



Climate stress tests: Are banks fit for the green transition?*

By Ursula Walther, Deutsche Bank Research

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Climate stress tests have emerged as a key tool for looking into the financial system's vulnerability to climate risks. Banks' exposure to climate risks stems from (1) physical risks that are closely related to geography, and (2) transition risks mainly from loans to carbon-intensive sectors. Exercises by the ECB and BoE suggest that banks' credit losses in a disorderly transition would be higher than in an orderly transition scenario, and even higher in a "hot house world" with unabated global warming. Banks would be able to absorb climate-related losses due to strong capital buffers. Results are subject to data limitations and modelling constraints. So far, climate stress tests are declared learning exercises with no direct implications for capital requirements. However, supervisors are urging banks to set up a comprehensive climate risk management.

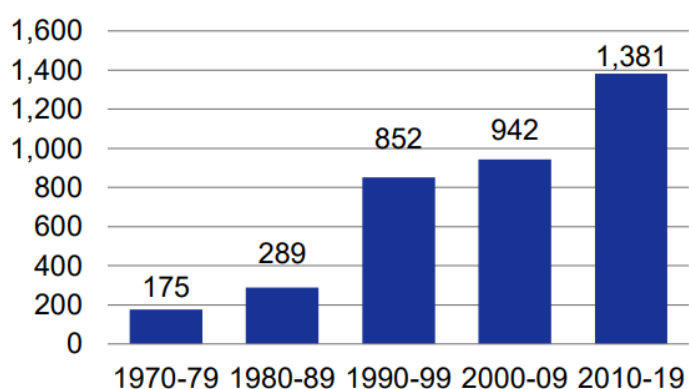
*This Policy Note is based on the publication "[Climate stress tests: Are banks fit for the green transition?](#)" by Ursula Walther (Editor: Jan Schildbach), Deutsche Bank Research, January 2023.

Financial system vulnerabilities to climate risks

Climate change has moved high on the agenda of financial institutions, regulators and supervisors. The looming risk of unabated global warming has once again been brought to the fore by last year's heatwaves, droughts and floods across the globe. Over the last 50 years, the number of climate-related natural hazards has increased fivefold, and the associated economic losses have grown by a factor of eight (Chart 1).¹ Losses and damages from climate change were also a key issue at the recent COP27 climate conference, resulting in an agreement to install a fund to compensate the most vulnerable countries.

Chart 1: Climate-related losses growing significantly

Reported economic losses from weather, climate, and water related hazards, in USD bn*



* in 2018 prices

Sources: WMO (2021), Deutsche Bank Research

Against this backdrop, banks and financial supervisors have started to look at the resilience of the financial system towards climate risks. Given the long-term nature of climate change, climate stress tests or scenario analyses have emerged as a key tool for such assessments. A recent survey among supervisory authorities² counted 67 completed, ongoing or planned climate stress tests. For example, in September 2022, the Fed announced that six large US banks will participate in a pilot climate scenario exercise this year. In Europe, the latest example is the ECB climate stress test (CST) conducted in the first half of 2022.

This paper will take a closer look at climate stress tests with a focus on the 2022 ECB CST, but also include scenario analyses from other major supervisory authorities. Comparing these exercises yields key findings about banks' exposure to climate risks as well as potential implications for financial stability.³

Banks' exposure to climate risks

Global warming as well as measures to address it involve **two types of climate risks** for financial and non-financial companies:

- **Physical risk** stemming from changes in weather and climate. This includes acute risks such as floods, droughts, heatwaves and wildfires as well as chronic risks like rising temperatures and sea levels.
- **Transition risk** arising from (i) changes in climate policies, (ii) emergence of new technologies and increasing affordability of low-carbon technologies, and (iii) changes in investor and consumer preferences.

¹ World Meteorological Organization (2021). WMO atlas of mortality and economic losses from weather, climate and water extremes (1970-2019). WMO-No. 1267.

² FSB/NGFS (2022). Climate scenario analysis by jurisdictions. Initial findings and lessons. November.

³ For an investor view on sustainability considerations for European banks, including takeaways from the 2022 ECB CST, see Deutsche Bank Research (2022). ESG for European Banking. Financing the future. November.

