022	2023	2024	2025	2022	2023	2024	2025
1	3.658	3.847	3.919	4.231	19,4	20,4	20,7	22,4
2	5.333	5.207	5.076	4.990	28,2	27,6	26,9	26,4
3	2.709	2.560	2.476	2.309	14,3	13,6	13,1	12,2
4	2.079	1.975	1.854	1.684	11,0	10,5	9,8	8,9
5	1.676	1.714	1.721	1.621	8,9	9,1	9,1	8,6
6	1.394	1.448	1.546	1.528	7,4	7,7	8,2	8,1
7	1.016	1.097	1.100	1.098	5,4	5,8	5,8	5,8
8	925	1.039	1.041	1.028	4,9	5,5	5,5	5,4
DF			25	74	0,0	0,0	0,1	0,4
UN	97		129	324	0,5	0,0	0,7	1,7
Total	18.887	18.887	18.887	18.887	100,0	100,0	100,0	100,0

PD mean (portfolio %)			
2022	2023	2024	2025
3,66	3,87	4,03	4,26

SCORE 2022	SCORE 2023										
	1	2	3	4	5	6	7	8	DF	UN	Total
1	75,8	19,0	2,6	1,4	0,8	0,3	0,1	0,1			100,0
2	16,6	57,2	14,4	5,7	2,9	1,9	1,0	0,4			100,0
3	4,2	32,1	29,2	15,9	9,9	5,4	2,3	1,2			100,0
4	2,1	17,2	22,3	25,0	16,3	9,3	5,3	2,6			100,0
5	0,8	7,6	14,1	22,0	24,8	15,5	9,8	5,4			100,0
6	0,4	3,6	8,5	14,1	21,6	27,1	15,2	9,5			100,0
7	0,4	2,3	4,6	6,4	15,1	22,6	28,8	19,8			100,0
8	0,1	0,9	2,3	3,6	5,0	13,8	20,6	53,7			100,0
DF											
UN	10,3	27,8	23,7	8,2	8,2	6,2	10,3	5,2			100,0
Total	20,4	27,6	13,6	10,5	9,1	7,7	5,8	5,5			100,0

	%
UPGRADE	26,4
STABLE	46,1
DOWNGRADE	27,0

SCORE 2023	SCORE 2024										
	1	2	3	4	5	6	7	8	DF	UN	Total
1	76,0	18,8	2,7	1,0	0,6	0,4	0,2	0,1	0,0	0,3	100,0
2	16,1	58,0	14,1	5,3	3,0	2,0	0,6	0,4	0,0	0,6	100,0
3	3,6	31,0	30,4	16,7	9,7	4,7	2,3	1,1	0,1	0,4	100,0
4	2,2	14,8	22,8	23,6	17,1	11,6	4,8	2,4	0,0	0,6	100,0
5	0,9	8,1	14,1	19,9	25,0	18,4	8,5	4,0	0,4	0,6	100,0
6	0,4	4,7	7,6	13,3	22,4	26,2	15,3	8,7	0,1	1,3	100,0
7	0,0	2,5	3,4	6,7	12,5	23,8	28,7	20,4	0,3	1,8	100,0
8	0,3	1,3	2,1	3,8	6,4	11,8	21,5	50,4	0,8	1,6	100,0
DF											
UN											
Total	20,7	26,9	13,1	9,8	9,1	8,2	5,8	5,5	0,1	0,7	100,0

	%
UPGRADE	26,1
STABLE	46,8
DOWNGRADE	26,3

SCORE 2024	SCORE 2025										
	1	2	3	4	5	6	7	8	DF	UN	Total
1	77,0	18,3	2,1	0,9	0,6	0,5	0,2	0,1	0,1	0,3	100,0
2	20,3	56,8	12,1	4,6	2,7	1,6	0,6	0,4	0,0	0,9	100,0
3	4,4	32,1	31,2	14,2	9,0	4,2	2,3	1,1	0,2	1,3	100,0
4	2,5	16,9	24,1	23,4	15,2	9,7	4,0	2,5	0,2	1,5	100,0
5	0,8	9,6	12,4	19,6	25,0	17,7	9,2	4,5	0,2	1,1	100,0
6	0,6	4,6	7,4	11,6	19,2	30,0	15,5	8,9	0,6	1,6	100,0
7	0,2	2,1	3,7	6,4	14,1	21,0	28,4	21,3	0,8	2,1	100,0
8	0,1	1,4	1,9	3,6	7,0	13,4	21,0	46,5	1,2	3,9	100,0
DF	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	100,0	0,0	100,0
UN	1,6	5,4	3,1	3,1	1,6	2,3	0,8	0,8	3,1	78,3	100,0
Total	22,4	26,4	12,2	8,9	8,6	8,1	5,8	5,4	0,4	1,7	100,0

	%
UPGRADE	23,8
STABLE	46,6
DOWNGRADE	27,4

SCORE 2023	SCORE 2025										
	1	2	3	4	5	6	7	8	DF	UN	Total
1	71,8	19,9	3,5	1,7	1,1	0,8	0,3	0,1	0,1	0,6	100,0
2	21,8	50,2	12,3	6,1	3,8	2,5	1,3	0,6	0,2	1,2	100,0
3	6,6	34,0	23,9	12,9	9,8	6,4	2,7	1,7	0,2	1,8	100,0
4	4,6	17,8	22,5	17,4	14,7	11,3	5,7	4,3	0,3	1,6	100,0
5	2,3	11,1	14,4	18,1	19,3	17,4	9,0	6,0	0,9	1,7	100,0
6	1,3	8,4	9,7	13,1	18,0	22,2	13,4	10,8	0,6	2,6	100,0
7	0,6	4,7	5,1	7,5	13,5	20,1	25,6	18,1	1,0	3,7	100,0
8	0,7	2,2	3,2	4,8	9,6	13,6	20,0	39,0	1,6	5,3	100,0
DF											
UN											
Total	22,4	26,4	12,2	8,9	8,6	8,1	5,8	5,4	0,4	1,7	100,0

