Assessment of Climate-related Vulnerabilities

Analytical framework and toolkit

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Executive Summary

There is a growing focus on potential risks to financial stability from climate change. Climate-related events are becoming more common, which raises concerns over institutions' ability to manage their risks and to continue to provide financial services in certain segments and geographies. Financial authorities in various FSB member jurisdictions are taking steps to integrate climate-related financial risks in their financial stability assessments.

Climate-related vulnerabilities in the financial system, when triggered by climate shocks, could threaten financial stability through various transmission channels and amplification mechanisms. Analysing climate-related vulnerabilities consists of tracing through how climate shocks trigger the traditional vulnerabilities laid out in the FSB's financial stability surveillance framework. This can be more complicated than for non-climate shocks given uncertainties around their timing and magnitude, non-linearities from tipping points, as well as second-order and spillover effects. The FSB's work focuses on assessing climate-related vulnerabilities in the global financial system, particularly from a cross-border and cross-sectoral perspective. It forms part of the FSB's 2021 Roadmap to coordinate work across standard-setting and other international bodies to address the financial risks of climate change.

This report describes a framework and analytical toolkit to assess the build-up of climate-related vulnerabilities. Building on previous work carried out by the FSB and its members, the framework traces how physical and transition climate risks could be transmitted to and amplified by the global financial system. Complementing the framework, the report includes some metrics that could, given the forward-looking nature of climate risks, potentially be used to monitor climate-related vulnerabilities with a focus on providing a forward-looking perspective. The framework and toolkit should be considered live documents, subject to refinement as understanding evolves on how climate-related vulnerabilities could affect financial stability.

Climate shocks can interact with existing financial vulnerabilities in the real economy or the financial system and lead to financial losses. Climate shocks could materialise through abrupt changes in policies, technological innovation or consumer preferences (transition risks), or through the materialisation of physical hazards, such as floods, droughts or windstorms (physical risks). The interactions of transition and physical risks or among physical risks could be a particular source for non-linear climate dynamics and compound climate shocks could be further amplified by existing financial vulnerabilities, such as asset mispricing or high leverage, creating financial losses.

The framework outlines the transmission of climate physical and transition risks to the financial system, including potential amplification and feedback effects. To reach a system-wide view, the framework considers a broad range of cross-sectoral and cross-border channels that may affect the financial system via real assets and financial markets, and distinguishes between the effects of climate shocks, their transmission and amplification. Once crystalised, climate-related risks are transmitted and amplified through the traditional channels used in financial stability assessments, including credit, market, and liquidity risks. Climate shocks could also affect the real economy through damage to real assets or the creation of stranded assets, or a disruption to economic activity that can feed back to the financial system. The ultimate effect of such channels on the financial system depends upon the magnitude of climate shocks, the extent to which they are anticipated and thus priced into asset values, where the associated financial risks materialise, and how they are managed. Risks that are opaque and not well-managed could create correlated shocks whose impact is magnified as they propagate through the system.

To demonstrate how the framework can be applied in practice, the report examines the potential financial stability consequences of the crystallisation of climate physical risks via real estate markets. The analysis involves a severe yet plausible conceptual scenario of how a climate physical shock to the real estate sector may affect financial stability if insurance becomes less available, which causes risks to shift to households and businesses or to governments. It also identifies the different channels through which risks could spread across the financial system and relevant metrics to monitor such channels.

To assess the vulnerabilities along the different transmission channels in line with the framework, the analytical toolkit sets out three high-level categories of metrics: proxies, exposure metrics and risk metrics. By monitoring all three types of metrics, the toolkit offers the possibility to provide early signal on potential drivers of transition and physical risks that can impact the financial system (proxies), trace the transmission of these climate risk drivers through the system given direct and indirect financial exposures (exposure metrics), and quantify the scale of financial impacts for financial institutions and the system as a whole (risk metrics). The report includes examples of the different types of metrics used by FSB members. The FSB has not yet identified a definitive list of metrics for the toolkit but expects to work to identify metrics that merit additional analysis by the FSB, which could include some of those discussed in this report or others that the FSB may identify. These metrics would be subject to further vetting and prioritisation to ensure their usefulness in practice.

A number of methodological and data challenges need to be overcome to be able to use these metrics for global monitoring of climate-related vulnerabilities. The indicators and metrics discussed in this report can be calculated for some jurisdictions with currently available data. At this stage, however, there are various challenges regarding the consistency of definitions and modelling assumptions across jurisdictions as well as the availability of data to compute them. There is also a need to enhance the consistency and comparability of these metrics to be able to use them from a global perspective, while preserving flexibility and recognising differences among jurisdictions. While there has been some progress on this front due to ongoing international climate data initiatives, more work is needed to address data coverage, granularity, consistency, comparability, and quality issues.

Looking ahead, the FSB will continue to develop its framework to assess climate-related vulnerabilities in the global financial system. Work on this front will proceed in two ways: (1) operationalise the toolkit by prioritising further analysis of a subset of metrics from the long list of metrics discussed in this report; and (2) conduct analytical deep dives to provide concrete insights on specific types of climate-related vulnerabilities that may have global financial stability implications. To inform its work, the FSB will draw on the work of its members and coordinate with relevant external stakeholders through outreach events. Any additional metrics identified through these channels would also be assessed for inclusion in the toolkit. Progress in vulnerabilities analysis is expected to inform other pillars of the FSB's climate roadmap, such as to address data gaps and to design regulatory and supervisory frameworks and tools that address identified climate-related risks to financial stability.

1. Introduction

There is a growing focus on potential risks to financial stability from climate change. The January-September 2024 global mean surface air temperature was 1.5ºC above the pre-industrial average and 2015-2024 will be the warmest ten years on record.[1] At the same time, global greenhouse gas (GHG) emissions are projected to decrease by 4% in 2030 relative to 2019 levels, as compared to the 28% reduction needed to be aligned with the 2ºC scenario and by 42% in order to be aligned with the 1.5ºC scenario, which reflects a widening gap between climate goals and action taken globally.[2] Physical risks are resulting in greater economic damage, which may impact institutions' ability to continue to provide financial services in certain segments and geographies. Transition risks may materialise from abrupt government action to bring policies more into line with the goal of limiting global warming, or changes in investor expectations or preferences. This may result in a sudden re-evaluation of the materiality of climate-related financial risks by market participants. A large-scale shift in beliefs or awareness about the economic and financial implications of these risks could cause a significant and abrupt repricing of climate-exposed assets. Transition and physical risks could have widespread, albeit heterogenous, impacts across entities, sectors and economies. Given this, financial authorities in various FSB member jurisdictions are taking steps to integrate climate-related financial risks in their financial stability assessments.

While climate shocks are transmitted through the financial system via conventional transmission channels, the channels may differ and warrant particular focus to ensure they are captured well in financial stability frameworks. Financial risks from climate shocks could materialise via convential channels used in financial stability assesssments, such as credit, market, and liquidity risks. However, traditional micro- and macro-prudential approaches tend to rely more on direct exposures, a shorter time horizon in the materialisation of risks, and historical loss experiences, which poses challenges on capturing the unique features of climate-related risks. These unique features include, for example, the forward-looking nature of these risks wherein climate shocks are expected to grow in terms of their frequency and magnitude, which makes historical data ill-suited to assess future impacts. Additonally, there are uncertainties around the timing of climate-related events and the magnitude of impact, non-linearities from tipping points,[3] as well as second-order and spillover effects. There is also the possibility, given these complexities, that climate-related risks may be relatively more opaque and hence mispriced or mismanaged by entities in the financial system. Under these conditions, climate risks could create correlated shocks whose impact can be magnified as they propagate through the financial system, in a similar manner to other unexpected shocks to the economy.

This report describes a framework and analytical toolkit to assess climate-related vulnerabilities using a forward-looking approach. Building on previous work carried out by the FSB and its members, the framework traces how physical and transition climate risks could be transmitted to and amplified by the global financial system. Complementing the framework, the report includes some metrics that can be used to monitor climate-related vulnerabilities from a forward-

1 See World Meteorological Organisation (2024), *State of the climate 2024*.

2 See United Nations Environment Programme (2024), *Emissions Gap Report*, October.

3 Tipping points are thresholds that cause a system to move to a very different state, often abruptly or irreversibly. See Lenton et al. (2019), *Climate Tipping Points — Too Risky to Bet Against*, Nature.

looking perspective. The framework and toolkit should be considered live documents, subject to refinement as understanding evolves on how climate-related vulnerabilities could affect financial stability.

The FSB's work to assess climate-related vulnerabilities forms part of the FSB's Roadmap to address climate-related financial risks. The FSB supports international coordination of work to address financial risks from climate change through its 2021 Climate Roadmap (Roadmap).[4] The Roadmap, which was welcomed by G20 Leaders at the Rome Summit, outlines key actions to be taken by standard-setting bodies (SSBs) and international organisations (IOs) over a multi-year period in four policy areas: firm-level disclosures, data, vulnerabilities analysis, and regulatory and supervisory practices and tools.[5] In previous work on climate-related vulnerabilities, the FSB examined the implications for financial stability[6] and sought to identify data to monitor and assess these vulnerabilities from a forward-looking perspective.[7] It also took stock, together with the Network for Greening the Financial System (NGFS), of authorities' work to assess financial stability risks from climate change using scenario analyses.[8]

The report is structured as follows. Section 2 describes the conceptual framework for the assessment of climate-related vulnerabilities. It outlines transmission channels from climate-related shocks to the financial system and real economy, accounting for potential amplification and feedback loops. Section 3 outlines potential forward-looking metrics that could be used to monitor the transmission and amplification channels outlined in the framework. Section 4 sets out next steps for the FSB to operationalise its framework and analytical toolkit as understanding of climate risks, methodologies and data needs continues to evolve.

2. Framework for the assessment of climate-related vulnerabilities

The FSB's financial stability surveillance framework (or Surveillance Framework)[9] provides an overarching framework for assessing vulnerabilities in the financial system. A vulnerability is defined in the framework as a property of the financial system that: (i) reflects the accumulation of imbalances; (ii) may increase the likelihood of a shock; and (iii) when acted upon by a shock, may lead to systemic disruption. Shocks, on the other hand, are hard to predict and typically cannot be targeted by policy action in the same way. If not properly managed, vulnerabilities when acted upon by a shock, can propagate strains through the financial system (transmission), amplify stress through which the financial system would increase the initial impact of the climate shock (amplification or feedback), and lead to systemic disruption.

Assessing financial stability risks posed by climate change requires linking climate-specific shocks to financial system vulnerabilities. When these shocks materialise, they may interact with pre-existing vulnerabilities in the non-financial and the financial sectors that further amplify the effects of those shocks. In line with the Surveillance Framework, this report focuses on climate-

4 FSB (2021), *FSB Roadmap for Addressing Climate-related Financial Risks*, July.

5 FSB (2023), *FSB Roadmap for Addressing Financial Risks from Climate Change: 2023 Progress report*, July.

6 FSB (2020), *The implications of climate change for financial stability*, December.

7 FSB (2021), *The Availability of Data with which to Monitor and Assess Climate-related Risks to Financial Stability*, July.

8 FSB-NGFS (2022), *Climate scenario analysis by jurisdictions: Initial findings and lessons*, November.

9 FSB (2021), *FSB Financial Stability Surveillance Framework*, September.

related vulnerabilities rather than seeking to predict the possible shocks that could trigger them. It aims at providing a global and cross-sectoral perspective that can shed light on the extent to which a particular type of climate-related vulnerability is relevant to a large number of jurisdictions or has the potential to spill over between jurisdictions and financial sectors.

Climate shocks are expected to grow in terms of their frequency and magnitude, making past observations potentially ill-suited to assess future implications.[10] As a result, the impact of climate dynamics does not follow common business or financial cycle dynamics usually surveilled by the FSB and places a premium on forward-looking assessments. Moreover, analytical approaches need to also account for direct and indirect exposures via asset locations, value-chain dependencies, and sectoral exposures in order to provide a holistic view of how climate risks may be transmitted across the real economy and the financial system. The framework therefore seeks to strike a balanced approach in considering the conventional risk transmission and amplification channels used in financial stability assessments but making it more forward-looking and granular to reflect climate specificities.

2.1. Framework

Climate shocks could be transmitted to the financial system and the real economy through transition risks, physical risks, or both (Figure 1). Climate-related shocks could materialise through abrupt changes in policies, technological innovation and/or consumer preferences (transition risks), or through the materialisation of physical hazards, such as floods, droughts or windstorms (physical risks). Compound risks[11] from the interaction of transition and physical risks or among physical risks may create non-linear climate, economic and financial dynamics. An additional source of non-linearities from climate-related factors relates to changed dynamics when tipping points in the climate system are reached or crossed.

Climate shocks can interact with climate-related vulnerabilities in the real economy or the financial system and give rise to financial losses. These shocks could affect the real economy through damage to real assets, the creation of stranded assets,[12] or a disruption to economic activity. Adverse macroeconomic impacts could be exacerbated or mitigated as households, non-financial companies and sovereigns adjust to climate-related shocks through changes in consumption, production and investment, including with different forms of loss-sharing. Cross-border interconnections could further amplify or mitigate climate shocks for nonfinancial corporates through trade and production interdependencies.

The extent to which a climate event impacts the financial system depends on the system's exposure to physical or transition risks and on how well these risks are managed. Once climate shocks interact with the vulnerabilities of the economy or the financial sector, their transmission occurs through similar channels assessed in traditional financial stability analysis. The relative

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[10] While historical observations may offer limited insights for assessing climate risks due to their non-stationary nature, this limitation affects financial stability analysis across other topics.