Physical risk is closely linked to geography. The 2021 ECB economy-wide climate stress test⁴ found that banks' exposure to physical risk is particularly high in Southern European countries (e.g. Greece, Portugal and Spain; Chart 2). In these countries, banks have more than 60% of their loans to non-financial corporates (NFC) exposed to high physical risk. It is important to note that most euro-area banks predominantly lend to domestic counterparties (except for banks located in Luxembourg and Ireland). For the euro area as a whole, 22% of NFC loans are subject to high physical risks, notably wildfires and floods. Insurance is an important mitigating factor for losses caused by natural hazards. However, there appears to be a significant protection gap, with insurance coverage for only 35% of past losses caused by extreme weather events across Europe.⁵

Chart 2: Banks' exposure to physical risk - strongly concentrated on Southern Europe

Share of NFC loans which are exposed to physical risk, in %

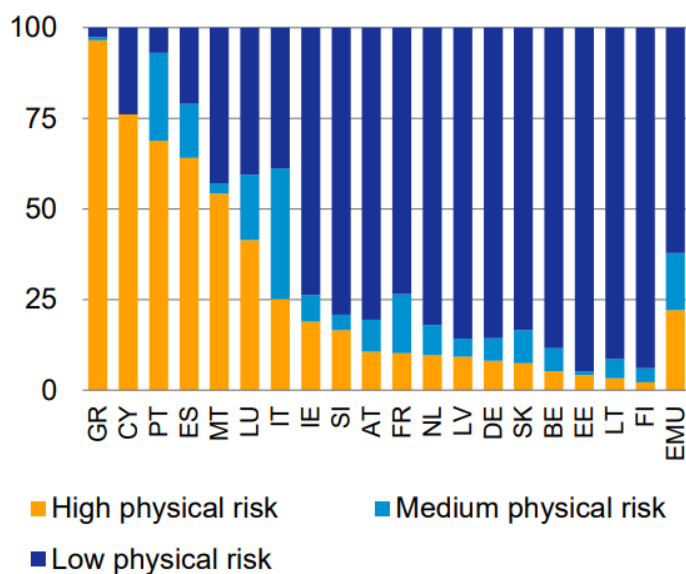
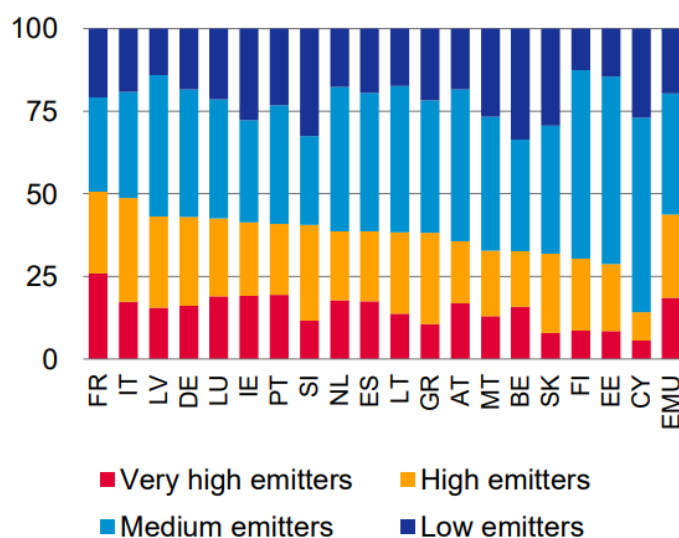


Chart 3: Banks' exposure to transition risk - similar across the euro area

Share of NFC loans which are exposed to transition risk, in %



Sources: 2021 ECB economy-wide climate stress test, Deutsche Bank Research

Transition risk mainly stems from loans to carbon-intensive sectors – a small part of banks' total portfolio. Transition risk is usually determined via a counterparty's carbon footprint⁶ or economic sector. According to the 2021 ECB economy-wide CST, more than 40% of euro-area banks' total NFC loans are granted to high emitters, with little variation across countries (Chart 3). A closer look, however, shows that emission levels vary greatly among carbon-intensive sectors (Chart 4). Overall, loan-financed emissions concentrate in a rather small portion of banks' loan books. An ECB/ESRB study estimates that the 15 most polluting sectors⁷ are responsible for two-thirds of loan-financed emissions, while they account for only 11% of total NFC loans. Moreover, loans to high-emitting industries are fairly concentrated within the banking sector. Among the 1,600 banks analysed in the 2021 ECB economy-wide CST, the 10% of banks with the most polluting portfolios financed 65% of emissions, while representing only 30% of total NFC loans. This points to a greater exposure of larger banks to transition risk. Similarly, according to the 2022 ECB CST, global systemically important banks (G-SIB) and

⁴ This top-down exercise analysed the resilience of 1,600 euro-area banks towards climate risks, using a comprehensive dataset pulled together from different statistics. For more details, see Alogoskoufis et al. (2021). ECB economy-wide climate stress test. ECB Occasional Paper 281. September.