	%
UPGRADE	27,1
STABLE	40,6
DOWNGRADE	30,2

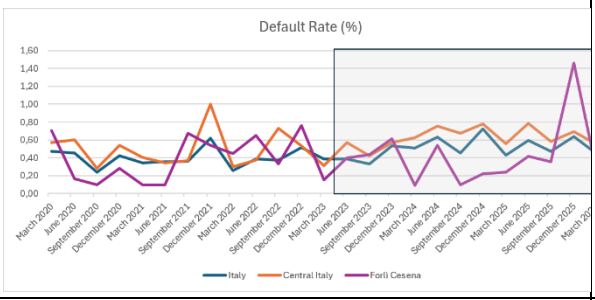
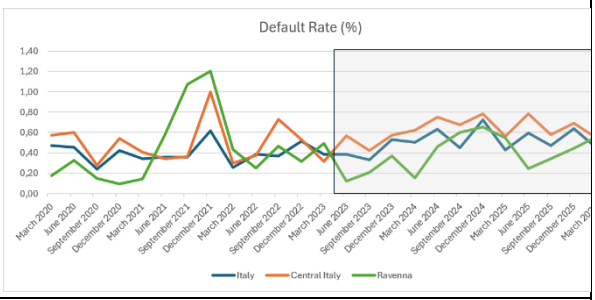
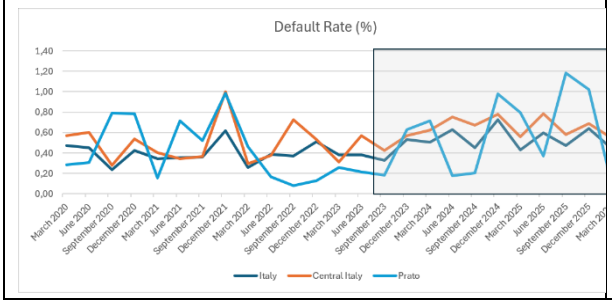
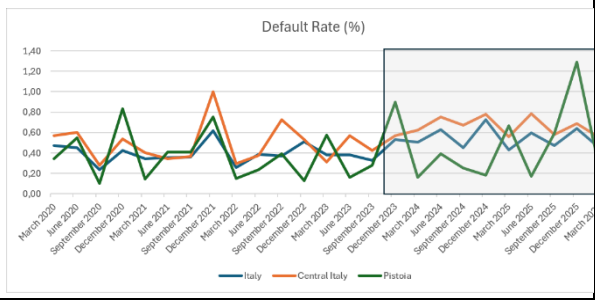
SCORE 2022	SCORE 2025										
	1	2	3	4	5	6	7	8	DF	UN	Total
1	68,6	21,7	3,9	1,9	1,2	0,9	0,6	0,3	0,1	0,7	100,0
2	23,4	45,2	13,0	6,6	4,5	3,2	1,5	1,2	0,2	1,4	100,0
3	9,0	32,0	21,9	12,6	9,2	7,8	3,6	2,4	0,2	1,4	100,0
4	5,4	20,8	17,2	16,5	14,2	11,4	7,1	4,7	0,5	2,1	100,0
5	2,9	12,6	14,4	15,6	18,1	15,9	9,7	8,1	0,4	2,1	100,0
6	2,4	10,0	10,1	11,0	17,1	20,7	14,8	10,6	0,9	2,2	100,0
7	1,3	6,6	8,1	9,8	14,7	18,6	18,4	18,6	1,2	2,8	100,0
8	0,6	5,2	5,0	5,5	10,2	12,9	20,6	33,9	1,4	4,6	100,0
DF											
UN											
Total	22,4	26,4	12,2	8,9	8,6	8,1	5,8	5,4	0,4	1,7	100,0

	%
UPGRADE	29,4
STABLE	36,8
DOWNGRADE	31,2

The PD deterioration trend is consistent with the data on quarterly default rates from the Bank of Italy by province[367].

[367] Source: Bank of Italy, TRI30633 - Quarterly loan deterioration rate (adjusted default – utilised) for the non-financial corporate sector.

Table 39: Quarterly default rates by province (Bank of Italy)

FORLI' - CESENA	RAVENNA
	
PRATO	**PISTOIA**
	

The improvement observed in 2023 credit scores should be interpreted with caution, as it may partly reflect the post pandemic recovery rather than a structural change in firms' underlying risk profiles: following the Covid 19 shock many companies progressively emerged from the distress experienced in 2020–2021, with a gradual normalisation of liquidity positions, profitability levels and capital structures. The same caveat applies to the transition matrices, whose migration patterns in the years immediately following the pandemic may incorporate a rebound effect linked to the removal of Covid related pressures. It applies equally to the estimated relationship between credit risk and climate events: in the recovery phase the improvement in credit conditions may reduce the apparent sensitivity of credit risk to climate shocks, not because climate-related exposures have diminished, but because the dominant source of stress has shifted from pandemic-related factors to more typical business cycle dynamics. The 2023 results, both in terms of score evolution and of credit risk transitions, must therefore be contextualised within this exceptional period, to avoid attributing to climate risk mechanisms what may instead be the residual effect of a macroeconomic shock and its subsequent normalisation.

To enhance the understanding of credit-risk dynamics and to provide a clearer, more intuitive view of how exposures shift across risk categories, several aggregations are introduced:

- the original credit score classes were reorganized into a simplified risk scale, grouping score classes 1 to 3 into "very low risk," classes 4 and 5 into "low risk," class 6 into "medium risk," class 7 into "high risk," and class 8 into "very high risk",
- in line with the observation and performance period, the temporal window of credit risk evolution was separated into two distinct periods: the first period covers the years

up to 2023, drawing on credit score data from 2022 and 2023 and financial statements from 2021 and 2022; the second period focuses on the years after 2023, using credit score data from 2024 and 2025 together with financial statements from 2023 and 2024.

This re-aggregation allows to observe how credit profiles shifted before and after the climate event, highlighting potential changes linked to the shock and offering a clearer understanding of the relationship between climate impacts and credit risk trajectories.