[11] For an introduction to compound risks, see Zscheischler et al. (2018), *Future climate risks from compound events*, Nature Climate Change, 8(6), 469-477.

[12] Abrupt government action to bring policies more into line with the goal of limiting global warming, or changes in investor expectations or preferences, could result in stranded assets and deteriorating financial conditions for certain borrowers. An abrupt policy change in the other direction, e.g. a reduction of subsidies for green investments, could also entail transition risk and result in stranded green assets.

importance of these transmission channels depends on the nature of climate shock, financial system characteristics, and structure of the real economy. Some channels that feature in the framework are:

- **Credit risk** arising from concerns about the ability of counterparties affected by climate shocks to meet their obligations (e.g. direct damages from physical risks affecting borrowers' capacity to repay and the value of their collateral or decrease in firms' profitability due to sharp changes in consumer preferences or sudden and sizeable price changes in transition-sensitive sectors due to technological innovation).

- **Market risk** triggered by abrupt asset repricing as market participants incorporate expectations associated with new transition paths or unfolding physical risks, increasing risk premiums and market volatility. If the climate shock is sufficiently material, these risk channels could affect the solvency of a wide variety of financial institutions, sectors and geographies in a highly correlated manner, leading to systemic risks.

- **Liquidity risk** driven by withdrawal of funding by counterparties (e.g. depositors, investors) from financial institutions that are perceived to be overly exposed to climate risks or liquidity outflows due to margin calls as a result of abrupt repricing and reduced access to funding due to reputational damage.

- **Underwriting risk** that insurers may face due to increased asset damages and deterioration in human health from acute and chronic physical risks.

- **Other risks:** Beyond these channels that operate via the non-financial sector, climate-related risks may directly impact the financial sector, such as through changes in risk perceptions in financial markets, economic damages to real assets owned by the bank and legal liability risk that both the non-financial and the financial sectors may face.[13] Climate shocks may also give rise to operational losses, such as climate physical risks resulting in damages to data centers or bank branches.[14]

Climate shocks that affect the non-financial sector could also be transmitted to the financial system through financial markets and interlinkages between financial institutions (e.g. global banks, investment funds and reinsurers). The interdependencies among financial institutions and investors' changing expectations may generate destabilising dynamics due to fire sales, correlated procyclical behaviour or common portfolio exposures. For example, a climate shock affecting exposures of investment funds could be propagated to other sectors in the financial system, amplifying the initial shock through interconnectedness.[15] Similarly, banks providing credit to investment funds would face increased credit and liquidity risk if the funds struggle to repay amid falling asset valuations and growing redemption demand.

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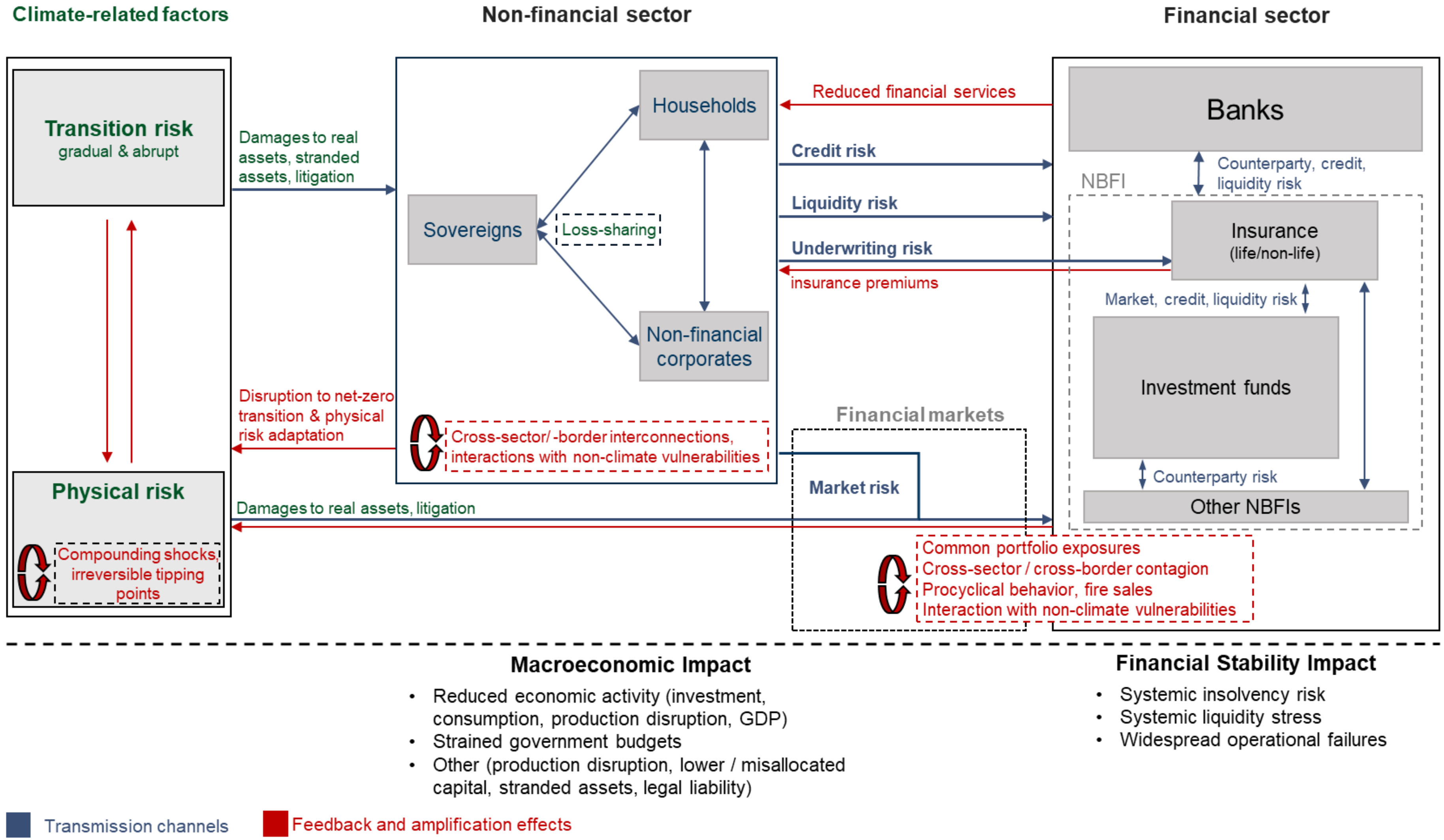
13 For example, litigation cases for breaches of due diligence laws, for greenwashing, or breaches of fiduciary duties. For more information see NGFS (2023), *Climate-related litigation: recent trends and developments* and Setzer and Higham (2024), *Global trends in climate change litigation: 2024 snapshot*, The Grantham Research Institute on Climate Change and the Environment.

14 Berger et al. (2023), Climate risks in the U.S. banking sector: Evidence from operational losses and extreme storms, *Federal Reserve Bank of Philadelphia working paper*, November.

15 See, for instance, Gazzani et al. (2023), Flight to Climatic Safety: Local Natural Disasters and Global Portfolio Flows, *SSRN working paper*, June.

Framework for the assessment of climate-related vulnerabilities **Figure 1**

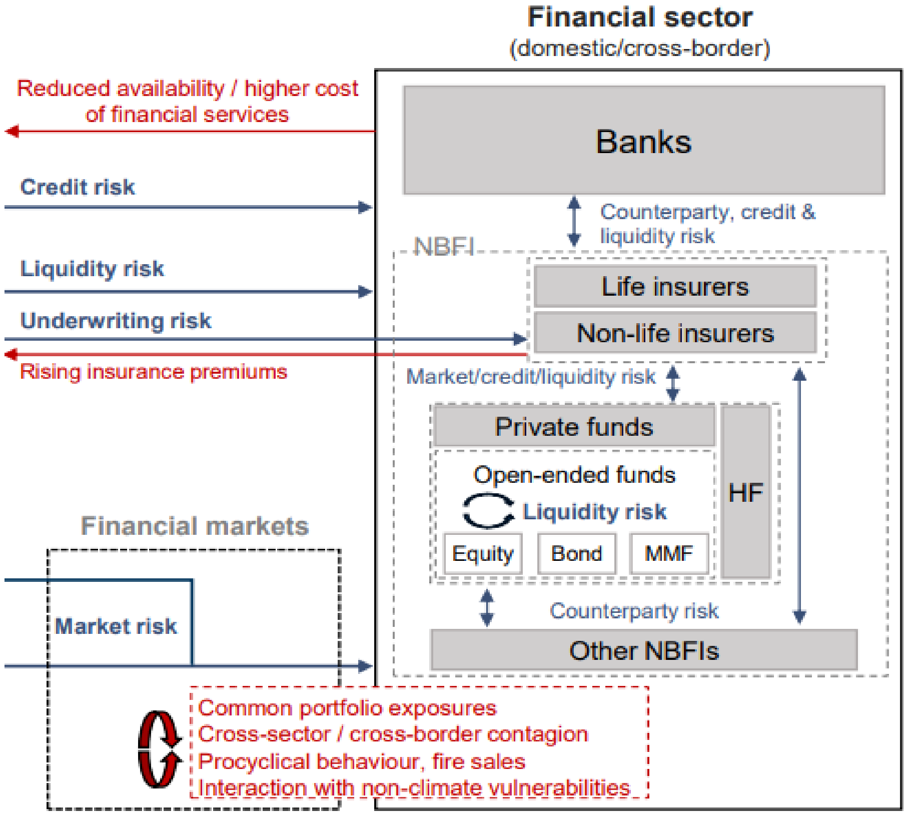


Source: FSB

The framework elaborates on different transmission and amplification channels through which insurers, investment funds and other non-bank financial institutions (NBFIs) could be affected (left panel of Figure 2). Providing more granularity for these institutions is based on the view that the nature of their investments is often different than for banks, and could therefore involve different transmission and amplification channels. Given their size in the global financial system, NBFIs collectively are an important channel for financing the transition to lower GHG emissions in line with national targets and pathways. Some transmission and amplification channels that could give rise to financial stability risks are summarised in the right panel of Figure 2.The FSB's focus is on better understanding how climate shocks could be further transmitted and amplified as the different risk channels mutually reinforce each other and give rise to second-round effects due to financial interconnections between NBFIs.

The framework also accounts for other system-wide aspects, such as spillovers, risk transfers and amplification mechanisms, including feedback loops. Spillovers and risk transfers could happen between the different sectors of the financial system through direct and indirect financial interlinkages. Examples include fire sale or redemption risks for the insurance and asset management sectors in response to climate shocks and the lack of insurability of certain assets, which results in higher credit risk for banks. Feedback loops may also materialise between the financial system and the real economy via reductions in bank lending and in insurance coverage. If this were to occur, risks related to physical hazards could be transferred to other parts of the financial and non-financial system, including potentially the public sector as the de facto backstop or insurer of last resort. This risk transfer could lead to sizable redistributive impacts and create additional financial stability concerns. Ultimately, the mutual amplifications could weaken the financial system, create systemic credit, market and liquidity risk and reduce economic activity, especially if exacerbated by the presence of other financial stability vulnerabilities at the outset of the climate-related shocks.

NBFI block of FSB's framework and NBFI risk transmission channels Figure 2



Risk channels	Transmission sources
Credit risk	Issuers of securities held in NBFI portfolios may default or face financial difficulties, especially for economic sectors with stranded assets Insurers may face credit risks through their direct lending and reinsurance contracts
Market risk	Exposed due to their portfolio holdings of equities and debt securities issued by non-financial corporates, financial institutions and sovereigns that are vulnerable to climate risks
Underwriting risk	Climate change may increase the cost of natural catastrophe claims as physical risks increase, which may lead to underwriting losses if insurers do not reflect this in their premiums or policy coverage
Liquidity risk	Abrupt repricing of some asset classes and sentiment shocks can trigger correlated redemption requests and increased collateral requirements across investors

Source: FSB

2.2. Applying the framework

2.2.1. Deep dive on climate physical risks in real estate markets

To demonstrate how the framework can be applied in practice, the FSB examined the financial stability consequences of the crystallisation of climate physical risks via real estate markets. This topic was driven by growing concerns that rising frequency and severity of physical shocks caused, in part, by the effects of climate change and less insurance coverage could result in significant losses for households, firms and other financial institutions. A broad-based repricing of physical risk could further impose losses on investors that are not adequately factoring in such risks in asset prices, and transmit shocks across borders and financial sectors.

The analysis considered potential financial stability implications of (a continuation of) climate trends and reassessment of climate risks for real estate markets. So far, historical evidence provides limited indications of broader financial system distress caused by extreme weather events through real estate. However, historical experience may be inadequate for sizing future impacts since physical impacts of climate change are growing and future effects may exceed current expectations. To mitigate such concerns, the analysis used a forward-looking conceptual approach that considers how climate-related vulnerabilities, when acted upon by climate physical shocks, can propagate strains through the financial system and may lead to real estate revaluations and significant declines in the availability of private insurance (see Box 1).