⁵ EIOPA (2022). European insurers' exposure to physical climate change risk. Potential implications for non-life business. May.

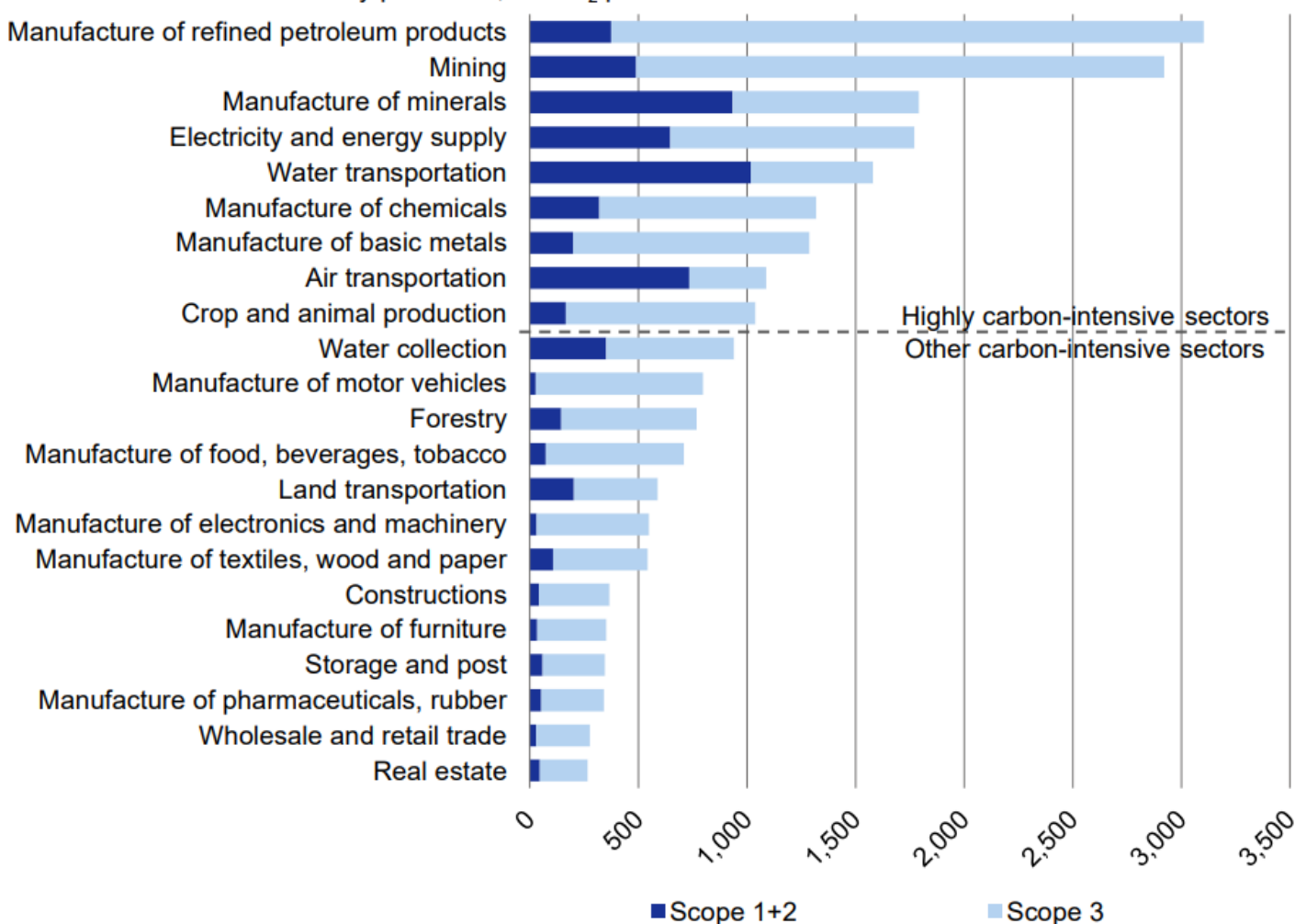
⁶ Either absolute level of greenhouse gas (GHG) emissions or emission intensity, i.e. emissions relative to revenues.