Table 40: Transition matrix - Observation vs performance period

	PERFORMANCE PERIOD (2024-2025)					
OBSERVATION PERIOD (2022-2023)	**0**	**1**	**2**	**3 def**	**3 liq**	**Total**
0	13.548	845	682	37	191	**15.303**
	88,53	5,52	4,46	0,24	1,25	**100**
1	729	322	351	9	37	**1.448**
	50,35	22,24	24,24	0,62	2,56	**100**
2	558	361	1.093	28	96	**2.136**
	26,12	16,9	51,17	1,31	4,49	**100**
Total	**14.835**	**1.528**	**2.126**	**74**	**324**	**18.887**
	78,55	8,09	11,26	0,39	1,72	**100**

5.1 Relation to economic vulnerability

Because the primary objective of the risk assessment is to verify any impact arising from climate events, the subsequent phase of the analysis investigates whether and how the firm's risk profile relates to the vulnerability of the economic sector in which it operates. The firm's risk profile was compared with the vulnerability profile of the company, using the overall vulnerability intensity sector score (overall VIS) and, given the nature of the event behind the portfolio selection, the specific assessment of water-related risks (water-related area VIS). To provide a clearer, more intuitive view of the relationship, also the original seven classes of the vulnerability intensity sector score were reorganized into a simplified 4-groups risk scale, grouping VIS score classes 1 and 2 into "Negligible/Very low Vulnerability" (group 0) classes 3 and 4 into "Moderate vulnerability" (group 1), classes 5 and 6 into "High Vulnerability" (group 2) and class 7 into "Very High Vulnerability" (group 3).

Below some statistics of the VIS applied to this portfolio, for both overall VIS and water-related area-VIS. The tables show a clear and consistent pattern across vulnerability classes and credit-risk profiles: although the portfolio maintains a very high share of in-bonis positions in all categories, the differences in exposure to climate-related risk — reflected in the default rates — indicate that entities operating in more exposed sectors experience higher credit deterioration. As vulnerability increases, the default rate rises accordingly, and the default rate observed in the high-vulnerability classes (group 2) is roughly twice that of the low-vulnerability class, highlighting positive relationship between vulnerability and credit deterioration and the stronger sensitivity of more exposed sectors to climate-related stress. By contrast, liquidation rates display a less linear relationship with vulnerability, with a comparatively higher incidence in the low-vulnerability class. This pattern may reflect

structural factors unrelated to climate-related exposure — such as sector specific business dynamics, preexisting operative or financial fragilities, or the presence of firms already undergoing orderly market exit — which can lead to higher liquidation rates even in sectors classified as less vulnerable to climate related risks.

Table 41: Credit score relation to economic vulnerability

OVERALL_VIS_class	Freq.	Percent	Cum.
1-Negligible	1.761	9,3	9,3
2-Very Low Intensity	1.687	8,9	18,3
3-Low Intensity	855	4,5	22,8
4-Medium Intensity	5.168	27,4	50,2
5-High Intensity	2.981	15,8	65,9
6-Very High Intensity	3.934	20,8	86,8
7-Extreme Intensity	2.501	13,2	100,0
Total	**18.887**	**100**	

OVERALL_VIS_group	Freq.	Percent	Cum.
0-Negligible or Very Low	3.448	18,3	27,6
1-Moderate	6.023	31,9	72,9
2- High	6.915	36,6	152,7
3-Strong	2.501	13,2	100,0
Total	**18.887**	**100**	

	CREDIT RISK PROFILE					
	IN BONIS	DEF24	DEF25	IN LIQUID	Total	DEF (tot)
OVERALL_VIS						
0	3.374	1	7	66	3.448	
Negligible or Very Low	**97,9**	**0,03**	**0,20**	**1,91**	**100,0**	**0,23**
1	5.909	7	13	94	6.023	
Moderate	**98,1**	**0,12**	**0,22**	**1,56**	**100**	**0,34**
2	6.757	14	21	123	6.915	
High	**97,7**	**0,20**	**0,30**	**1,78**	100,0	**0,50**
3	2.449	3	8	41	2.501	
Strong	**97,9**	**0,12**	**0,32**	**1,64**	100,0	**0,44**
Total	**18.489**	**25**	**49**	**324**	**18.887**	
	97,9	**0,13**	**0,26**	**1,72**	100,0	**0,39%**

WATER-RELATED_VIS_class	Freq.	Percent	Cum.
1-Negligible	1.945	10,3	10,3
2-Very Low Intensity	1.503	8,0	18,3
3-Low Intensity	5.649	29,9	48,2
4-Medium Intensity	619	3,3	51,4
5-High Intensity	85	0,5	51,9
6-Very High Intensity	6.585	34,9	86,8
7-Extreme Intensity	2.501	13,2	100,0
Total	**18.887**	**100**	

WATER-RELATED_VIS_group	Freq.	Percent	Cum.
0-Negligible or Very Low	3.448	18,3	28,6
1-Moderate	6.268	33,2	99,6
2- High	6.670	35,3	138,7
3-Strong	2.501	13,2	100,0
Total	**18.887**	**100**	

	CREDIT RISK PROFILE					
	IN BONIS	DEF24	DEF25	IN LIQUID	Total	DEF (tot)
WATER_VIS						
0	3.374	1	7	66	3.448	
Negligible or Very Low	**97,9**	**0,03**	**0,20**	**1,91**	**100,0**	**0,23**
1	6.145	7	13	103	6.268	
Moderate	**98,0**	**0,11**	**0,21**	**1,64**	**100**	**0,32**
2	6.521	14	21	114	6.670	
High	**97,8**	**0,21**	**0,31**	**1,71**	100,0	**0,52**
3	2.449	3	8	41	2.501	
Strong	**97,9**	**0,12**	**0,32**	**1,64**	100,0	**0,44**
Total	**18.489**	**25**	**49**	**324**	**18.887**	
	97,9	**0,13**	**0,26**	**1,72**	100,0	**0,39%**

5.2 Statistical evidence

Given the positive relationship between vulnerability and credit-risk outcomes observed in the previous results, further investigation have been carried out using logistic regression to assess whether and how the vulnerability score relates to the probability of default.

The logistic regressions have analysed this relation between the vulnerability intensity sector score in both versions -overall VIS and water-related area VIS- and the default status both in annual (in 2024 and 2025) and in 2-years period of performance.