Box 1: Analysis on the impact of climate physical risk on real estate markets

From a global perspective, insurance protection gaps are sizeable and vary across regions and perils. In 2023, 62% of the global losses from natural disasters were uninsured and this share has been roughly constant over the past few years.[16] When looking at insurance coverage across regions and jurisdictions, there is considerable heterogeneity. For instance, according to a global reinsurer, Asia and Africa have low insured losses relative to total losses. In Asia-Pacific, Japan (47%) and Australia (40%) have higher coverage than the rest of region (about 5%).[17] Coverage also varies by peril, with 56% of damage caused by meteorological events (e.g. hurricanes and storm surges) insured in Europe, which falls to 28% for hydrological events (e.g. landslides and floods) and 7% for climatological events (e.g. droughts, extreme temperatures and wildfires).[18]

There are indications that insurance premiums have been rising in certain vulnerable areas to reflect expected or realised increases in physical risks (see Graph 1), with some insurers withdrawing from markets that are deemed too risky.[19] Historical data indicates an upward trend in insurance premiums, particularly in areas that are more susceptible to risks. Higher insurance premiums reflect various factors including higher house prices, increased construction costs, increase in exposures, as well as rising natural catastrophe (NatCat) risk associated with climate-related events.[20]

[16] Swiss Re Institute (2024a). *Natural catastrophes in 2023: gearing up for today's and tomorrow's weather risks*.

[17] Data drawn from Munich Re website.

[18] EIOPA (2021), *Climate change, catastrophes and the macroeconomic benefits of insurance*.

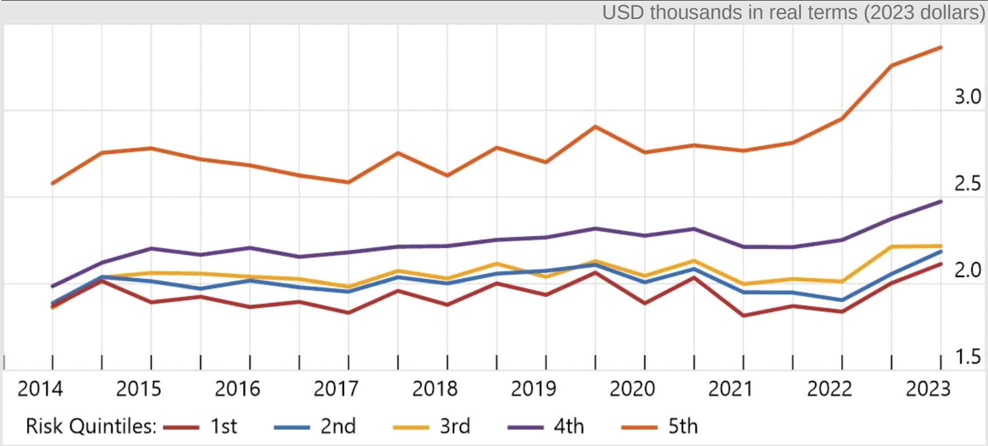
[19] See, for instance, BBC, Climate change is fuelling the US insurance problem, 18 March 2024; Bloomberg, Here's why insurers are leaving disaster-prone places, 26 September 2023; EIOPA (2022), European insurers' exposure to physical climate change risk, May; Chen, C. et al. (2024), Changing climate in Brazil: Key vulnerabilities and opportunities, IMF working paper; Financial Times, The crippling home insurance crisis hitting America, April 24, 2024.

[20] It is important to note that not all NatCat events are directly related to climate change. Natural catastrophes can also be caused by geological events such as earthquakes and volcanic eruptions, which are not influenced by climate change

US homeowners' insurance premiums are rising, especially in riskiest areas

Graph 1

USD thousands in real terms (2023 dollars)



Note: The graph shows the average insurance premiums by disaster risk exposure quintile by year for a balanced sample of over 17,000 US ZIP codes.

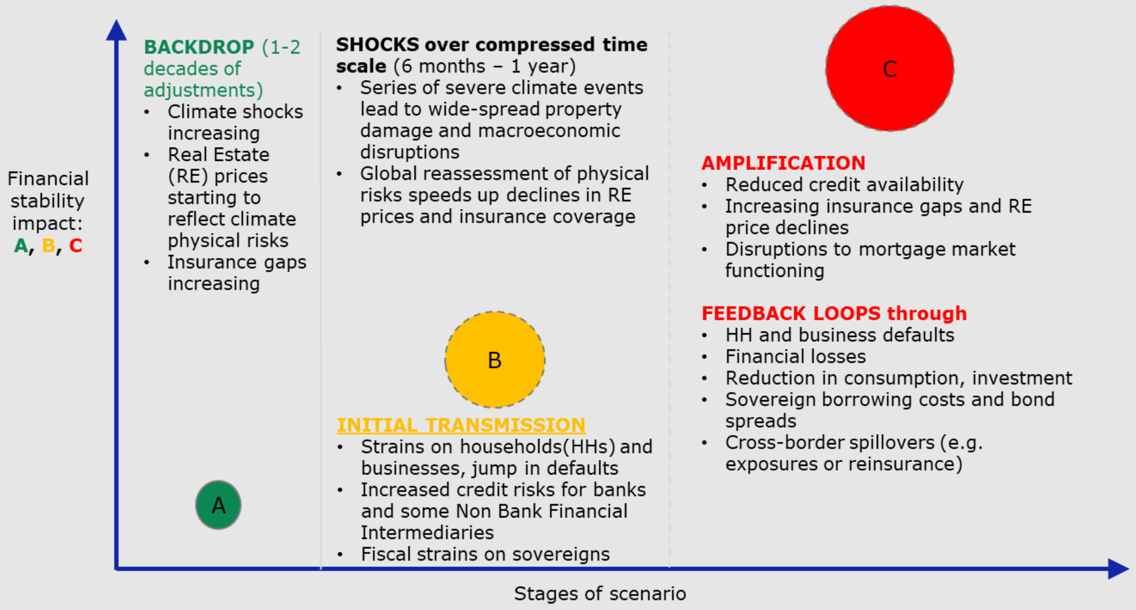
Source: Keys and Mulder (2024), *Property insurance and disaster risk: New evidence from mortgage escrow data*, NBER working paper 32579, June.

The FSB's analysis took a two-step approach to highlight the potential financial stability implications that may arise from climate physical shocks via real estate markets if insurance were to become less available or affordable. First, it developed a conceptual narrative that described a severe yet plausible conceptual scenario of how a climate physical shock to the real estate sector may affect financial stability if insurance were to become less available. Second, it identified what metrics would ideally be needed to quantify the channels identified in the scenario.

The conceptual narrative consists of three stages that trace the impact of climate shocks across the financial system using a plausible but severe scenario. As a starting point, the narrative considers a setting where financial stability impacts from climate physical shocks are idiosyncratic or financial risk protection is sufficient to mitigate physical shocks (Figure 3, point A). While there are concerns that climate events may become more prominent and disruptive to real estate and mortgage markets, these changes are expected to occur over a 10-20 year time horizon. However, the scenario envisions a compression of this time frame due to a series of extreme climate events that result in direct damages and a global reassessment of physical risks (point B). This results in larger uninsured property damages that affect borrower risk characteristics (e.g. via loan-to-value ratios) and increase bank credit risk. The final stage (point C) outlines various potential amplification mechanisms, consistent with those used in traditional financial stability analysis. For instance, banks could reduce lending, including for recovery to already vulnerable households and corporates. There could also be an abrupt, broad-based repricing of climate-physical risk, as the expectation of larger future losses are incorporated into current prices and impact sectors and jurisdictions not currently directly affected by disasters.

The various channels outlined in the scenario were then mapped to metrics that differ in terms of complexity and informativeness. Simpler metrics, e.g. data on the price and availability of insurance for these physical risks, could act as an early signal that vulnerabilities are increasing or becoming more proximate, while the more complex metrics could inform the materiality of potential financial impacts. For instance, specific metrics were identified for the insurance market (e.g. changes in premiums and coverage), households (e.g. changes in property values and loan-to-value ratios from losses due to natural disasters), and government sector (e.g. debt-to-GDP ratios and sovereign bond risk premiums). The analysis also outlined a high-level approach to be able to compute credit risk metrics that are grounded in standard financial stability analysis (for example, considering how bank solvency could be affected by falls in house prices and increases in Loan to Value (LTV) ratios). It then traced these impacts across bank real estate exposures to compute expected credit losses from climate events. Cross-border considerations are also pertinent in this context, which may require focusing on some metrics to better understand the role of reinsurance in global insurance and financial markets.

Overview of scenario structure **Figure 3**



Source: FSB.

Applying the framework illustrates how physical climate shocks could be transmitted to the financial system in ways that are similar to conventional financial shocks. Growing intensity of climate-related natural catastrophes, in underinsured areas could increase household and business debt burdens and reduce incomes, leading to significant increases in consumer and business defaults. The implications of these higher debt burdens depend on vulnerabilities such as the leverage of nonfinancial borrowers, the stability of asset valuations, and the liquidity and capital positions of lenders. Moreover, given the highly interconnected nature of the financial system, losses may materialise for financial market participants not directly exposed to climate risk but connected with others who are exposed. In addition, the risks arising from the crystallisation of physical risks in one part of the system could also lead to correlated shocks elsewhere as previously opaque risks become more apparent, including through uncertainty over continued availability or effectiveness of risk transfer mechanisms. One potential channel in this context is underwriting risk and its impact on insurer solvency.

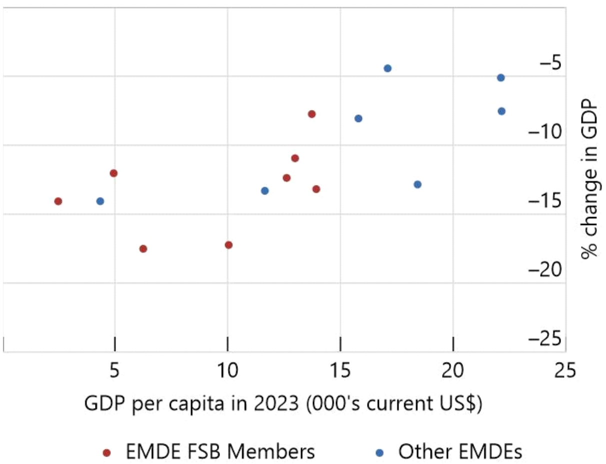
The analysis also identified new channels that helped inform the FSB's framework. In particular, the analysis highlighted the importance of accounting for risk transfers and feedback effects between the different sectors of the financial system. For example, the risk of previously insured assets becoming uninsurable, either because the premiums become prohibitively expensive or because insurance coverage is withdrawn, can affect other parts of the financial system that rely on insurance to mitigate this risk. There could also be cross-border transmission due to international financial exposures via real estate lending as well as potentially through the global reinsurance market where losses to reinsurers could contribute further to triggering a combination of premium increases and reduced coverage. In addition, the exercise highlighted feedback loops within the financial system, or between the financial system and the real economy, which could result in more persistent macro-financial impacts from reduction in lending by banks to vulnerable regions, and reduction in consumption and investments.

2.2.2. *Relevance of the framework to emerging market and developing economies (EMDEs)*

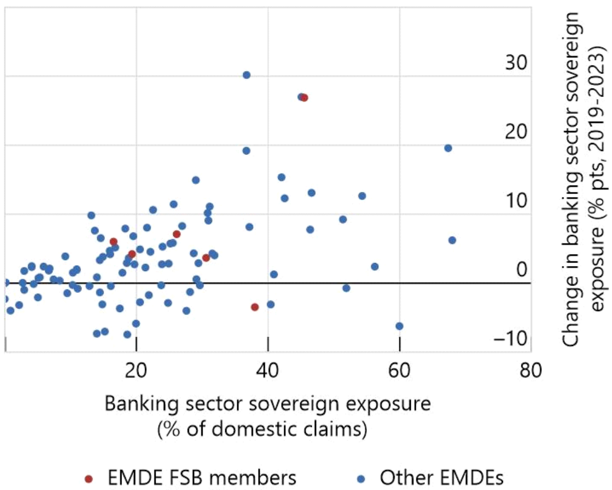
The framework is flexible and can be applied to different jurisdictions, while still retaining an overall common structure in how the transmission and amplification of climate shocks propagate through the financial system. This flexibility allows for the consideration of unique climate-related vulnerabilities and economic structures specific to EMDEs. For instance, some EMDEs have higher exposure to climate risks, given their geographic exposure to physical risks and reliance on climate-sensitive sectors like agriculture. As a result, climate shocks could result in more widespread and persistent macroeconomic impacts. NGFS estimates show that the GDP impacts for some EMDEs could reach over 18% by 2050 under the delayed transition scenario (Graph 2, panel A).

Estimated GDP impacts from climate change and sovereign debt levels in EMDEs — **Graph 2**

A. Estimated GDP impacts for EMDEs under NGFS delayed transition scenario by 2050[1]



B. EMDE banks' exposure to sovereign debt



[1] The chart shows the estimates under the delayed transition scenario (REMIND-MAgPIE 3.3-4.8) from the NGFS Phase V scenarios.
Sources: NGFS, World Bank, FSB calculations.

Adverse macroeconomic impacts from climate shocks could further interact with pre-existing EMDE financial vulnerabilities. Since the end of 2019, banks in many EMDEs have increased their exposure to domestic governments as borrowing rose, partly due to the COVID-19 pandemic (Graph 2, panel B). This increase is more pronounced in areas with already high sovereign exposures, intensifying the connection between banks and governments. These pressures could lead to simultaneous sovereign debt crises in several economies. Extreme NatCat events can result in growing burden on EMDEs to take on contingent liabilities due to lower baseline levels of financial risk protection. This can add further burden on sovereign debt levels and spillover to bank balance sheets, particularly if those balance sheets are weak.[21] However, some other amplification channels may be less pronounced for EMDEs, such as the smaller size of the NBFI sector in these jurisdictions.