⁷ Based on scope 1 and 2 emissions; sectors not identical to those in Chart 4. For more details see ECB/ESRB (2021). Climate-related risk and financial stability. July.

universal banks tend to be more exposed to highly carbon-intensive sectors⁸ than other types of banks. Moreover, these sectors on average stood for 21% of banks' interest income from their NFC business. All 22 carbon-intensive sectors listed in Chart 4 account for even 60% of interest income from the NFC business.

Chart 4: Carbon-intensive sectors: Transition risk varies greatly

Median GHG emission intensity per sector, in tCO₂ per EUR million of revenue*

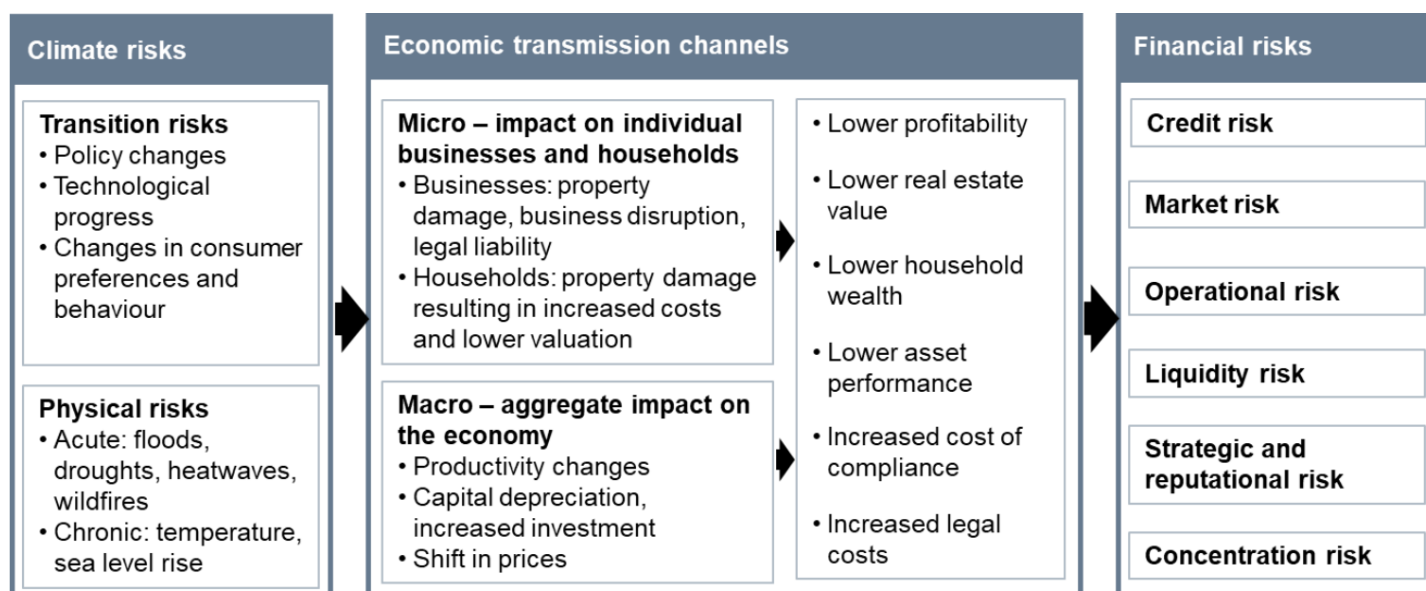


*ECB calculations based on GHG emission intensity reported by banks for the 15 largest exposures in each sector. Sources: 2022 ECB CST, Deutsche Bank Research

How do climate risks affect banks? The materialisation of climate risks can have a significant impact on households and firms and thus on banks through their loan exposures and asset holdings (see Chart 5). For example, floods can cause damage to buildings and disrupt production. For banks, this could erode the value of collateral and increase the probability of default of their customers. Importantly, transmission channels are multi-layered. So far, climate stress tests mostly focus on the NFC loan portfolio and credit risk. Some also include mortgages and/or market risk.

⁸ Sectors with a GHG emission intensity above 1,000 tons of CO₂ (tCO₂) per EUR million of revenue (see Chart 4).

Chart 5: How do climate risks translate into financial risks?