Table 42: Logistic regression results

OVERALL VIS score and DEFAULT 2024

```
Iteration 0:  Log likelihood = -190.66728
Iteration 1:  Log likelihood = -188.39713
Iteration 2:  Log likelihood = -188.28212
Iteration 3:  Log likelihood = -188.28172
Iteration 4:  Log likelihood = -188.28172

Logistic regression                                     Number of obs = 18,887
                                                        LR chi2(1)    =   4.77
                                                        Prob > chi2   = 0.0289
Log likelihood = -188.28172                             Pseudo R2     = 0.0125
```

def24	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
OVERALL_score	.0174334	.0084586	2.06	0.039	.0008548	.034012
_cons	-7.584158	.5489273	-13.82	0.000	-8.660036	-6.50828

OVERALL VIS score and DEFAULT 2025

```
Iteration 0:  Log likelihood = -340.70242
Iteration 1:  Log likelihood = -340.03777
Iteration 2:  Log likelihood = -340.03295
Iteration 3:  Log likelihood = -340.03295

Logistic regression                                     Number of obs = 18,887
                                                        LR chi2(1)    =   1.34
                                                        Prob > chi2   = 0.2472
Log likelihood = -340.03295                             Pseudo R2     = 0.0020
```

def25	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
OVERALL_score	.0062225	.0054475	1.14	0.253	-.0044544	.0168993
_cons	-6.270443	.3241504	-19.34	0.000	-6.905766	-5.63512

OVERALL VIS score and DEFAULT 2024 and 2025

```
Iteration 0:  Log likelihood = -483.97498
Iteration 1:  Log likelihood = -481.59896
Iteration 2:  Log likelihood = -481.55808
Iteration 3:  Log likelihood = -481.55806

Logistic regression                                     Number of obs = 18,887
                                                        LR chi2(1)    =   4.83
                                                        Prob > chi2   = 0.0279
Log likelihood = -481.55806                             Pseudo R2     = 0.0050
```

def	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
OVERALL_score	.0097814	.0045585	2.15	0.032	.0008468	.018716
_cons	-6.051094	.2796047	-21.64	0.000	-6.599109	-5.503079

WATER-Related AREA VIS score and DEFAULT 2024

```
Iteration 0:  Log likelihood = -190.66728
Iteration 1:  Log likelihood = -188.59998
Iteration 2:  Log likelihood = -188.50612
Iteration 3:  Log likelihood = -188.50583
Iteration 4:  Log likelihood = -188.50583

Logistic regression                                     Number of obs = 18,887
                                                        LR chi2(1)    =   4.32
                                                        Prob > chi2   = 0.0376
Log likelihood = -188.50583                             Pseudo R2     = 0.0113
```

def24	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
WATER_score	.0165669	.0083993	1.97	0.049	.0001045	.0330293
_cons	-7.498354	.5256528	-14.26	0.000	-8.528615	-6.468094

WATER-Related AREA VIS score and DEFAULT 2025

```
Iteration 0:  Log likelihood = -340.70242
Iteration 1:  Log likelihood = -339.89533
Iteration 2:  Log likelihood = -339.88835
Iteration 3:  Log likelihood = -339.88835

Logistic regression                                     Number of obs = 18,887
                                                        LR chi2(1)    =   1.63
                                                        Prob > chi2   = 0.2020
Log likelihood = -339.88835                             Pseudo R2     = 0.0024
```

def25	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
WATER_score	.0069227	.0055004	1.26	0.208	-.0038579	.0177033
_cons	-6.294146	.319038	-19.73	0.000	-6.919449	-5.668843

WATER-Related AREA VIS score and DEFAULT 2024 and 2025

```
Iteration 0:  Log likelihood = -483.97498
Iteration 1:  Log likelihood = -481.51275
Iteration 2:  Log likelihood = -481.46953
Iteration 3:  Log likelihood = -481.46951

Logistic regression                                     Number of obs = 18,887
                                                        LR chi2(1)    =   5.01
                                                        Prob > chi2   = 0.0252
Log likelihood = -481.46951                             Pseudo R2     = 0.0052
```

def	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
WATER_score	.0100204	.0045842	2.19	0.029	.0010356	.0190053
_cons	-6.044271	.2730353	-22.14	0.000	-6.57941	-5.509131

The logistic regressions indicate that the Vulnerability Intensity Sector score have a statistically significant but modest effect on the probability of default. The coefficient is positive at the 5% level, meaning that higher vulnerability is associated with a higher likelihood of default. However, the magnitude of the effect is small, and the pseudo R^2 suggests that the VIS explains only a limited portion of the variation in default events. This is consistent with the idea that vulnerability contributes to credit deterioration, but default outcomes are driven by a broader set of financial and structural factors beyond the vulnerability score alone: the result confirms that climate vulnerability plays a role in credit-risk dynamics, but it is not the primary driver of default. Instead, it reflects an incremental impact, consistent with the nature of physical risk, which acts as a stress factor rather than a standalone cause. The statistical evidence of 2025 results could be explained by the effect of debt moratoria.

6. Integration of the impact into the credit risk measure

This section describes how the economic vulnerability and the hazard probability are combined and translated into an adjustment to the one-year probability of default (PD) estimated by the credit scoring model.

6.1 Rationale and design principles

In the design of the model three approaches were considered: a multiplicative adjustment, in which the credit PD is scaled up by a climate factor given by the product of vulnerability and hazard; a composite score, in which credit risk, vulnerability and hazard are combined through a weighted average and then mapped to a PD; and a calibrated model, which separates the overall intensity of the climate adjustment (α) from the parameter governing the interaction between vulnerability and hazard (β), while keeping the adjusted PD between 0 and 1.

The model chosen is the first, based on a multiplicative adjustment:

6.2 Climate adjustment approach

$$F_{climate} = 1 + \alpha \times Vulnerability \times Hazard\ Probability$$

And then:

$$PD_{adjusted} = PD_{credit} \times F_{climate}$$

Example with α = 5; vulnerability score = 86 (VIS Class 7); Hazard probability = high risk (probability 1.50%); PD rate = 2%

$$F_{climate} = 1 + 5 \times 0{,}86 \times 0{,}0150 = 1{,}065$$
$$PD_{adjusted} = 2\% \times 1{,}065 = 2{,}13\%$$

The adjustment is built around the following considerations:

- Risk as the product of hazard and vulnerability. Physical climate risk materialises only where an exposed asset is both located in a hazard prone area and operates in an economic activity sensitive to that hazard. The two components interact rather than add up: a firm in a highly vulnerable sector but in a low hazard municipality, and a firm in a high hazard municipality but in a resilient sector, both receive a limited uplift. This is coherent with the IPCC definition of physical risk[368].
- Incremental, not substitutive. The adjustment modifies an existing PD rather than replacing it. Creditworthiness remains driven by the financial, behavioural and public record information underlying the credit score, while the climate adjustment factor acts as a stress overlay, consistent with the empirical finding that vulnerability contributes to, but does not dominate, default outcomes.