[21] World Bank (2024), *Finance and prosperity 2024*, August.

Existing analytical work on EMDEs in other fora show that financial stability risks could become material and require continued emphasis in the FSB's work. Financial sector assessments conducted by the International Monetary Fund (IMF) and the World Bank have established jurisdiction-specific narratives for how climate-related vulnerabilities in EMDEs could raise domestic financial stability risks. These are often compounded by pre-existing macro-financial vulnerabilities, including via external flows. Although overall financial stability impacts in these analyses appear to be manageable, the resilience of individual banks can differ markedly due to heterogeneity in asset sectoral and geographical concentrations.[22] This work has also noted data and methodological gaps and challenges that need to be addressed for analytical work to advance. Moving beyond a domestic financial stability narrative, the FSB's framework can add value by exploring how global financial stability risks may arise from climate shocks in EMDEs, such as materialisation of climate-related vulnerabilities across several EMDEs or in parallel to adverse macroeconomic events. Adverse shocks could also originate in the real economy and transmit internationally. For instance, climate shocks in some EMDEs that provide agricultural and mining products to the rest of the world, including Advanced Economies (AEs), could have broader implications.

3. Analytical toolkit

To assess and monitor climate-related vulnerabilities identified in the framework, the FSB has developed an analytical toolkit containing three high-level categories of metrics: proxies, exposure metrics and risk metrics. The toolkit includes indicators on vulnerabilities in the financial system that could interact with climate shocks; metrics that trace their transmission, including across jurisdictions and sectors; and their potential amplification within the financial system and the real economy:

- **Proxies** provide an early signal on potential drivers of transition and physical risks. They include information on the likelihood and severity of hazards or potential alignment gaps of GHG emissions between projected and reference transition paths of jurisdictions.

- **Exposure metrics** provide insights on how climate risk drivers identified by proxies could transmit through the financial system and affect different sectors (financial and non-financial). These metrics build on a combination of climate-specific, non-financial- and financial-sector information.

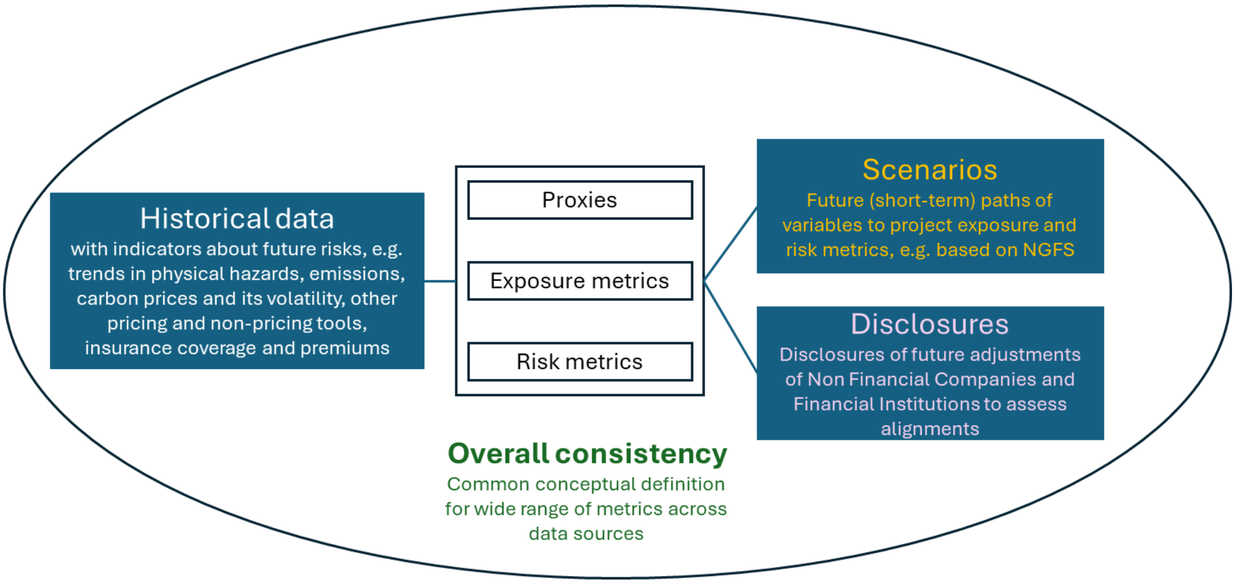
- **Risk metrics** build on the information contained in proxies and exposure metrics to quantify the scale of financial impacts as climate shocks transmit through the financial system by interacting with vulnerabilities. Some examples of these risk metrics are a portfolio's sensitivity to climate factors, valuations, leverage and liquidity transformation.

Over time, the FSB will endeavour to select a basket of indicators based on their relevance for financial stability analysis, forward-looking nature, and using consistent and comparable approaches to compute the metrics where possible. The metrics would be drawn from domestic work done by financial authorities, and further screened for their relevance to financial stability

[22] Stress tests done as part of the World Bank and IMF Financial Stability Assessment Programs (FSAPs) in Colombia, Morocco, and Mexico indicate that overall physical risks such as droughts and floods, as well as transition risks, are relatively benign for the financial system. See, for instance, IMF (2021), *Climate-related stress testing: Transition risk in Colombia*, November; IMF and World Bank (2024), *From extreme events to extreme seasons: Financial stability risks of climate change in Mexico*, January; and World Bank (2024), *Double Trouble? Assessing climate physical and transition risks for the Moroccan banking sector*, April.

and whether they can be consistently computed across financial sectors and jurisdictions. To strengthen their forward-looking interpretation and application, some of the metrics would be based on data drawn from climate scenarios and climate disclosures, including transition plans (Figure 4). For instance, emissions-based data could be made forward-looking by using scenario-based projections of emissions of economic sectors or by aggregating such data from the transition plans of non-financial firms that become available over time.

Making metrics forward-looking **Figure 4**



Source: FSB

Analytical work by FSB members provides a starting point for metrics to consider as the most appropriate for inclusion in a toolkit. The following sections provide an overview of various metrics that have been used by some FSB members under each of the three high-level categories of metrics. At this stage, there are various challenges regarding the consistency of definitions and modelling assumptions across jurisdictions as well as the availability of data to compute them (see section 3.4). There is also a need to enhance the consistency and comparability of these metrics to be able to use them from a global perspective, while preserving flexibility and recognising differences among jurisdictions. Accordingly, this report has not yet identified a definitive set of metrics for the toolkit, but will work to identify them in the future subject to further vetting and prioritisation to ensure their usefulness in practice.

3.1. Proxies

Metrics for proxies provide an early signal on potential drivers of transition and physical risks, which may transmit throughout the financial system to generate losses (Table 1). Some members proxy for transition risk by reflecting emissions together with their forward-looking pathways for a given set of climate goals. A more disorderly adjustment in emissions is typically modelled via an abrupt increase in carbon prices, which could result in rapid reallocation of capital from polluting to cleaner and sustainable sectors which may result in stranded assets and volatility in commodity prices, and terms-of-trade adjustments for exporters and importers.[23] Stranded assets could also materialise from abrupt policy changes in the other direction, e.g. a reduction of subsidies for green investments. While this approach helps identify ways in which transition risks may materialise, jurisdictions tend to rely on various other non-pricing-based tools in their policy mix to meet climate goals, which need to be considered when drawing insights. Metrics for physical risk is captured via both historical losses from different physical hazards and how projected losses may evolve under different climate scenarios. As jurisdictions typically differ in terms of their vulnerability and exposure to different types of transition and physical risks, the proxies provide an overall context within which to frame the discussion around the extent of climate-related risk drivers.

Table 1: Examples of metrics for proxies used by some FSB members[24]

	Link to framework	FSB members that report using the metric
Trends in absolute emissions and carbon prices (Transition risks)	Diverging trends between current emissions (carbon prices) and scenario-implied emissions (scenario-implied carbon prices) could indicate potential transition risks which may disproportionally affect certain economic sectors and result in stranded assets. These could result in higher **credit** and **market risks** for sectors with high exposure to transition risks.	Bank of England (BoE), European Central Bank (ECB), IMF
Economic losses from climate physical hazards (Physical risks)	Losses could indicate regions most vulnerable to changing climate risks, with potential impacts on value and supply chains. Higher losses could reflect greater **credit risks** due to deteriorating ability of borrowers (probability of default (PD)) to repay and affect the value of collateral (loss given default (LGD)).	ECB, Banque de France, BoE

Rising GHG emissions, based on emissions-based proxies, indicate that transition risks could materialise in a disorderly manner due to delayed and/or uncoordinated mitigation efforts. Since global GHG emissions have not peaked, a disorderly transition could materialise where market participants suddenly re-evaluate the materiality of climate-related financial risks, potentially driven by stronger awareness of the economic and financial implications resulting from the materialisation of physical risks or technological developments.[25] An indicative proxy for the magnitude of the changes needed to limit global warming to 1.5C is the projected carbon price under the Net Zero 2050 scenario, as it reflects the required level (as estimated by the NGFS) that should be in place (Graph 3, panel A). According to the World Bank, only 24% of global emissions are currently covered by some form of carbon tax or emissions trading system, and only 1% of global emissions are priced above the recommended level.[26] Economy-wide impacts

[23] The report does not discuss the causes or forms of transition shocks, which could manifest in different ways. For example, these could arise from technological innovations such as the development and viability of certain mitigation technologies or due to some real assets becoming unviable from structural shifts aimed at reducing emissions-intensive production processes.

[24] In the tables we cite metrics that are mentioned in official publications of FSB members, such as climate stress tests, dashboards, and other climate exercises. The list of members is non-exhaustive.

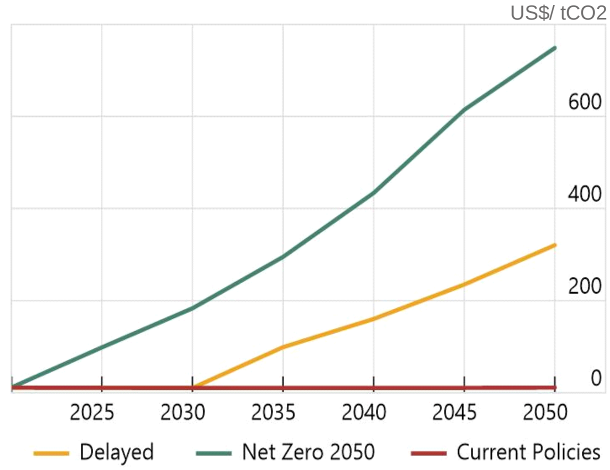
[25] United Nations (2023), *World massively off track to limiting global warming to 1.5C*, press release, November.

[26] See World Bank's carbon pricing dashboard here.

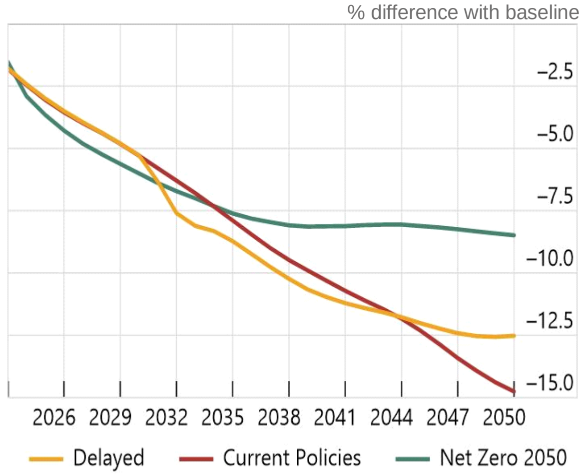
may also be felt as household consumption drops due to higher precautionary savings and reduced investments in certain sectors. The NGFS is working on producing quantitative estimates for these channels via short-term climate scenarios, which may be published in 2025.

Emissions and macro-financial impacts under different climate pathways **Graph 3**

A. Projected global carbon prices[1]



B. Projected GDP impacts under different scenarios[2]



[1] Projected carbon price obtained from the NGFS Phase V scenarios. [2] Projected GDP impacts obtained from NGFS Phase V scenarios (REMIND-MAgPIE 3.3-4.8).

The "Current Policies" scenario assumes that only currently implemented policies are preserved, leading to high physical risks. The "Delayed Transition" scenario assumes global annual emissions do not decrease until 2030. Strong policies are then needed to limit warming to below 2 °C. The "Net Zero 2050" scenario is an ambitious scenario that limits global warming to 1.5 °C through stringent climate policies and innovation, reaching net zero CO_2 emissions around 2050.

Source: NGFS; FSB calculations.

Proxies for economic losses from acute physical risks (e.g. floods) show that the impacts have historically been localized, but the growing intensity or frequency of such events could trigger widespread losses. Historical estimates put average annual economic losses at between 0.18%-0.61% of GDP across different regions with part of the financial burden shared by public and private insurance.[27] If current trends were to continue under current climate policies, NGFS estimates that projected physical risk impact could cause global GDP to decline, versus the baseline, by 5.3% by 2030 and by up to 15% by 2050 under current policies (Graph 3, panel B).[28] These losses would be more persistent and therefore result in widespread dislocation in the real economy. Economic costs related to these risks arise due to direct damages to assets, and reduced economic activity, while amplified by interconnected supply chains. More broadly, the materialisation can also lead to reassessment of climate-related physical risks not only in geographies already considered to be at risk, but also in geographies whose climate exposures had been hitherto considered to be more moderate.