Sources: Deutsche Bank Research based on EBA and NGFS

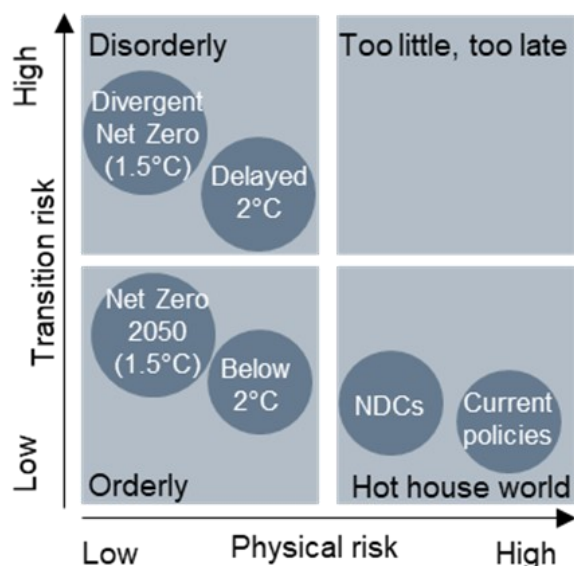
Climate stress tests – how prepared are banks for the transition?

A novel form of stress testing. Climate stress tests help analyse banks' vulnerability to climate risks. In contrast to economic shocks modelled in traditional stress tests, these novel exercises include different climate shock scenarios. Further differences to traditional stress tests are:

- Climate stress tests are so far declared **learning exercises** for banks and supervisors. Their results thus do not (yet) have direct implications for banks' capital requirements.
- Climate stress tests cover a much longer **time horizon of up to 30 years** given the anticipated long-term effects of climate change. They are usually based on **scenario analysis** in a framework developed by the Network for Greening the Financial System (NGFS, see Chart 6). It includes three main scenarios, outlining possible paths for future climate policy:

- an orderly transition scenario which entails an early and swift implementation of climate policies to achieve climate targets by 2050 (modelled mainly through a gradual increase in carbon prices),
- a disorderly transition scenario with a delayed introduction of policy measures to achieve climate targets by 2050 (sudden and steep hike in carbon prices),
- a “hot house world” scenario with no further policy action.

Chart 6: NGFS Scenario Framework



Note: Circles represent scenarios based on different climate targets and policies. NDC = Nationally Determined Contribution.

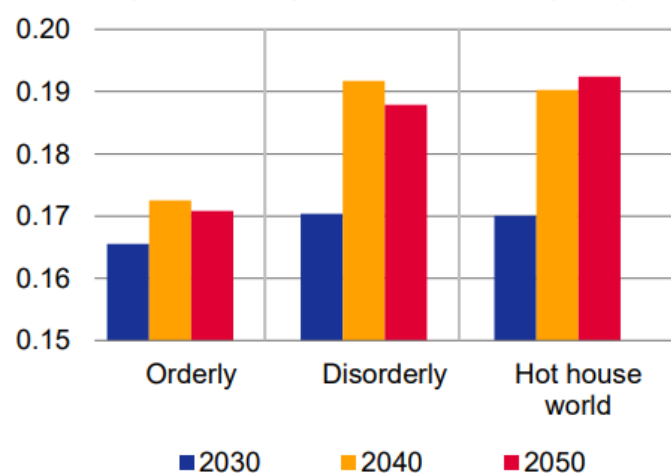
Sources: NGFS, Deutsche Bank Research

The last scenario carries high physical risk, as climate change remains largely unabated. By contrast, the disorderly transition scenario entails high transition risk, as drastic policy measures may be required to still achieve climate goals. In an orderly transition, both physical and transition risks are assumed to be moderate.

Results: Climate risk losses sizeable but manageable for banks

**Chart 7: 2022 ECB climate stress test:
Lowest losses in orderly transition scenario**

Projected credit losses per decade, in % of performing exposures (NFC loans and mortgages)



Sources: 2022 ECB CST, Deutsche Bank Research

Long-term scenario analysis. The results of long-term NGFS scenario-based analyses are rather straightforward. They all conclude that banks' expected credit losses would be lower under an orderly transition than under a disorderly transition or a "hot house world" scenario. However, the magnitude of the estimated effects varies across exercises due to differences in model calibrations and scope.⁹ In the 2022 ECB CST, the 41 banks participating in the scenario analysis projected that, by 2050, overall credit losses in the NFC loan and mortgage portfolio would be 10% higher under a disorderly than under an orderly transition. In a "hot house world" scenario, they would be 13% higher (see Charts 7 and 8). In a similar – but not directly comparable – exercise of the Bank of England (BoE)¹⁰, a disorderly transition was estimated to entail 30% higher credit losses than an orderly transition. The findings from large-sample top-down exercises point in the same direction. For example, the 2021 ECB economy-wide CST projected that credit losses would be 3.5% higher under a disorderly than under an orderly transition and 8% higher in a "hot house world" scenario.