[368] IPCC AR6 Risk Assessment | IPCC Data Distribution Centre

- Conservative adjustment. The factor is bounded below at 1, so the factor increases or maintains the PD (no downward impact). The absence of observed benefit from low vulnerability does not warrant a credit improvement, and a one-sided design avoids offsetting effects at portfolio level.
- Proportionality. The adjustment scales the existing PD rather than adding a fixed increment. This embeds the assumption that a climate shock amplifies preexisting financial fragility: the same shock produces a larger absolute deterioration for an already weak borrower than for a financially sound one.
- Transparency and reproducibility. The factor depends on two observable inputs and a single free parameter, with no estimated coefficients. Every step can be reconstructed from the municipality of the registered office, the NACE 2digit code and the published mapping hazard tables. It can also be improved with a 3 or 4 NACE digit and refined territorial geolocation definition (where assets have a different location from the firm's registered office). No financial variables are considered; therefore, the adjustment can be performed in absence of financial accounts information and can be applied also to the small business segment.
- Applicability across customer segments and lending products. The adjustment operates on the PD alone and uses no product specific parameter, no collateral information and no exposure measure. It therefore applies unchanged to every customer segment for which a sectoral vulnerability score can be assigned — corporates, SMEs, sole traders, public sector and non-profit entities — and to every lending product, from term loans and revolving facilities to trade finance and leasing. The consumer segment is out of scope, because the vulnerability score is defined on the economic activity of the borrower and private individuals have no NACE classification.

6.3 Climate Adjustment Methodology

The adjustment approach combines two components, each capturing a distinct dimension of risk. The hazard component measures how likely it is that a significant flood event will affect the municipality where the firm is located. The vulnerability component measures how sensitive the firm's sector is to physical climate events. The two components are combined into a climate adjustment factor that scales the credit PD upwards.

Because they are measured in different units, the hazard as an annual probability in percentage points and the vulnerability as a score from 0 to 100, both are first normalised to the unit interval so that they can be combined consistently. Probabilities of hazard are expressed in percentage points and normalised to the unit interval by division by 100, so that p lies between 0.0020 and 0.0500.

$$p(m) = P(m) \text{ in percentage points} / 100$$

Table 43: Normalised annual flood probability by AWARE risk class

AWARE flood risk class	Annual probability P	Implied return period	Normalised p
1 – Very low	0.20%	~500 years	0.0020
2 – Low	0.35%	~285 years	0.0035
3 – Medium	0.75%	~133 years	0.0075
4 – High	1.50%	~67 years	0.0150
5 – Very high	5.00%	~20 years	0.0500

The vulnerability component is the overall Vulnerability Intensity Score (overall VIS[369]) developed under the Sector Vulnerability Framework and assigned at NACE 2digit level. The score is expressed on a 0–100 scale and is normalised by division by 100, so that V lies between 0 and 1.

$$v(s) = VIS(s) / 100$$

Table 44: Normalised vulnerability by VIS class

VIS CLASS	SCORE min	SCORE max	Normalised v min	Normalised v max
1-Non intensive	1	9	0.01	0.09
2-Very Low Intensity	10	18	0.1	0.18
3-Low Intensity	19	34	0.19	0.34
4-Medium Intensity	35	51	0.35	0.51
5-High Intensity	52	67	0.52	0.67
6-Very High Intensity	68	84	0.68	0.84
7-Extreme Intensity	85	100	0.85	1.00

6.4 The climate adjustment factor (F_c)

For each company (i), operating in sector (s) and located in municipality (m), the climate adjustment factor and the adjusted probability of default are then defined as:

$$F_{climate} = 1 + \alpha \times v(s) \times p(m)$$

$$PD_{adjusted\ (i)} = PD_{(i)} \times F_{climate\,(i)}$$

α is the only free parameter of the model and define the ceiling of the adjustment, PD(i) is the one-year probability of default associated with the company's credit score in the reference year, v(s) is the normalised overall VIS of the company's sector and p(m) is the normalised annual flood probability of the company's location. Because the climate factor

[369] The overall VIS is used in preference to the water-related area VIS because the adjustment is intended to apply to physical climate risk. The water-related variant is retained as an alternative specification in the sensitivity analysis and is the more appropriate choice where the exercise is restricted to flood hazard alone.

is dimensionless, the adjustment can equivalently be applied to the PD expressed in percentage points: normalising the PD is not required for the computation. The adjusted PD is therefore returned on the same scale as the PD input.

6.5 Calibration of the scaling parameter

α was set using the difference in credit deterioration between more and less vulnerable sectors over the observation and performance periods (α = 5). With α = 5 the factor is bounded in the interval [1, 1.25]: since the maximum attainable factor equals 1 + 0.05α no position can have its PD increased by more than 25%, and the ceiling binds only for a company in the most vulnerable sector located in a class 5 of hazard.

$$Uplift\ (\%) = 100 \times (F_{climate} - 1) = \frac{v(s) \times p(m)}{\alpha}$$

The resulting value of the climate factor and the uplift over the full range of the two inputs is:

Table 45: Climate adjustment factor by VIS score and hazard class

F_C Value	Hazard class				
VIS (0–100)	1 -Very Low	2-Low	3-Medium	4-High	5-Very High
20	1,002	1,004	1,008	1,015	1,050
40	1,004	1,007	1,015	1,030	1,100
60	1,006	1,011	1,023	1,045	1,150
80	1,008	1,014	1,030	1,060	1,200
100	1,010	1,018	1,038	1,075	1,250

Table 46: PD uplift by VIS score and hazard class

Uplift	Hazard class				
VIS (0–100)	1 -Very Low	2-Low	3-Medium	4-High	5-Very High
20	+0.2%	+0.35%	+0.75%	+1.5%	+5.0%
40	+0.4%	+0.70%	+1.50%	+3.0%	+10.0%
60	+0.6%	+1.05%	+2.25%	+4.5%	+15.0%
80	+0.8%	+1.40%	+3.00%	+6.0%	+20.0%
100	+1.0%	+1.75%	+3.75%	+7.5%	+25.0%

For example, a firm with a PD of 2% in a sector with a VIS of 86, located in a high-hazard municipality (P = 1.50% Hazard Class 4 - High), has a factor of 1.0645 and an adjusted PD of 2.13% corresponding to a 6,5% uplift. The same firm located in a very-high-hazard municipality (P = 5.00% - Class 5 Very High) would have a factor of 1.215 and an adjusted PD of 2.43% (corresponding to an uplift of 21,5%).