It is important to also consider proxies that capture non-linear dynamics arising from factors such as compound risks and tipping points in assessments of climate-related vulnerabilities. Compound risks refer to the combination of multiple risk drivers and/or hazards that give rise to non-linear dynamics and amplify the impacts of the individual risks. They can include both physical risks interacting with each other, as well as physical risks compounding with other types

27 UNDRR (2020), _Human cost of disasters: an overview of the last 20 years (2000-2019)_.

28 As compared to the last iteration of NGFS scenarios, the expected economic impact of unabated climate change has significantly increased due to the implementation of the new damage function, modelling changes and updating the data to reflect updated country commitments.

of risks, e.g. transition risks and other economic, environmental, societal, or geopolitical risks (see also transmission in Figure 1). Moreover, failure to account for tipping points may result in underestimating the impact of shocks, driving calls to better capture tipping points in climate risk assessments for the financial sector.

3.2. Exposure metrics

Exposure metrics provide insights on how climate risk drivers identified by proxies could transmit through the financial system and affect different sectors (financial and non-financial). They take into account the extent of direct connections between the financial system and particular types of climate-related shocks. Exposure metrics combine proxies (section 3.1) with exposures of the non-financial sector (e.g. nature of economic activities, capital structure) and financial sector (e.g. investment and financing activities) to those risk drivers.

Exposure metrics could indicate the materiality of some of the transmission and amplification channels in the framework. For instance, banks' loan book exposures to climate-sensitive sectors can indicate their vulnerability to credit risk in the event of climate shocks; climate-sensitive securities exposures for financial institutions can be an indicator for market risk from repricing of investment portfolios. Such metrics could help identify concentrated risks in specific sectors or common exposures across financial sectors to counterparties exposed to transition or physical risks. The forward-looking nature of these metrics can be further enhanced with the use of corresponding scenario-based data and, where possible, with information from transition plans of financial institutions and non-financial firms.

While these metrics reflect the scale of exposures, they need to be combined with risk metrics (section 3.3) to indicate the materiality of financial losses. For example, the FSB's real estate deep dive (see section 2.2) showed how the combination of information from mortgage exposures (using loan-to-value ratios) with expected damages from physical shocks could identify pockets of vulnerabilities where credit risk may become a material concern.[29]

3.2.1. Exposures to drivers of transition risk

Some FSB members use a mix of backward- and forward-looking metrics to capture exposures of financial firms to transition risk (Table 2). These metrics generally rely on emission-intensity of non-financial corporates or economic sectors, which need to be supplemented with more forward-looking and granular information. Emission intensity offers a common starting point to assess the magnitude of transition risks for the real economy and how financial sectors may be affected via their financial exposures. These emission-based metrics look at historical emissions but do not reflect, for example, the potential future GHG emission reduction effects of financing aimed at the green transition (e.g. for firms to improve their energy efficiency or optimize their supply chain). Emission intensity metrics, therefore, need to be supplemented with additional information to provide a more forward-looking view.

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[29] Already, several financial authorities are studying the link between climate physical shocks and loan-to-value ratios. See, for example, Bellrose et al. (2021), *Climate change risks to Australian banks*, RBA Bulletin, September; Caloia et al. (2023), *Floods and financial stability: Scenario-based evidence from below sea level*, DNB working paper 796, December; and Johnston et al. (2023), *Climate-related flood risk to residential lending portfolios in Canada*, Bank of Canada Staff Discussion Paper, December.

To offer a forward-looking interpretation, some FSB members have used scenario-based data that compare current exposures with those based on future emission pathways or benchmarks.[30] A gap between the current and projected emission intensities implied by certain climate scenarios (e.g. Nationally Determined Contributions, limiting global warming to below 2 C) would indicate a jurisdiction's aggregate adjustment needed to reach the level of the respective pathway. By nature, any particular scenario embeds a set of underlying assumptions about actions that firms would take and policies that jurisdictions would enact to reach these goals. Thus, the results of any scenario should be interpreted according to the plausibility of the assumed pathway with the understanding that emissions paths, climate goals or lack thereof, legal frameworks, and other institutional features can vary significantly across jurisdictions. As a result, while common "gap-based" scenarios may be informative for some jurisdictions, they can be significantly less so for others.

Table 2: Examples of exposure metrics used by some FSB members

Metric	Link to framework	FSB members that report using the metric
	Transition risks	
Weighted Average Carbon Intensity (WACI)	Financial institutions with higher exposure to carbon-intensive firms or sectors may be at risk of an abrupt transition shock. Reflects **credit risk** channel for bank loan portfolios and **market risk** for equity or bond investments.	BoE, Bank of Canada, De Nederlandsche Bank (DNB), ECB, Hong Kong Monetary Authority (HKMA), IMF
Exposure concentration	Measures the concentration of FI exposures to NFCs / sectors with high transition risk and/or the Carbon-weighted Herfindahl-Hirschman Index (cwHHI) applied to financial institutions or to sectoral exposures. A subset of a given bank's exposures could suffer simultaneous, significant losses in value because of the materialisation of transition risk.	ECB
Common exposures to high transition risk counterparties	Measures the extent to which individual FIs or financial sectors are jointly exposed to NFCs or sectors with high climate-related risks. When climate risks materialise, common exposures may amplify initial shocks if FIs adjust their portfolio in a similar way, giving rise to fire sales with potential financial stability risks.	ECB
	Physical risks	
Exposure of financial institutions' assets to climate physical hazards	Indicates **credit risk** arising from financial institution's portfolio that is exposed to climate physical hazards under different climate scenarios.	ECB, BoE, HKMA

[30] Bank of England (2024), *The Bank of England's climate-related financial disclosure 2024*; Leung et al. (2023), Climate risk exposure of Hong Kong-domiciled investment funds: An assessment using portfolio holdings data, *HKMA research memorandum*, December; ECB (2024), *Risks from misalignment of banks' financing with the EU climate objectives*, January.

Climate-stressed Loan-to-value (LTV) ratios	Distribution of exposures by LTV ratios and damages from physical hazards under different climate scenarios could reflect potential **credit risks.**	DNB
Trends in insurance premiums and protection gaps	Growing protection gaps reflect structural vulnerabilities that may shift losses from damages and trigger **amplification channels** as asset values deteriorate if certain assets become uninsurable.	BoE, International Association of Insurance Supervisors (IAIS)
Trends in reinsurance markets	Reinsurance premiums, market concentration and coverage could provide leading indicators of potential shifts and their implications for insurers and the broader financial system	BoE, IAIS
	Both transition and physical risks	
Overlapping portfolio exposures to counterparties	**Amplification channel** via common exposures across financial institutions to sectors exposed to high transition risk or sectors/geographies exposed to high physical risk, which implies higher **solvency risks** with pro-cyclical behaviour and fire-sales.	European Securities and Markets Authority, ECB

Aggregating financial exposures across financial sectors could help identify concentrated exposures in particular pockets of the financial system, which may be triggered if climate shocks were to materialise. Emissions-related concentration risk is the risk that a subset of exposures by financial institutions could suffer significantly higher losses due to transition risk. Such concentration measures, which consider historical or future emissions relative to a climate benchmark, serve as an important indicator to identify clustered losses within and across financial institutions or jurisdictions. [31,32]

Similar to scenario data, transition plans could provide a forward-looking view of changing exposures of the real economy (e.g. NFC activity and investments for adaptation) and the financial system at specific points in time. In a recent report, the FSB concluded that in those jurisdictions where transition plans are leveraged for financial stability monitoring, standardisation of transition plan disclosures would support greater comparability, reliability and coverage, and could ultimately support efforts by financial stability authorities to use information drawn from transition plans for this purpose. Transition plans could include information useful for drawing financial stability insights, such as the degree of portfolio alignment of financial sectors, financial institutions' planned investment and financing activities as well as targets, and qualitative information on strategic ambition and engagement strategy.[33] However, financial authorities are at an early stage of thinking about the potential use of transition plans for financial stability purposes. The FSB will reflect further on how the report's findings could inform the construction of some metrics discussed in this section.

While the exposure metrics identified to assess transition risk can inform financial vulnerabilities, they have three main shortcomings. First, these approaches require assumptions on the future

[31] Similar to the discussion of gap-based metrics above, the results of any scenario should be interpreted according to the plausibility of the assumed pathway with the understanding that emissions paths, climate goals or lack thereof, legal frameworks, and other institutional features can vary significantly across jurisdictions, which may affect their relevance for jurisdictions.

[32] See, for instance, ECB (2022), *Carbon-related concentration risk: measurement and applications*, Financial Stability Review, November.

[33] FSB (2025), *The relevance of transition plans for financial stability*, January.

emissions trajectory and on the granular breakdown to sectors or firms, which makes it difficult to compare across sectors and jurisdictions.[34] Trends in emissions could be driven by various factors, including policy choices. Some of these factors could be captured by using scenario-based outputs, which can then be translated into a measure of financial risk.[35] Moreover, reflecting value-chain linkages via Scope 3 emissions data remains difficult since the coverage is too patchy for use at the global level. Second, revenues or value added used in the denominator of some of the variables may be affected by price inflation, requiring adjustments using a deflator or price index for comparisons over time. Third, the alignment gap does not account for heterogeneity in how easily firms in different sectors can pass on costs of transition risk to customers, the price and availability of substitutes, and technological progress. These sector-specific factors could limit the impact on profits and the materiality of financial risks.

3.2.2. Exposures to drivers of physical risk

The growing frequency and intensity of physical hazards in affected regions, when coupled with material financial sector exposures, could provide the basis for vulnerability assessments. Financial institutions with larger exposures to regions projected to experience more intense natural hazards may face elevated credit risks as physical hazards cause direct damage to assets and depress economic activity. A broad-based repricing of physical risk may impact asset prices and materialise in the form of market risks, which affects investors that are not adequately factoring in such risks. The FSB's deep dive on physical risks and real estate markets shows that some of these channels may be important to monitor as the physical risks become more widespread and material. For instance, plotting the distribution of exposures by LTV ratios and damages from physical hazards under different climate scenarios could reflect potential credit risks.

Exposure metrics for physical risk across different jurisdictions highlight substantial heterogeneity, depending strongly on the hazards considered. The World Bank's analysis shows significant heterogeneity in the fraction of bank loans that are exposed to physical risks across jurisdictions in Latin America and the Caribbean (Graph 4, panel A).[36] Similar results for Europe indicate that banks are significantly exposed to high physical risk, especially for exposures to river flooding, which are projected to intensify by 2050 when considering the RCP8.5 scenario (Panel B) and intensification of coastal floods towards 2100.[37,38] Computing some of these metrics requires a more careful consideration of heterogeneities in exposures to physical risk across jurisdictions, jurisdiction-specific approaches to flood protection, the need for granular

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[34] The computation of the metrics relies on several assumptions to relate the objectives at the level of the jurisdiction to the sectoral or the firm level. In particular, the measurement of portfolio alignment with climate benchmarks for a given firm will be conditional on the emissions for all other firms in the economy. At the same time, it is not always clear exactly what firm behavior is driving a change in the portfolio alignment with climate benchmarks. This could be due to either emissions reduction, or due to offsetting behavior such as the purchase of carbon credits. Lastly, the portfolio alignment with climate benchmarksfor a firm/sector is likely conditional on government policy in the jurisdiction the firm/sector is located in. Jurisdictions with potentially higher ambitions may imply a stronger misalignment reflecting transition risk in the form of increased litigation risk instead of credit or market risk.

[35] See, for instance, Pastor et al. (2024), *Carbon burden*, Fama-Miller working paper series.

[36] Calice and Miguel (2021), *Climate-related and environmental risks for the banking sector in Latin America and the Caribbean*, World Bank policy research working paper 9694, June.

[37] The Representative Concentration Pathways (RCP) 8.5 scenario combines assumptions about high population and relatively slow income growth with modest rates of technological change and energy intensity improvements, leading in the long term to high energy demand and GHG emissions in absence of climate change policies. Compared to the other RCPs, RCP 8.5 thus corresponds to the pathway with the highest GHG emissions.

[38] See ECB, *Analytical indicators on physical risks*; ECB (2024), *Climate change-related statistical indicators*, ECB Statistics Paper Series no. 48, April.

data on geographic exposures, and the appropriate time horizon over which such metrics should be computed.

Bank exposures to physical risk across jurisdictions

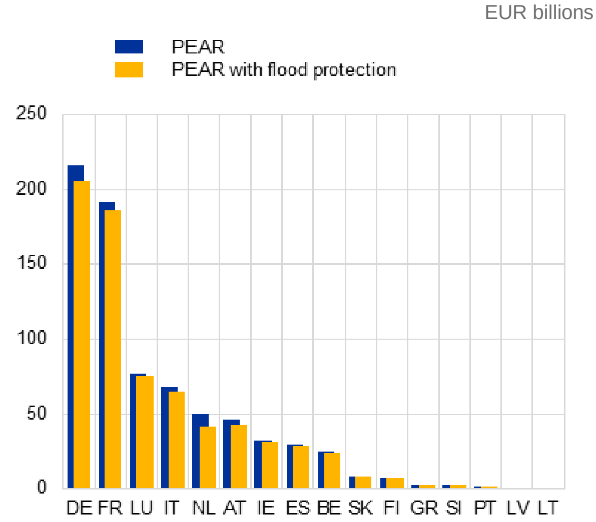
Graph 4

A. Exposures of bank assets to physical risks across some EMDEs[1]

0-25 24-50 50-75 75-100

Hazard	BR	MX	CL	CO	PE	AR	EC	BO	DO
Wildfires	0.4	1.9	0.3	2.2	3.8	0	0.5	0.2	2
Floods	28.6	10.7	0.6	26.9	1	15.2	17.4	50.3	19.5
Landslides	1.1	1	2.7	9.5	6.2	0.1	5.4	4.5	0.7
Earthquake		0.3	13.4	4.4	5.5	0.1	24.2		
Cyclone		18.1		0.3					19.8
Drought		0.3	2.1		0.2	0.3		0.1	

B. Euro area bank exposures to river floods[2]



[1] Percentage of first-level geographical units (e.g. state, province, region) with high hazard mapping (colors) by hazard type (vertical) and country (horizontal) and share of bank assets (numbers in cells) potentially exposed to physical risks. The table shows, that e.g. in Brazil, 75-100% of geographical units are exposed to high flood risk and 28.6% of bank assets are located in these regions.