⁹ FSB/NGFS (2022) provides an overview of the different modelling approaches.

¹⁰ BoE (2022). Results of the 2021 Climate Biennial Exploratory Scenario. May. Seven large UK banks participated.

Chart 8: Results of selected long-term NGFS scenario-based analyses (2020-50)

Climate stress test	Scope	Approach	Main results – evolution of banks' NFC credit portfolios under different climate scenarios
ECB (2022a), climate risk stress test	104 SSM banks, 41 of which were requested to submit scenario projections	Bottom-up	- Compared to an orderly transition, banks' credit losses* by 2050 are projected to be 10% higher in a disorderly transition and 13% higher under a "hot house world" scenario.
BoE (2022), Climate Biennial Exploratory Scenario	7 large UK banks, accounting for about 70% of bank lending	Bottom-up	- Compared to an orderly transition, banks' credit losses* by 2050 are projected to be 30% higher in a disorderly transition and 50% higher under a "hot house world" scenario. - On average, this would reduce annual profits by 10-15%.
ECB (2021), economy-wide climate stress test	1,600 euro-area banks, accounting for about 80% of NFC lending	Top-down	- Compared to an orderly transition, banks' credit losses by 2050 are projected to be 3.5% higher in a disorderly transition and 8% higher under a "hot house world" scenario.
ECB/ESRB (2022), climate stress and scenario analysis ¹¹	2,300 euro-area banks	Top-down	- Compared to a "hot house world" scenario, projected credit losses in an orderly transition would be 14% higher by 2030, but then decrease steadily and be 27% lower by 2050. In a delayed transition, losses would be 13% higher by 2030, but then decrease steadily and be 15% lower by 2050.

Note: Due to differences in methodological approaches and scope, the results are not directly comparable.

**NFC loans and mortgages.*

Source: Deutsche Bank Research

Short-term climate shocks. Some climate stress tests also include short-term stress scenarios. They help capture the effects of a sudden climate-related shock that would be smoothed out in long-term projections. The short-term scenarios often contain (1) shocks stemming from extreme weather events, and (2) shocks triggered by a sudden and sharp hike in carbon prices. However, it is even more difficult to compare these short-term exercises than the long-term NGFS-based analyses because they do not build on a consistent framework. Moreover, physical risk scenarios highly depend on local conditions. In the 2022 ECB CST, the 41 participating banks estimated overall credit and market risk losses of EUR 70 bn for three short-term stress scenarios combined (Chart 9). According to the ECB, this might underestimate the magnitude of the actual risk, especially since the climate stress scenarios do not include a simultaneous economic downturn. A sudden carbon price shock would hit banks much harder (projected losses of 0.7% of outstanding corporate loans) than a shock caused by an extreme weather event (0.004%), a recent top-down projection for euro-area banks by the ECB/ESRB points out. This rather negligible effect of physical risk in the short term stands in stark contrast to its potential magnitude in the long term. In this regard, the CST by the Hong Kong Monetary Authority (HKMA) provides some insights. It assumes climate conditions projected for 2050 in a "hot house world" scenario (higher sea level and temperatures) and analyses the short-term impact of typhoons and floods on banks under these conditions. These hazards would notably impact residential mortgages, for which the participating banks project a 25-fold increase in expected credit losses.

¹¹ ECB/ESRB (2022). The macroprudential challenge of climate change. July.