6.6 Calibration Test

α is calibrated on the portfolio with a difference-in-differences approach. Firms in high and very high vulnerability sectors (VIS groups 2 and 3, 9,416 positions) form the treated pool, and firms in sectors with negligible, low or moderate vulnerability (groups 0 and 1, 9,471 positions) form the control pool. Because the adjustment is linear in α, equating the excess PD deterioration of the treated pool over the observation and performance periods to the difference in expected uplift between the two pools gives:

$$\alpha = DiD / (m_T - m_C)$$

where DiD is the difference-in-differences in average PD and mT and mC are the mean values of PD × v × p in the treated and control pools, equal to 0.0672 and 0.0185 respectively. The resulting value is $\alpha = 5$.

With $\alpha = 5$ the factor lies between 1 and 1.25, so no PD can increase by more than 25%, and this ceiling is reached only by a firm in a sector with a VIS of 100 located in a class 5 municipality. With the VIS on its 0–100 scale and the hazard probability P in percentage points, the uplift has a simple closed form:

$$\text{Uplift (\%)} = 100 \times (F_{climate} - 1) = VIS \times P / 20$$

6.7 Choice of the multiplicative specification: scope of application and advantages

The multiplicative specification set out above was selected in preference to additive alternatives, in which a climate increment is added to the PD independently of its level. Six features support the choice.

- Portfolio specific calibration. The specification has a single free parameter. Each intermediary can set α on its own portfolio composition, hazard mix and risk appetite without estimating the model or rederiving the vulnerability scores, and can document the choice as a discrete, auditable calibration decision that is straightforward to revise as evidence accumulates.
- Independence from the source of the score/rating. The climate factor requires only a PD, a NACE 2digit code and geolocation parameters. It therefore applies equally to a PD produced by an internal rating model, whether AIRB or FIRB, and to a score or PD supplied by an external provider or credit rating agency. No access to the internals of the underlying model and no recalibration of it are required, so the adjustment can be applied downstream of the rating process without affecting the validation perimeter of the rating system. It can be used as a variable of the rating model.
- Because the adjustment is applied downstream of the rating assignment, it does not modify the regulatory PD used for capital requirements unless it is explicitly incorporated into the rating system. In its present form it is intended for risk management, portfolio steering, climate stress scenario analysis and disclosure purposes.
- Rating models typically estimate PD over a one-year horizon. When a longer-horizon PD is not available, α can be recalibrated to capture the higher cumulative exposure to

climate events over the period of interest. This adjustment extends the horizon of the climate component only; the underlying credit PD remains a one-year estimate.

- Independence from the source of the hazard data: the climate factor requires geolocation parameters and hazard probabilities (return period) which are available from any climate data provider (a list of open-source providers is supplied in Annex IV). The determination of which hazard is financially material to a given borrower remains a judgment-based step to be exercised by the user (e.g., the credit analyst or risk manager).
- Transparency and governance. With no estimated coefficients, the adjustment can be reproduced from published inputs, the contribution of each component can be isolated, and the calibration can be revised without a model change. Furthermore, no need of balance sheet information but only NACE sector codes.

7. Climate Factor Adjustments - results

The total debt outstanding of the firms included in the portfolio amounted to EUR10.9 billion; the portfolio mean Probability of Default is 3.87% the Adjusted PD is 4.08% this PD adjustment generates a delta Expected Losses of EUR7.1m. See table below.

Table 47. Expected loss before and after the adjustment (LGD 40%, € million)

Rating class	PD	PD adj	PD uplift	Exposure	EL base	EL adj	Δ EL
1	0.72%	0.75%	+4.2%	3,920	11.29	11.76	+0.47
2	1.30%	1.36%	+4.6%	3,107	16.16	16.90	+0.75
3	2.00%	2.10%	+5.0%	1,128	9.02	9.48	+0.45
4	2.46%	2.59%	+5.3%	914	8.99	9.47	+0.48
5	3.44%	3.61%	+4.9%	615	8.46	8.88	+0.42
6	5.44%	5.73%	+5.3%	447	9.73	10.25	+0.52
7	9.50%	10.02%	+5.5%	364	13.83	14.59	+0.76
8	28.22%	29.86%	+5.8%	498	56.21	59.48	+3.27
Total	3.04%	3.20%	+5.3%	10,993	133.70	140.80	+7.10

- Expected loss rises by €7.10 million, from €133.70 million to €140.80 million. In relative terms the increase is 5.3%, equivalent to a move from 122 to 128 basis points of exposure, or +6.5 bps. The exposure-weighted probability of default rises from 3.04% to 3.20%.
- Two effects compound in the same direction. The PD uplift is not uniform across the portfolio: it rises monotonically from 4.2% in class 1 to 5.8% in class 8. And expected loss is proportional to the starting PD, which in class 8 is forty times that of class 1. The combination means that class 8, holding 4.5% of exposure, absorbs 46% of the total increase, and classes 7 and 8 together absorb 57%.
- This is the intended behaviour of the adjustment. The climate factor does not inflate the portfolio indiscriminately — six basis points on the total is a contained effect — but concentrates on positions that are already impaired, where a marginal deterioration in the probability of default carries the greatest economic consequence and where the margin before the next class threshold is thinnest.

8. Limitations

- Default definition. Because access to granular banking data is restricted by privacy and prudential rules, the analysis relies on public default events only, namely bankruptcy, insolvency proceedings and compulsory liquidation. The regulatory categories of unlikely to pay and past due are not observable, so the earliest stages of credit deterioration are not captured. This narrows the definition of default relative to the one used in banking practice, reduces the number of observed events and is likely to make the calibration of α conservative
- Geographic proxy. The hazard class is assigned on the municipality of the registered office, with the limitations set out above. Where productive assets are located elsewhere, the adjustment may be applied on the basis of a hazard level that does not correspond to the firm's actual exposure, in either direction.
- Sectoral granularity. The VIS is constant within NACE 2‑digit divisions and does not reflect firm level adaptation, business continuity arrangements or insurance coverage.
- Single hazard calibration. The probability mapping covers flood hazard only, in line with the events underlying the portfolio selection. Extension to drought, heat stress and wildfire requires an equivalent probability mapping for each hazard and an explicit rule for aggregating multiple hazards, which has not been defined at this stage.
- Gross physical exposure versus net credit impact. The VIS measures the gross physical exposure of an economic activity to the hazard. It does not capture the net effect on creditworthiness, which can be of the opposite sign where the event generates demand for the sector, or where the sector is emerging from an earlier shock.
- Absence of a geographic control sample. All positions are in provinces affected by the 2023 events, so no unaffected geographic control is available. The prevent observation was the only test available.