Calice and Miguel (2021) Climate-Related and Environmental Risks for the Banking Sector in Latin America and the Caribbean, World Bank.

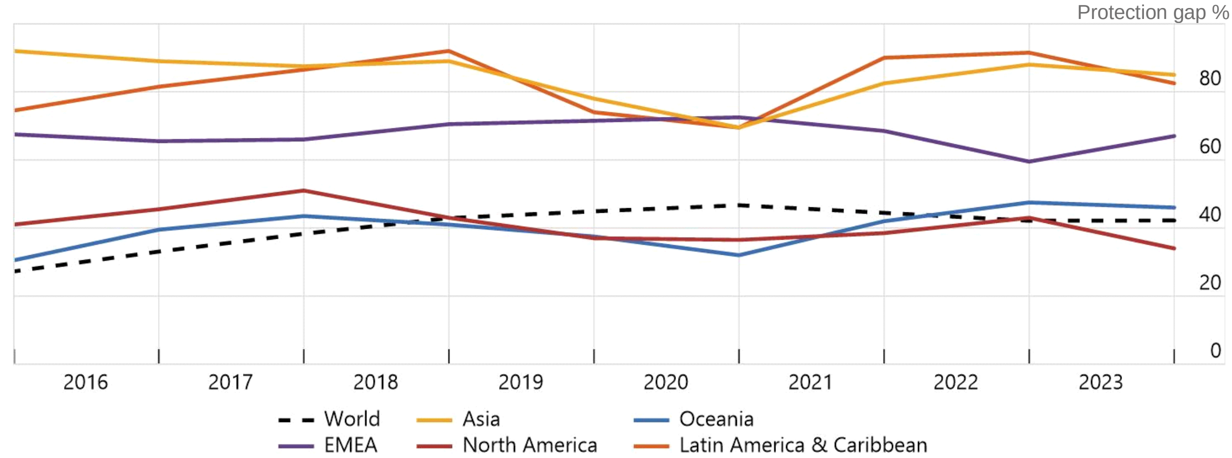
[2] The Potential Exposure at Risk (PEAR) indicator provides insight into the prevalence of a natural phenomenon and is compiled as a sum of risk scores (from 1 – low risk to 3 – high risk). For more information on this metric, please see the annex. Portfolio exposures cover loans, debt securities and equity portfolios of euro area financial institutions vis-à-vis non-financial corporations. RCP 8.5 projections are for 2050. Financial institutions include deposit-taking corporations except central banks (S122), non-money market fund investment funds (S124), insurance corporations (S128) and pension funds (S129). Some countries have been removed owing to confidentiality constraints.

Sources: World Bank, European Central Bank based on AnaCredit, RIAD, SHSS, Delft University of Technology (TUD), Joint Research Centre (JRC).

The ultimate impact of physical risks also depends on existing levels of financial risk protection. One metric to capture this is via insurance protection gaps that compares estimates of insured losses from natural disasters to total economic losses. While protection gaps are sizeable and have not changed by much over the last few years, there is significant heterogeneity across geographical regions (Graph 5). The FSB's deep dive on physical risks in real estate markets noted that such measures rely on backward-looking information and there is value in supplementing them with a risk-based modelling approach, such as the one used by the European Insurance and Occupational Pensions Authority (EIOPA) to estimate the current view on the insurance protection gap information. Another potentially useful indicator is the Swiss Re Insurance Resilience Index, which measures how insurance contributes to maintaining households' and businesses' financial stability by transferring or absorbing risks to life, health and property. The Swiss Re global natural catastrophe resilience index improved to 25.7% in 2023, 90 basis points above 2022 and 190 basis points above its level in 2013. Despite the upward trend in the index, global resilience to natural disasters is still low, especially in EMDEs, where protection gaps are already at elevated levels (Graph 5).

Insurance protection gap for NatCat

Graph 5



[1] The protection gap refers to uninsured losses from natural disasters scaled by total economic losses. The dotted line shows the two-year rolling average for different geographical regions. The global trend is based on the aggregate level of insured losses across all regions, scaled by the sum of insured and uninsured losses.

Sources: Swiss Re, FSB calculations.

Exposure metrics could also indicate the build-up of system-wide vulnerabilities due to overlapping portfolios that could be triggered by climate physical shocks. In the case of overlapping portfolios, resulting losses from materialising physical risks in one geographic area or a re-evaluation for one sector, can trigger balance sheet adjustments with ensuing fire sales, even if the portfolio at the level of individual institutions appears diversified. A metric was used by the ECB to compute asset-level similarity in exposures of EU financial institutions (banks, insurers and investment funds). Their study showed that country hazard-related portfolio similarity across sectors has been declining since 2016, which was driven by insurers, investment funds and pension funds increasing their exposure to US hazards more than banks and other institutions, while euro area banks have shifted their hazard exposure slightly from France to Germany.[39] However, further insights on data and methodology are needed to understand why there has been an overall decrease in similarity across all three types of financial institutions given that there have not been material shifts in their balance sheet composition. Moreover, the measure does not capture climate risk exposures on the liability side, which may be material for insurers.

Another factor to take into account for climate-related vulnerabilities assessments is the complex interplay of physical hazards. The overlapping nature of physical hazards, particularly correlated ones like water stress and wildfires, should be considered when drawing financial stability insights. However, the computation requires information on the interdependencies of physical hazards and more detailed geographical breakdown of financial sector exposures.

3.3. Risk metrics

Risk metrics build on the information contained in proxies and exposure metrics to quantify the scale of financial impacts as climate shocks transmit through the financial system by interacting with vulnerabilities. These metrics can be directly mapped to the transmission and amplification channels of the conceptual framework in section 2, and are often climate-related versions of standard risk metrics used in regular financial stability assessments.

[39] ECB-ESRB (2023), Towards macroprudential frameworks for managing climate risk, December.

Table 3: Examples of risk metrics used by some FSB members

Metric	Link to framework	FSB members that report using the metric
Credit risks		
Carbon earnings at risk[40]	Sectors/firms with higher sensitivity of earnings to carbon pricing may reflect greater credit risk in bank loan portfolios.	IMF, HKMA
Transition to corporate default risk	Exposures to sectors/firms that experience increases in **default risk** from transition shocks could reflect pockets of vulnerabilities with credit risks for financial institutions.	BoC, ECB, HKMA
Normalised/ Collateral-adjusted exposure-at-risk	Reflects expected losses from climate physical risks by considering (non-linear) damage functions to quantify economic impact of NFCs' physical assets with another measure also accounting for pledged collateral.	ECB
Market risks		
Climate beta	Reflects sensitivity of (financial or non-financial) stock prices to climate transition or physical risks. Leading indicator could indicate abrupt shifts in market valuation and spillover to other financial institutions.	ECB
CRISK[41]	CRISK captures market-based expected capital shortfall for individual financial institutions or financial sectors conditional on pre-defined climate stress.	ECB
Carbon Value at Risk	Estimates the implied total Value-at-Risk of securities due to future changes in the carbon price.	BoE, ECB
Climate spread	Climate-related spreads among set of securities could indicate that climate risks are priced in with repercussions for financing costs of borrowers exposed to climate-risk.	ECB
Underwriting risks		
Materiality of insurers' required capital for NatCat risk	Aggregated 1-in-200 year loss (gross, net) across different physical hazards and region relative to total capital requirements.	IAIS, Banque de France (BdF)
Reliance on reinsurance	Reflects the degree to which NatCat exposures (mean or tail risk) are mitigated through reinsurance arrangements. Higher reliance to reinsurance reduces exposure to NatCat risks but changes in pricing and availability of reinsurance could impact insurers' operating results and capital adequacy.	IAIS, BdF

40 The metric relies on 'Unpriced carbon cost', which is defined as the difference between what a company pays for carbon today and what it may pay at a given future date based on current levels of emissions and on its sector, operations and a given price policy scenario. Absorption capacity also depends on the cost pass through onto producer prices and the availability of (low-carbon) substitutes. For example, high competition accentuates the effect on earnings, whereas a monopolist may pass on the increase in carbon costs more easily and maintain stable profits.

41 See, for instance, Jung et al. (2023), CRISK: Measuring the climate risk exposure of the financial system, *Federal Reserve Bank of New York staff report 977*.

3.3.1. Credit risks

Credit risks from climate transition risks

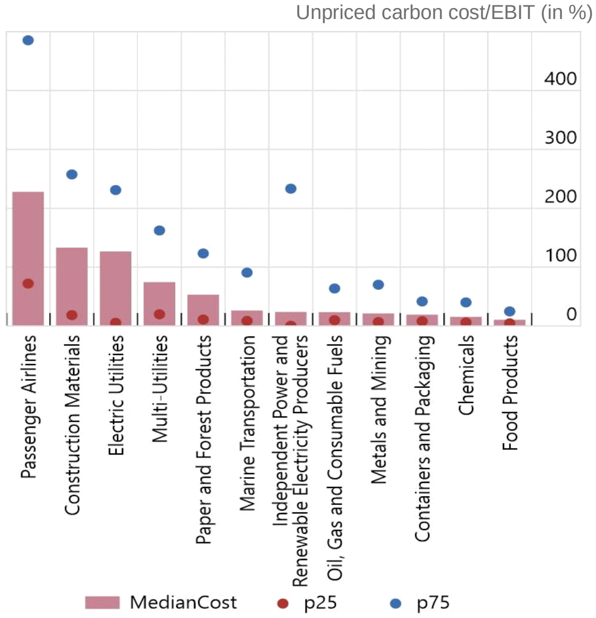
Abrupt changes in transition could give rise to credit risks by having a material financial impact on corporate earnings, which gets transmitted to financial institutions due to their credit portfolios. These changes may occur due to shifts in carbon pricing and non-pricing instruments.[42] For instance, the IMF and HKMA have used Carbon Earnings at Risk, which shows the modeled increase in carbon costs relative to company earnings under different climate scenarios.[43] The direct impact of a delayed transition for a median firm in some sectors could be particularly acute (Graph 6), especially for sectors that may already have high levels of leverage. Although the measure does not directly quantify the default risk, the impact on earnings affects the repayment ability as well as interest coverage ratio or return-on-assets, and can be further used in estimates for creditworthiness. Moreover, these metrics rely on the assumption that policies are in place that impose carbon prices consistent with a particular climate scenario or pathway. Relevance of this assumption and that of the concerned metrics depends on jurisdiction-specific context, especially in relation to emission pathways, climate goals or lack thereof, legal frameworks or other institutional features.

[42] Non-pricing carbon instruments are regulatory and policy tools aimed at reducing GHG emissions without directly setting a price on carbon, including regulations, subsidies, R&D support, information campaigns, voluntary agreements, public procurement policies, and land use policies. These instruments encourage or mandate emission reductions through various means, such as setting standards, providing financial incentives, and promoting sustainable practices.

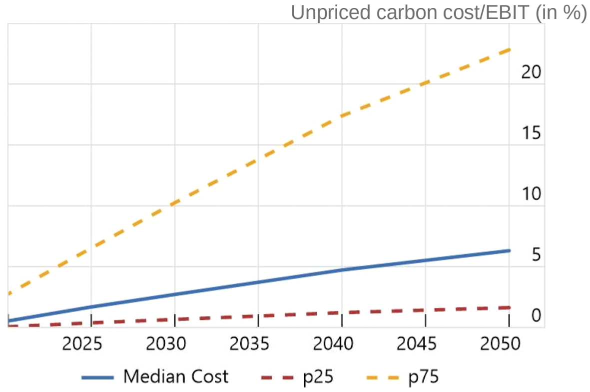
[43] See the IMF's climate change dashboard and HKMA's assessment of the climate risk exposure of Hong Kong domiciled investment funds.

Earnings sensitivity to carbon price change (across sectors, over time) Graph 6

A. Most affected sectors[1]



B. Unpriced carbon cost over EBIT over different horizons for the median firm[2]



[1] This is based on the "Medium" scenario and the horizon date is 2030. [2] This is based on the "Medium" scenario and shows the impact on the median firm.

Note that the metric is scaled with current earnings before interest and taxes (EBIT) (using 2022 data). Trucost's Carbon Earnings at Risk data quantifies the potential impact to company earnings today if companies had to pay a future price for their GHG emissions. Trucost calculates the difference between what a company pays for carbon today and what it may pay at a given future date based on its sector and location and a given carbon price policy scenario. The "Medium Carbon price scenario" that is used for the charts above, assumes that policies will be implemented to reduce GHG emissions and limit climate change to 2 degrees Celsius in the long term, but with action delayed in the short term.