Chart 9: Results of selected short-term climate stress scenario analyses

Climate stress test	Scope	Approach	Short-term climate stress scenarios	Main results
ECB (2022a), climate risk stress test	104 SSM banks, 41 of which were requested to submit scenario projections	Bottom-up	<ul style="list-style-type: none"> - Physical risk stress scenario 1: Flood risk scenario (1-year time horizon); modelled via a shock to commercial and residential real estate prices depending on flood risk - Physical risk stress scenario 2: Drought & heat risk scenario (1 year); modelled via a labour productivity shock - Transition risk stress scenario (3 years): Sudden and sharp increase in carbon prices 	<p>Aggregated across all scenarios, credit and market risk losses for all participating banks would amount to around EUR 70 bn.</p> <p>Under the transition risk stress scenario, banks project an increase of 73 bp in cumulative impairments compared to the baseline.</p>
ECB/ESRB (2022), climate stress and scenario analysis	2,300 euro-area banks	Top-down	<ul style="list-style-type: none"> - Physical risk stress scenario 1: Extreme flood event; production interruption and damage to assets and properties - Physical risk stress scenario 2: Long heatwave period; modelled via a labour productivity shock - Transition risk stress scenario: Sudden and sharp increase in carbon prices <p>5-year time horizon for all scenarios</p>	<p>Physical risk stress scenarios: Peak losses of 0.004%/0.003% of outstanding corporate loans under an extreme flood/long heatwave period.</p> <p>Transition risk stress scenario: Losses of 0.7% of outstanding corporate loans. This is seven times more than projected peak losses from the same shock under a long-term disorderly transition scenario.</p>
HKMA (2021), pilot banking sector climate risk stress test	27 banks, accounting for 80% of total lending	Bottom-up	<ul style="list-style-type: none"> - Physical risk scenario based on Hong Kong's climatic condition in 2050 under a high emission pathway; increased likelihood of typhoons and floods (1 year, aggregate of the worst annual impact projected by the participating banks) 	<p>Expected credit losses from residential mortgages to increase 25 times to HKD 17.3 bn, compared to HKD 0.7 bn in Q4 2020.</p> <p>Annual operational losses from damaged own premises estimated at HKD 2.2 bn, equivalent to 0.8% of banks' profit before tax in 2019.</p>

Source: Deutsche Bank Research

Key takeaways. Despite the differences in approach and scope, all climate stress tests reach similar qualitative conclusions:

- **The materialisation of climate risk can have a sizeable impact on bank profitability.** In the short term, transition risk tends to be an important source of financial risk. Especially the current energy crisis and some countries' decision to resort to coal and other fossil energy sources has increased the risk of a disorderly transition scenario becoming reality – including heightened transition risks. Physical risks are relevant too, but currently mostly associated with local extreme weather events. Thus, they seem to be more manageable in the short term, at least for large banks. In the long term, however, if global warming continues unabated, physical risk will gain weight as the likelihood of extreme weather events increases and higher temperatures could affect the economy on a larger scale (e.g. decline in labour productivity due to high temperatures).

- **Banks should be able to absorb climate-related losses due to strong capital buffers.** However, we believe these results should be taken with a grain of salt as they face several limitations with respect to data and modelling. They may cause the exercises to underestimate the vulnerability of financial institutions to climate risks. In this context, the FSB and NGFS warn of tail risks that “may not be as manageable”.¹²

Limitations of climate stress tests. These results are rather preliminary and subject to several limitations:

- **Deep uncertainty and high complexity:** The long-term and potentially nonlinear nature of climate change (i.e. possible tipping points) and complex chain of effects make it difficult to model future transition pathways. The NGFS scenario approach clearly helps to reduce complexity, but uncertainty remains high.
- **Data gaps** reduce the accuracy of the projections. Key counterparty data such as the level of greenhouse gas emissions is not readily available. In the 2022 ECB CST, banks overall estimated 70-85% of their counterparty emission data. Furthermore, estimated Scope 3 GHG emissions of a particular company vary greatly among the participating banks. With respect to physical risk, there is a lack of precise geocoded data and banks often do not have information on different business locations of large counterparties.
- **Modelling constraints:** Most climate stress tests make simplifying assumptions such as static balance sheets and they often do not estimate second-round effects.

Initial climate stress tests are just the beginning

Not a one-off exercise. Currently, more than 30 climate stress tests are in the making or planned¹³ and others will follow. These will add further insights about the impact of climate risks on financial institutions and related vulnerabilities of the financial system. Most importantly, they will help refine the methodology, develop more coordinated and comparable exercises and address data gaps. The move towards more standardised and increasingly mandatory disclosures of *corporate* ESG metrics will support this. Key initiatives are (1) the proposed ISSB climate-related disclosure standard set to be finalised in early 2023, (2) the EU Corporate Sustainability Reporting Directive (CSRD) that entered into force in January 2023, and (3) in the US, the climate disclosure rules proposed by the SEC in March 2022.¹⁴

In the meantime, banks themselves will be busy building up climate stress-testing capabilities. In the 2022 ECB climate stress test, about 40% of the 104 participating banks indicated that they have a climate stress-testing framework in place. Even in most of these banks, however, it was not integrated into the internal capital adequacy assessment framework (ICAAP) or the broader stress-testing framework. Almost all banks without a climate stress-testing framework aim to develop one over the coming years. Thereby, they can build on experiences from past exercises. The ECB has published a collection of “good practices” from the 2022 CST.

¹² FSB/NGFS (2022, p. 23).

¹³ FSB/NGFS (2022).

¹⁴ For more details, see Walther, Ursula, and Jan Schildbach (2022). Sustainable finance – coming of age. Deutsche Bank Research, EU Monitor. September 2.