Annex IV – Climate risk indicators

This appendix lists publicly accessible platforms, atlases and screening tools providing physical climate risk indicators. It is intended as a reference for users of the framework who wish to source hazard data independently, or to cross-check the indicators applied in the assessment described in Chapter 6.

Sources are grouped by primary purpose. For each entry the table reports the provider where identified, a short description, the geographic coverage and the hazards addressed. Coverage and hazard labels follow the terminology used by each provider, which does not always correspond to the hazard taxon9omy adopted in section 6.1; where a provider addresses hazards outside that taxonomy — wildfire, hail, pollution, biodiversity loss — these are reported as given. All links were valid at the date of drafting and should be verified before use.

A. General climate atlases and multi-hazard screening platforms

Tool and source	Description	Coverage and hazards
1. IPCC Interactive Climate Atlas *IPCC* https://interactive-atlas.ipcc.ch/	Authoritative global atlas for exploring observed and projected climate change under IPCC scenarios. Provides a trusted scientific basis for checking regional climate signals and communicating scenario-based physical changes.	**Coverage:** Global **Hazards:** Heat stress, drought and water stress, rainfall patterns
2. Copernicus Climate Atlas *Copernicus Climate Change Service (C3S)* https://atlas.climate.copernicus.eu/atlas	Public atlas for exploring past and future climate change through interactive maps and charts. Supports broad screening of climate trends, scenario comparison and communication with non-technical users.	**Coverage:** Global **Hazards:** Heat stress, drought and water stress, rainfall patterns
3. WESR Climate *UNEP* https://app.mapx.org/	Global mapping environment for exploring climate drivers, pressures, states, impacts and responses. Helps in understanding the dynamics and locational characteristics of climate change.	**Coverage:** Global **Hazards:** Heat stress, wildfire, drought and water stress, and other
4.Data Delivery System (DDS) *CMCC* https://dds.cmcc.it/	Climate observations and model simulations of past and future climate, including variables like temperature, precipitation, ocean salinity and evapotranspiration, as well as climate indicators	**Coverage: Europe** **Hazards:** temperature, precipitation, ocean salinity and evapotranspiration
5. KlimafolgenOnline https://www.klimafolgenonline.com/eur/index_de.html?language_id=de	Public tool mapping climate indicators, hazards and socioeconomic context variables. Supports rapid regional screening, location comparison and communication of climate trends and exposure patterns.	**Coverage:** Europe (DE, FR, NL) **Hazards:** Heat stress, drought and water stress, flood and heavy rainfall, and others
6. IMPACT2C Web Atlas https://www.atlas.impact2c.eu/en/	Web atlas showing projected impacts of 2°C global warming across sectors and regions in Europe. Allows exploration of scenario-based effects on water, agriculture and other systems at screening level.	**Coverage:** Europe (DE, FR, NL) **Hazards:** Heat stress, wildfire, drought and water stress, and others

Tool and source	Description	Coverage and hazards
7. HazClim® *Rongyi Solutions* https://rongyisolutions.com/en/adapting-to-climate-change/	Decision-support method for assessing climate risk to assets, operations, people and supply chains. Supports structured site-based risk reviews and prioritisation of adaptation measures from a business perspective.	**Coverage:** Global **Hazards:** Heat stress, wildfire, drought and water stress, and others

B. Water and drought

Tool and source	Description	Coverage and hazards
8. Aqueduct Water Risk Atlas *World Resources Institute (WRI)* https://www.wri.org/data/aqueduct-water-risk-atlas	Global water-risk mapping tool covering stress, variability, flooding and related indicators. Supports site or portfolio screening, hotspot comparison and communication of water-related physical exposure.	**Coverage:** Global **Hazards:** Drought and water stress
9. Water Risk Filter *WWF* https://riskfilter.org/water/explore/map	Global screening tool for water-related physical and transition risk. Helps identify hotspots, compare locations and prioritise deeper analysis of water stress, flooding and governance risk.	**Coverage:** Global **Hazards:** Drought and water stress, flood and heavy rainfall, ecosystem loss
10. EDO – European Drought Observatory *European Commission, Joint Research Centre* http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1111	Official European drought-monitoring service with maps and indicators on precipitation, soil moisture and vegetation stress. Supports tracking of drought development and adds an operational monitoring perspective.	**Coverage:** Europe (DE, FR, NL) **Hazards:** Drought and water stress
11. Droughtwatch *Geocodis* https://droughtwatch.geocodis.com/	European drought-monitoring service with indicators and maps of drought conditions. Supports tracking of emerging drought stress, early awareness and an operational layer in drought-risk work.	**Coverage:** Europe (DE, FR, NL) **Hazards:** Wildfire, drought and water stress, ecosystem loss

Tool and source	Description	Coverage and hazards
12. Aqueduct FOOD *World Resources Institute (WRI)* https://www.wri.org/applications/aqueduct/food/	Mapping tool focused on cropland and food security under water risk. Helps screen where water stress may affect agricultural production and food systems across regions.	**Coverage:** Global **Hazards:** Drought and water stress
13. Water Footprint Assessment Tool *Water Footprint Network* https://www.waterfootprintassessmenttool.org/	Tool for estimating blue, green and grey water footprints of crops and production systems. Supports understanding of water-use pressure and complements broader water-risk assessment with a resource-efficiency lens.	**Coverage:** Global **Hazards:** Drought and water stress

C. Hazard-specific tools

Tool and source	Description	Coverage and hazards
14. Global Flood Awareness System (GloFAS) Map Viewer *Copernicus Emergency Management Service* https://global-flood.emergency.copernicus.eu/glofas-forecasting/	Global flood viewer offering forecasts, monitoring and historical information. Supports screening of river-flood conditions, hotspot exploration and the addition of operational flood context to broader risk assessment.	**Coverage:** Global **Hazards:** Flood and heavy rainfall
15. Coastal Risk Screening Tool *Climate Central* https://coastal.climatecentral.org/	Global coastal screening tool estimating current and future flood exposure from sea-level rise. Helps identify vulnerable coastal areas quickly and introduce location-specific inundation context into adaptation planning.	**Coverage:** Global **Hazards:** Sea level rise and coastal erosion
16. Local Sea Level Projections *Climate Analytics* http://localslr.climateanalytics.org/	Global tool providing local sea-level-rise projections for coastal locations. Supports rapid screening of coastal exposure, scenario comparison and place-specific sea-level information.	**Coverage:** Global **Hazards:** Sea level rise and coastal erosion
17. Thermal Trace *Copernicus Climate Change Service (C3S)* https://thermaltrace.climate.copernicus.eu	Global map-based tool showing heat-stress day indicators across time periods and thresholds (e.g. above 32°C or 38°C). Supports rapid screening and a range of heat-stress statistics.	**Coverage:** Global **Hazards:** Heat stress
18. Hail Risk Map *Nature Geoscience (peer-reviewed publication)* https://www.nature.com/articles/s41561-025-01868-0	Scientific map publication showing projected hail-risk patterns. Serves as a reference for screening hail exposure where dedicated open-access operational tools remain limited, particularly for broad comparative analysis. Not an interactive tool.	**Coverage:** Global **Hazards:** Hail