Source: Trucost, FSB Calculations

Work done by some FSB members using the transition-to-corporate default-risk metric indicates the future rise in corporate credit risk, especially for disorderly transition scenarios. For instance, HKMA's analysis indicates that firms in emission-intensive sectors are relatively more vulnerable under different NGFS transition scenarios, resulting in projected PD increases and fatter tails (Graph 7).[44] Under the "delayed transition" scenario and relative to the baseline in 2035, the median change in PD for emission-intensive sectors was found to be 37 bps, but this increase could reach around 360 bps at the 90th percentile. Other members obtain qualitatively comparable results, which provide indications to the importance of a careful management of the transition taking into account financial stability risks for the policy mix.

[44] Ho et al. (2022), *Assessing the financial impacts of climate-related risks on Hong Kong-listed non-financial firms: A forward-looking analysis based on NGFS scenarios*, HKMA research memorandum, March.

Transition-to-corporate default-risk under different NGFS scenarios

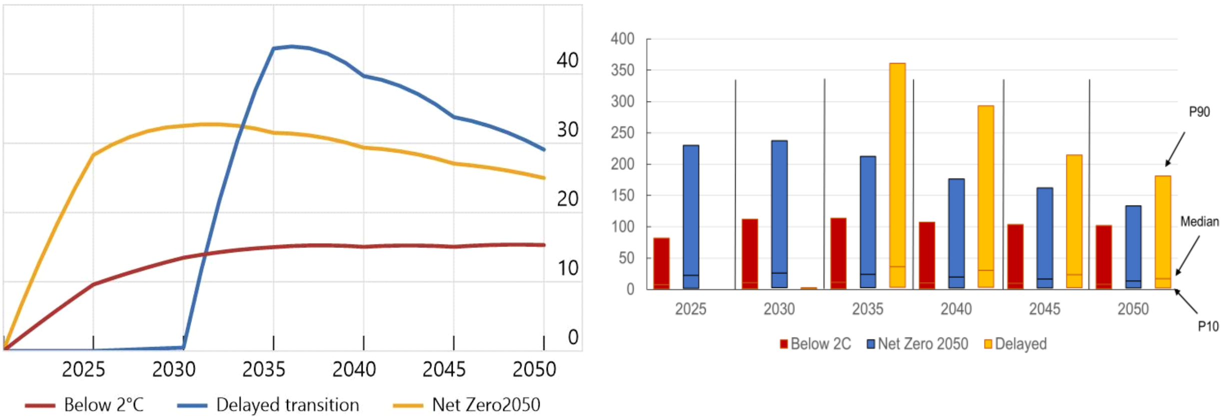
Graph 7

A. Projected change in firms' PD relative to baseline for firms from all non-financial sectors (weighted average by firm's asset)

Basis points

B. Projected change in PD relative to baseline for firms from emission-intensive sectors

Basis points



Sources: Ho et al. (2022); Bloomberg; S&P Capital IQ; S&P Trucost; NGFS; FSB calculations.

Credit risks from climate physical risks

Authorities that have computed credit risk metrics use it to monitor potential expected credit losses to banks and, in some cases, impact on capital. Forward-looking scenario analysis attempts to capture the banking sector effects under adverse scenarios of climate shocks to real estate. For instance, the ECB-ESRB's forward-looking scenario analysis informed potential impact to banks through their loan exposures to river floods.[45] Scenario analysis for Canada showed limited effects for banks.[46] Despite exposures to climate hazards, the analysis finds that potential losses from the direct damages of flooding on lenders' residential real estate portfolios appear to generate modest impacts on lenders' LGDs. This is partly due to the recent and rapid acceleration of house prices, which helps bolster the equity position of homeowners. The FSB's deep dive on physical risks also considered a high-level approach that computes credit risk metrics to quantify the impact of different transmission channels, including direct economic damages and rising insurance premiums, on real estate values. It then traces these impacts across bank real estate exposures to compute expected credit losses from climate events. The feasibility and relevance of these metrics could be assessed further.

Empirical research has shown that the impact of natural catastrophe losses on financial institutions may become more material if insurance coverage declines. Higher credit risk can result in losses for banks when private insurance and homeowner equity are unable to cover losses. For example, Kousky et al. (2020) find that two years after hurricane Harvey, the performance of loans decreased when the property was located in areas where borrowers were not required to have flood insurance.[47] Those loans were both more likely to receive a

45 ECB-ESRB (2023).

46 Johnston et al. (2023).

47 Kousky et al. (2020), *Flood damage and mortgage credit risk: A case study of Hurricane Harvey*, Journal of Housing Research, November.

modification and to become delinquent. Holtermans et al. (2023) find evidence that hurricanes Harvey and Sandy led to elevated levels of commercial mortgage delinquency.[48]

3.3.2. Underwriting risks

The earning and capital position of insurers with significant portfolio of NatCat insurance could be impacted in the event of extreme natural catastrophe events and by the response to such events by the reinsurance market in terms of pricing and availability of reinsurance cover. Relevant metrics for these channels (Table 3) have been used by the IAIS, which reflect the materiality of NatCat risks relative to insurer capital levels and the reliance on reinsurance to manage NatCat exposures over the next financial year. However, such metrics reflect both climate and non-climate related (e.g. earthquakes) events.

Current estimates by the IAIS show that NatCat risks are not material for insurers, but extreme NatCat events could reduce insurers' capital coverage ratios. The IAIS has been monitoring the materiality of NatCat risks to insurers through its annual data collection exercise with the latest analysis showing that the mean NatCat losses for non-life insurers and reinsurers with a 1-in-200 year net loss represent 3.4% of the total capital resources, although tail risk events could be as high as 34% of total required capital. Current estimates show that insurers reinsure 33% of the expected mean claims. If reinsurance levels were to fall by 50%, insurers' capital ratios could fall by 50% on average following a 1-in-200-year event, while for some insurers the drop could be higher than 75%.

As the cost of claims increase, expected under climate change, insurers are likely to increase premiums, making insurance more expensive or even unaffordable, and reduce coverage. In extreme cases, insurers may withdraw from market segments altogether as it becomes uneconomical to offer insurance, resulting in a larger protection gap. In turn, this could trigger second-round effects that could make the financial system less resilient.

3.3.3. Market risks

Market risks represent the reduction in financial asset values arising from the materialisation of or a sudden change in perception of climate risks, including the potential to trigger large, sudden and negative price adjustments where climate risk is not yet fully incorporated into prices. The resulting market risk can be transmitted to the financial sector through financial institutions' portfolio holdings or other exposures. The impact could be more pronounced for long duration assets issued by NFCs and sovereigns vulnerable to climate risks.

Climate risk could also lead to a breakdown in correlations between assets or a change in market liquidity for particular assets. For example, an unexpected repricing of assets of sufficient severity could trigger margin calls in selected asset trades. Dislocated prices can put selling pressure on financial intermediaries in the absence of sufficient liquidity or pledgeable collateral by the institution providing collateral. This may especially be the case for non-bank financial institutions without access to central bank liquidity facilities or precautionary liquidity facilities through the banking system. Furthermore, in case of significant common exposures to at-risk

48 Holtermans et al. (2023), Quantifying the impacts of climate shocks in commercial real estate markets, *Journal of Regional Science*, June.

sectors or geographies across banks and NBFIs, this mechanism can further amplify and become systemic. Similarly, a severe repricing of assets can also trigger a run on funds if the repricing causes investors to redeem their investment fund shares.

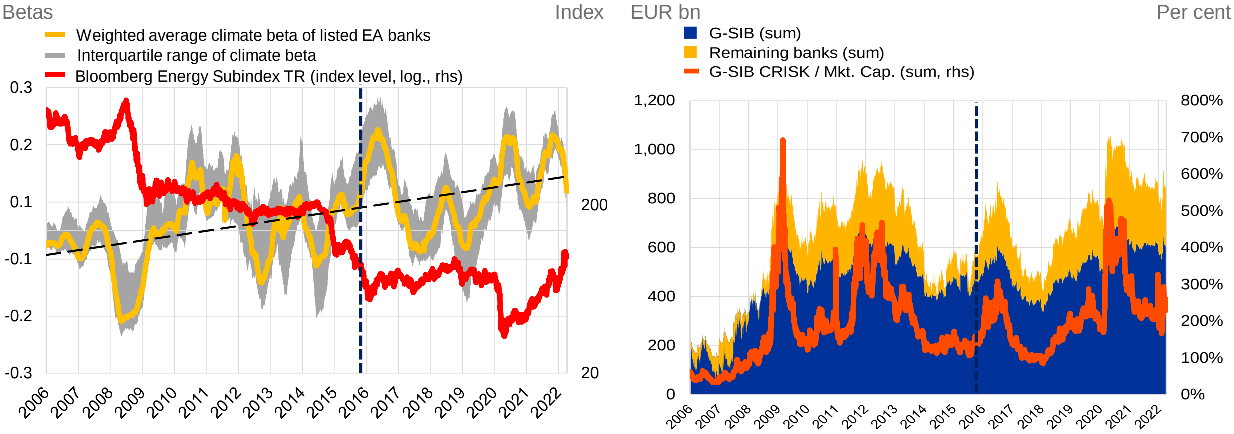
To monitor these market risk channels, some FSB members have used metrics that capture equity repricing, bond risk premiums and scenario-based market adjustments in the context of transition scenarios (Table 3). Climate beta, CRISK, and market-based earnings-at-risk have been used to measure exposure to equity repricing due to climate-related shocks, while bond risk premiums have been used to capture the climate spread. Together with scenario-based market price adjustments, these metrics can provide a forward-looking understanding of potential sensitivities and market-based impacts of climate risk factors. Sensitivity estimates for stocks or bonds at the issuer level (e.g. firms for equities or sovereigns for bonds) can be mapped to different types of financial institutions (e.g. funds, insurers) and aggregated to assess the broader financial system. However, the information content of market-based metrics may be limited to the extent that climate-related risks are not fully priced in asset values or documented movements in these metrics are driven by broader factors that are unrelated to climate risks.

Analytical work by the ECB indicates that equities and bonds of financial institutions are sensitive to climate risk exposures, but there appear to be limited systemic risks from climate change based on currently available information. The climate beta is forward-looking given its use of market values, which incorporate discounted future cash flows based on the current information regarding materiality of climate risks. Using a climate stress scenario for transition risk with a 50% decline in the climate factor over six months reveals that the estimated climate betas of euro area banks have been increasing since 2006, pointing to growing valuation sensitivity to transition risk (Graph 8, panel A). CRISK aggregates firm-level climate beta to the financial system and estimates capital shortfall conditional on a specific climate scenario. Aggregating this metric across financial institutions for each jurisdiction can provide additional insights and comparisons across jurisdictions and over time. For euro area banks, the CRISK remains well below the value observed during the financial turmoil, sovereign debt crisis or COVID-19 pandemic (Graph 8, panel B). The sizeable decline in CRISK was especially driven by the surge in energy commodity prices in 2022, reflecting lower probability that fossil fuels would become unviable quickly. A decomposition into the contribution of firms' debt (leverage), equity and the climate beta to the dynamics of CRISK can illustrate the sources of risk, whereby CRISK is sensitive not only to climate transition risk but also to macroeconomic and financial developments.

Climate beta and CRISK[1] **Graph 8**

A. Climate betas for euro area banks and the climate factor over time

B. Aggregate CRISK for euro area banks



Vertical lines indicate adoption of the Paris Agreement on December 12, 2015.

The Climate beta reflects the sensitivity of financial or non-financial stock prices to climate transition or physical risks.

CRISK is the expected capital shortfall of a financial institution in a climate stress generated via climate-related market and credit risk channels.

“EA” stands for “Euro Area” and “G-SIB” for “Global Systematically Important Bank”.

[1] April 2006-April 2022.

Sources: ECB; Bloomberg.

3.4. Data gaps

Comprehensive, consistent, and comparable data are essential for monitoring climate-related vulnerabilities globally. While there has been some progress on this front, persistent data gaps are a core challenge to operationalising the FSB’s analytical toolkit.[49] These gaps, which are particularly severe for forward-looking data, can be classified into four categories:

- **Data coverage**: To provide a holistic view, data used to compute the metrics needs to offer full view of the financial system exposures. However, the current data coverage remains limited, resulting in capturing only a subset of transmission channels, member jurisdictions and financial sectors. This further hinders the ability to draw insights on the second-round effects and feedback loops. Data coverage for EMDEs, which are likely to experience the most adverse effects of climate change, is particularly fragmented. Moreover, entity-specific data (e.g. GHG emissions, end energy mix) is difficult to obtain, especially for smaller and non-listed corporate counterparties.

- **Data granularity**: Indicators should be able to be computed with data at different levels of granularity, such as jurisdiction, sector, or individual financial institutions, to support tailored assessments. The absence of counterparty-level data collection by jurisdictions on a sectoral basis or the use of different statistical classifications[50] do not always allow for the categorization of economic activities at a sufficiently meaningful level of detail. In addition, geographical breakdown of exposure to physical risks, across regions and

49 FSB (2023).

50 Some of the commonly used industry classifications are the International Standard Industrial Classification (ISIC), the North American Industry Classification System (NAICS), and the Global Industry Classification Standard (GICS).

within jurisdictions, remains one of the most important data gaps to monitor the vulnerability to physical risks.

- **Data comparability and consistency**: Assessment of climate-related vulnerabilities across firms and jurisdictions requires data that is comparable and consistent. This is hindered by the lack of interoperability of climate disclosure standards and regulatory requirements. The publication of the two inaugural International Sustainability Standards Board (ISSB) standards in June 2023 aims to strengthen the decision-usefulness of climate-related financial disclosures.