Banks are under pressure to set up comprehensive climate risk management. In parallel to climate stress tests, supervisors are issuing guidelines urging banks to actively manage climate risks. These include:

- the ECB’s “Guide on climate-related and environmental risks” published in 2020;
- the Fed’s “Principles for climate-related financial risk management for large financial institutions” (i.e. institutions with over USD 100 bn in assets) proposed in December 2022;
- the Basel Committee’s “Principles for the effective management and supervision of climate-related financial risk” presented in June 2022.

All of these ask banks to integrate climate risks into their strategy, governance and risk management (including conducting climate stress tests). A recent review by the ECB¹⁵ reveals visible progress, with now 85% of supervised banks addressing the areas listed in the ECB guide. Still, it found implementation flaws at 55% of banks and blind spots in the assessment of climate risk exposures at almost every bank (96%). As a consequence, the ECB expects most institutions to further enhance their climate risk management and has set 2024 as a (rather ambitious) deadline to meet supervisory expectations (see Chart 11).

Chart 11: ECB banking supervision initiatives on climate and environmental risks

Date	Action
Nov. 2020	Issuance of the supervisory expectations “Guide on climate-related and environmental risks” (C&E risks)
Sep. 2021	Results of the economy-wide (top-down) climate stress test
Nov. 2021	Results of the supervisory review of banks’ C&E risk management approaches (self-assessment by banks); banks submitted action plans on how to align their practices with supervisory expectations
Mar. 2022	Report on the supervisory assessment of banks’ C&E risk disclosures
Jul. 2022	Results of the bottom-up climate stress test
Oct. 2022	Results of the thematic review on banks’ progress towards the ECB expectations on C&E risk management, incl. good practices
Dec. 2022	Report on good practices for climate stress-testing frameworks
2022	Integration of the qualitative stress-test results into SREP
Mar. 2023	ECB expects banks to categorise C&E risks and to assess their impact on bank activity
End-2023	ECB expects banks to include C&E risks in their governance, strategy and risk management
End-2024	ECB expects banks to be fully compliant with the expectations (incl. integration of C&E risks into ICAAP and climate stress testing)

Note: Actions related to climate stress tests are highlighted in blue.

Sources: ECB, Deutsche Bank Research

¹⁵ ECB (2022b). Walking the talk. Banks gearing up to manage risks from climate change and environmental degradation. Results of the 2022 thematic review on climate-related and environmental risks. November.

Including climate risks in the capital framework? Given they are designed as learning exercises, climate stress tests so far have had no *direct* implications for capital requirements. However, the ECB has included qualitative findings from the 2022 CST and its thematic review on C&E risk management in its 2022 Supervisory Review and Evaluation Process (SREP). For a few banks, this impacted their SREP scores and hence their Pillar 2 capital requirements.¹⁶ In the UK, the Prudential Regulation Authority (PRA) expects banks to capitalise climate-related financial risks, and it could also require an additional buffer if it deems a bank's risk management inadequate.¹⁷

Beyond that, there is an ongoing discussion about whether and how to include climate risks in the prudential framework. Ideas range from adjusting the Pillar 1 framework to introducing macroprudential climate buffers.¹⁸ Such measures are only conceivable in the medium term. Due to the limitations in data availability and methodological challenges, the results of climate stress tests do not yet provide a robust basis for prudential measures.¹⁹ Most importantly, although such measures may help mitigate the impact of climate risks on financial stability, the risks themselves can only be addressed with timely and ambitious action to combat climate change itself. ■

¹⁶ Ibid.

¹⁷ PRA (2021). Climate-related financial risk management and the role of capital requirements. Climate change adaptation report 2021. October.

¹⁸ For an overview, see IIF (2022). Climate and Capital: Views from the Institute of International Finance. July.

¹⁹ See also FSB/NGFS (2022) and Sustainable Fitch (2022). What investors want to know: bank climate stress test and credit. February 8.

About the author

Ursula Walther is a Research Associate at Deutsche Bank Research. Her recent work focuses on financial markets, sustainable finance as well as European and German politics. Before joining Deutsche Bank in 2022, she was a Senior Research Analyst at Evalueserve in Mumbai and Consultant at Ecoplan in Bern (Switzerland). Ursula holds a master's degree in political science with a minor in economics from the University of Bern.

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c/o OeNB
Otto-Wagner-Platz 3
A-1090 Vienna, Austria
Phone: +43-1-40420-7206
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