D. Agriculture and agri-food systems

Tool and source	Description	Coverage and hazards
19. CANARI – Climate Analysis for Agricultural Recommendations and Impacts https://canari-europe.com/	European agricultural climate tool mapping agro-climatic indicators and their likely implications for crops. Supports screening of where changing climate conditions may affect farming practices and adaptation needs.	**Coverage:** Europe (DE, FR, NL) **Hazards:** Heat stress, drought and water stress
20. AgriAdapt – Webtool for Adaptation https://awa.agriadapt.eu/en/	European webtool helping farmers and advisers assess climate vulnerability and adaptation options. Translates climate information into practical recommendations for agricultural management and resilience planning.	**Coverage:** Europe (DE, FR, NL) **Hazards:** Heat stress, drought and water stress
21. CRTB – Climate Risk Toolbox *FAO* https://data.apps.fao.org/?lang=en	Toolbox with agricultural climate-risk indicators, maps and supporting materials. Helps screen climate pressures on agriculture and bring a structured evidence base into agri-food risk work.	**Coverage:** Global **Hazards:** Soil degradation and erosion, pollution
22. ABC-Map *FAO* https://abc-map.fao.org/dashboard	Global tool assessing the environmental impact of land-use change in the agri-food sector. Users draw a polygon to inform land-use, biodiversity and climate-related decisions in agricultural value chains.	**Coverage:** Global **Hazards:** Heat stress, drought and water stress, snowfall and frost, and others
23. CRISP – Climate Risk Planning and Managing Tool for Development Programmes in Agri-Food Systems *Eurac Research* https://crisp.eurac.edu/	Practical tool for integrating climate-risk considerations into agri-food development programmes. Supports identification of relevant hazards, structured planning discussions and resilience mainstreaming in programme design.	**Coverage:** Global **Hazards:** Heat stress, drought and water stress, soil degradation, and others
24. Orbae *Adastra* https://orbae.adastra.eco/	Data platform visualising land-use change and the associated greenhouse-gas impacts of different crops. Helps screen climate and land-use implications in agricultural supply chains and sourcing decisions.	**Coverage:** Global **Hazards:** Soil degradation and erosion

E. Nature, biodiversity and ecosystem dependencies

Tool and source	Description	Coverage and hazards
25. ENCORE https://www.encorenature.org/en	Global tool mapping sector dependencies on and impacts upon nature, including climate- and biodiversity-relevant dimensions. Supports materiality screening, portfolio analysis and the linking of economic activities to ecosystem reliance and environmental pressure.	**Coverage:** Global **Hazards:** Drought and water stress, soil degradation, ecosystem and biodiversity loss, and others
26. UNEP Strata *UNEP* https://unepstrata.org/	Platform for mapping climate and nature risks and vulnerabilities. Supports broad spatial screening, hotspot exploration and a more integrated climate-nature perspective in risk discussions.	**Coverage:** Europe (DE, FR, NL) **Hazards:** Heat stress, flood and heavy rainfall, ecosystem and biodiversity loss
27. Biodiversity Risk Filter *WWF* https://riskfilter.org/biodiversity/explore/map	Global screening tool for biodiversity-related physical and transition risk. Supports identification of nature hotspots, prioritisation of locations or suppliers, and linkage of business activities to ecosystem sensitivity and degradation pressure.	**Coverage:** Global **Hazards:** Drought and water stress, flood and heavy rainfall, ecosystem and biodiversity loss
28. UN Biodiversity Lab https://map.unbiodiversitylab.org/	Global geospatial platform combining biodiversity and nature-related data layers. Supports mapping of protected areas, ecosystem indicators and spatial overlaps when screening nature-related risk, dependencies or conservation context.	**Coverage:** Global **Hazards:** Drought and water stress, sea level rise and coastal erosion, ecosystem and biodiversity loss

F. Italy-specific sources

Tool and source	Description	Coverage and hazards
29. AWARE© – Accident Weather Analytics Risk Events *SustainAdvisory (based on ISTAT, ISPRA and Italian Civil Protection Department data)* https://www.sustainadvisory.it/indicatori-di-rischio/	Municipality-based climate risk analytics platform for Italy. Users upload a portfolio of company locations and download the climate-risk indicators required; each location is benchmarked against the Italian territorial average. Designed to support financial institutions in identifying and disclosing credit exposure to climate events. This is the source used for the present exercise (see section 6.1.2).	**Coverage:** Italy (municipality / LAU level) **Hazards:** Intense and frequent rainfall, floods, temperature increase, landslides, precipitation trends, coastal erosion, droughts, cold and frost waves

The CLIMATEFIT project aims to support EU territories in their just and transformational journey toward climate resilience by bridging the finance gap, providing critical insight and building the capacities of (i) Public Authorities (PAs) to identify, orchestrate and attract various public and private financing sources and (ii) Financing & Investment Entities (FIEs) to identify and access resilient investment opportunities. CLIMATFIT opens a significant opportunity to foster innovative resilience investments in vulnerable EU territories and to boost competitiveness and EU leadership in a growing market. The project will build on a deep understanding of existing initiatives to sustain systemic and catalytic resilience investments by engaging its Technical Partners, PAs and FIEs in the co-creation of twenty innovative investment strategies, ten concrete and scalable investment plans and five bankable transformational investment cases, increasing the bankability of resilient project pipelines across a diversity of scales, financing gaps, contexts, barriers to financing, climate risks and vulnerabilities, biogeographical regions, adaptive capacities and maturity regarding climate change represented from its twenty case studies grouped in three clusters: Northwestern, Eastern and Southern.

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