- **Data quality**: Reliability will depend in part on the quality of information from financial institutions' counterparties and clients, such as corporate disclosures. Due to a fragmented data landscape, various aspects of underlying data are currently estimated by third-party providers. For instance, an NGFS report[51] noted that less than 25% of climate-related data items in their directory were based on official statistics or verified data and 39% of all items were based on estimations. Moreover, the report noted that differences in estimation methodologies across different data providers could impede data comparability across those providers.

These data gaps may start getting addressed over the next few years given a series of global initiatives that have emerged (Table 4). Moreover, important progress has been made over the last year in international and jurisdictional initiatives to strengthen the comparability, consistency and decision-usefulness of climate-related financial disclosures (e.g. publication of ISSB's finalised standards), which may further develop the climate disclosures landscape and facilitate the provision of granular firm-level data on emissions and climate targets.[52]

Additionally, more substantial data caveats include the absence of forward-looking data on the impact of tipping points on key sectors and individual assets, as well as on the combination between transition and physical risks for more exposed sectors. This points to the need for broader research and for discussions between relevant external stakeholders.

Table 4: Examples of international climate data initiatives

Initiative	Brief description	Climate metrics
NGFS climate data directory	Links climate-related data needs to sources, facilitating the identification of gaps (if raw data items that are needed cannot be linked to a source, they can be considered as gaps in the directory).	Various financial stability metrics (e.g. climate-related Probability of Default)
IMF Climate Change Indicators Dashboard	Provides macroeconomic and financial data related to climate change.	Carbon footprint of bank loans
G20 Data Gaps Initiative 3	Develop forward-looking physical risk indicators (e.g. populations, economic sectors and assets materially exposed to climate-related risks), and transition risk	Forward-looking transition and

[51] NGFS (2022), *Final report on bridging data gaps*, July.

[52] FSB (2024), *Achieving consistent and comparable climate-related disclosures: 2024 Progress report*, November.

	indicators (e.g. firms/sectors materially exposed to transition risks) with geographic/sectoral breakdowns	physical risk indicators
Net Zero Data Public Utility	Constructs climate transition-related data in a common framework that aims at allowing for improved data granularity, enhanced transparency of data, and the ability to identify data gaps.	GHG emissions (Scope 1/2/3) Net-zero targets

4. Next steps

Looking ahead, the FSB will continue developing its framework to assess climate-related vulnerabilities in the global financial system. Work on this front will proceed in two ways:

- **Operationalise the toolkit** by prioritising further analysis of a subset of metrics from the long list of metrics in this report. This would require work on common metric definitions, data and methodological considerations required to compute them, and approaches to make them more analytically robust and comparable across methods, sectors and jurisdictions. This will be an ongoing process with a view to assess the metrics based on criteria that could include granularity, quality, and coverage, ensuring that they are relevant for vulnerabilities assessments and continue to remain fit-for-purpose.
- **Conduct analytical deep dives** to provide concrete insights on specific types of climate-related vulnerabilities that may have global financial stability implications. Metrics identified in the deep dive could also inform work to operationalise the toolkit.

To inform its work, the FSB will draw on the work of its members and coordinate with relevant external stakeholders. In particular, the FSB will rely on the analytical work of member authorities, international organisations (e.g. IMF, Organisation for Economic Co-operation and Development (OECD), NGFS and World Bank) and standard-setting bodies (e.g. Basel Committee for Banking Supervision (BCBS), IAIS and International Organization of Securities Commissions (IOSCO)) to advance work on the metrics. It will also organise outreach events with non-FSB financial authorities (such as through its Regional Consultative Group meetings), private sector participants, academics and other stakeholders to exchange views on climate-related vulnerabilities in the financial system and how to assess them.

Progress in vulnerabilities analysis is expected to inform other pillars of the FSB's climate roadmap. Data gaps identified as part of the FSB's vulnerabilities work could provide input to international initiatives to quantify the impacts of climate change (e.g. NGFS work on short-term scenarios) and to enhance climate disclosures (e.g. ISSB's work). Progress on vulnerabilities analysis can also provide the basis for the design and application of regulatory and supervisory frameworks and tools to address identified climate-related risks to financial stability.

Annex: Detailed description of climate-related vulnerabilities metrics reported by some FSB members

Metric	Definition	Forward-looking interpretation	Caveats
Proxies			
Proxies for transition risk			
Emissions (current and future)	Trend of emissions based on current data (Scope 1 and 2 GHG emissions for non-financial companies (NFCs). Historical data can be complemented by scenarios and (quality assured) corporate transition plans (NFCs and FIs)	Climate scenarios and transition plans provide extension of historical data series	Current disclosures remain of heterogeneous scope across jurisdictions. Scope 3 emissions are an important component of transition risk, but most Scope 3 data is estimated based on heterogenous models used by commercial data providers.
Carbon prices (trends in actual and scenario-based prices)	Actual carbon price trends, potential climate policy-driven (actual or implied) carbon price targets and scenario-based carbon prices (e.g. from NGFS scenarios or internal models). Data should ideally be by jurisdiction and sector		Carbon pricing is one of the many tools for climate actions. Jurisdictions may employ a broader policy mix to meet their climate goals.
Proxies for physical risk			
Losses from natural hazards	Historical and estimated future losses from natural hazards, broken down by geographical regions and types of hazard.[53] This could include GDP impacts and estimates of financial losses (e.g. average annual loss, and losses over specific return periods by hazards) under different climate scenarios in 2030, 2050 and 2080	Climate scenarios by e.g. the IPCC quantify intensification and frequency increase of physical hazards which can serve as basis for forward-looking exposure and risk metrics.	Physical hazards may be correlated, and an assessment of compounded risks and the implications of tipping points need to be developed.
Exposure metrics			

[53] Initial focus could be on selected physical hazards (e.g. coastal and river flooding, windstorm) where analytical work is more progressed. Additional hazards to be included as the underlying data becomes available, such as wildfire, landslide, water stress, subsidence, droughts, precipitation intensity. Scores are based on historical distribution of hazard intensity, scientific units allow strong comparability, especially with conversion into economic damages.

Exposure metrics for transition risk			
Weighted Average Carbon Intensity (WACI)	Financial sectors' exposure to emissions-intensive NFCs, weighted by exposures of financial institutions to the respective NFCs. Measure is scalable to sector and jurisdiction using revenue and gross value added (GVA). Another variant of this metric are financed emissions, which capture GHG emissions of a company relative to its total value, weighted by financial institution exposures. Complements WACI and is also in line with indicators set out by the Sustainable Finance Disclosures Regulation.	Extendable to short- and long-term future with NGFS scenarios using (sectoral) emissions and GVA, and with transition plans for individual NFCs and FIs.	Data availability for non-listed firms patchy, emissions limited to Scope 1 and 2, comparison over times require price deflator for revenue and GVA.
Exposure concentration	Two variants: 1) exposure concentration of FI exposures to NFCs / sectors with high transition risk and 2) Carbon-weighted Herfindahl-Hirschman Index (cwHHI) applied to financial institutions or to sectoral exposures.	Same as WACI.	A threshold for high transition risk NFCs should be defined.
Common exposures to high transition risk counterparties	Measures the extent to which individual FIs or financial sectors are jointly exposed to NFCs or sectors with high climate-related risks. When climate risks materialise, common exposures may amplify initial shocks if FIs adjust their portfolio in a similar way, giving rise to fire sales with potential financial stability risks.	Future financial exposures not available, but sensitivity analysis could be done by assuming static and dynamic balance sheets.	The common exposure metric may be consistently defined across jurisdictions, e.g. by high emitters, by physical hazards, but financial stability implications depend on resilience of the financial system, extent of portfolio flows and elasticity of asset prices.
Exposure metrics for physical risk			
Potential exposure at risk (PEAR)	Measures financial exposures to debtors in areas at risk of individual hazards by summing the exposures with non-zero risk scores to individual counterparts in a financial institution's portfolio. The risk of hazards can be proxied using a metric that assigns scores (ordinal categories) of hazard	Can be extended based on climate-specific scenarios, e.g. RCP 4.5 or 8.5 by the IPCC.	Scores do not necessarily reflect the economic and financial impact of physical hazards as they do not capture resulting damages to the economy

	intensity based on the historical distribution of individual hazards to counterparties (NFCs) based on the location of the NFC or its assets, and weighted by FI exposure.		
Exposure of financial institutions' assets to climate physical hazards	Measures nominal exposures of FIs to countries with elevated acute and chronic physical risks as a percentage of total financial sector assets.	A forward-looking interpretation for financial stability would assume that cross-border exposures may be more volatile and revert faster than domestic exposures.	Distinction into acute and chronic may be challenging and the exposure to such broad buckets of risk may be difficult to interpret.
Climate-stressed LTV	Distribution of exposures by LTV ratios and damages from physical hazards under different climate scenarios for both residential and commercial real estate.	Relies on climate scenarios.	Shifts in LTV ratios may be due to non-climate factors, e.g. broader vulnerabilities in the real estate market.
Insurance coverage and gaps	Extent of insurance coverage (by hazard and at the aggregate level)_and the cost of coverage (insurance premiums) provide information on the extent and price of protection (indirect costs of physical risks). Another measure (Swiss Re Insurance Resilience Index) could be the resilience of the real economy and the financial system that is captured by how insurance contributes to maintaining households' and businesses' financial stability by transferring or absorbing risks to life, health and property.	Risk materialisation may impact future solvency of insurers and a declining coverage could spill over to sovereign risks.	Structural measures that may be slow-moving.
Trends in reinsurance markets	Reinsurance premiums, market concentration and coverage could provide leading indicators of potential shifts and their implications for insurers and the broader financial system	May reflect forward-looking view of the reinsurance industry on materiality of climate risks	Trends need to be supplemented with more granular data to draw cross-sectoral and cross-border insights

Risk metrics			
Credit risks			
Carbon earnings at risk	Measures NFC financial losses to changes in carbon pricing. Weighted by FI exposures.	Choice of a specific scenario can be adapted to the severity considered most relevant.	Do not directly measure default risk facing Fis.
Transition to corporate default risk	Assesses change in NFCs' probability of default (PD) related to transition risks, in the form of a full-scale scenario or change in Carbon prices, weighted by FI exposures. It builds on credit risk models available among members which may differ across jurisdictions.	Application of scenarios provides indications on size and timing of PDs across NFCs, sectors or jurisdictions.	Need jurisdiction-specific modelling assumptions and approaches.
Normalised exposure-at-risk (NEAR)	Measures FIs' expected losses in the event of natural hazards by considering (non-linear) damage functions to quantify economic impact of NFCs' physical assets.	Same as weighted average hazard risk score.	Damage functions available for some acute risks (floods and windstorms), but generally not available across the majority of hazards. Given that expected losses are calculated at the debtor level and their impact on credit risk is not straightforward, the associated metrics are based on simplified assumptions.
Collateral-adjusted exposure-at-risk (CEAR)	Estimates expected credit losses within a bank's portfolio after taking into account the mitigating effect of collateral pledged with a loan commitment.	Same as weighted hazard risk score.	Same as Normalised exposure-at-risk (NEAR). Physical collateral could be tied to the location of the hazard and damaged following a natural disaster. Valuation losses from damages accounted for in the indicator but not valuation impacts from externalities.
Market risks			
Climate beta	Assesses impact of financial institution's stock return in response to variations in a specified climate risk factor (transition or physical risk).	Degree to which forward-looking information that investors observe and reflect in their decision-making.	Interpretation of climate beta depends on how the climate risk factor is constructed and may potentially include confounding factors.

CRISK	Expected capital shortfall of a financial institution in a climate stress generated via climate-related market and credit risk channels. It builds on climate beta for impact estimation.	Choice of scenario can be adapted to the severity considered most suitable for market conditions.	Relies on market values of listed banks, thus far not applicable to wider set of financial institutions; Caveats of Climate beta metric also apply here.
Market-Based Carbon Value at Risk (VaR)	Estimates the implied total value-at-risk of securities due to future changes in the carbon price.	Same as for Climate beta metric	Climate VaR requires use of sophisticated dynamic models which may limit use across authorities; Caveats of Climate beta metric also apply here.
Climate spread	Difference in yields between bonds with different exposures to climate risk but otherwise identical characteristics. It indicates the degree to which investors are pricing in the potential impact of climate risk.	Could provide an early indication of potential mispricing of climate-related factors over time in a timely fashion.	Estimates rely on identifying benchmark portfolios where bonds have different exposures to climate risk but similar in terms of other financial characteristics (e.g. maturity, credit quality, and geography).
Underwriting risks			
Materiality of insurers' required capital for NatCat risk relative to overall required capital	Gross and net mean NatCat losses as % of total capital resources, which captures materiality of average annual NatCat claims before and after reinsurance. Gross and Net 99.5% NatCat VaR as % of total required capital, which captures materiality of tail NatCat risks before and after reinsurance.	Standard insurance metrics to measure the materiality of NatCat risk relative to other risks and net assets. They measure the prospective impact over the next financial year.	Prospective metrics but with a projection period of one year and they do not account for the long-term impact of climate change.
Reliance on reinsurance	Net NatCat VaR as % of gross NatCat VaR, which reflects reliance on reinsurance for managing capital for NatCat. Net mean NatCat losses as % of gross mean NatCat losses, which reflects reliance on reinsurance for managing earnings impact of NatCat.	Standard insurance metrics to assess insurers' reliance on reinsurance to manage NatCat's exposure over the next financial year	Prospective metrics but with a projection period of one year and they do not account for the long-term impact of climate change