Network for Greening the Financial System

Technical document

Conceptual note on short-term climate scenarios

October 2023

NGFS

Central Banks and Supervisors

Network for Greening the Financial System

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Acknowledgements

The technical document *Conceptual note on short-term climate scenarios* is a collaborative effort of the members of the NGFS Workstream on Scenario Design and Analysis. This document was prepared under the auspices of the Chair of the Workstream, Livio Stracca (ECB). The drafting of the document was coordinated and led by Laura Nowzohour (ECB) and Stéphane Dees (Banque de France), serving as co-leads of the sub stream on short-term scenarios, with support from the chair's team (Martina Spaggiari, Laura Parisi, Mario Morelli, Paula González Escribano and Claudia Albers) and the NGFS Secretariat (Paul Champey, Jacques De la Rue Du Can, Anke Kablau and Clément Payerols).

This document relies on the analysis and drafting work of a dedicated team composed of Workstream members. The NGFS is especially thankful to the drafting team: Maria Alessia Aiello (Banca d'Italia), Pietro Cova (Banca d'Italia), Stéphane Dees (Banque de France), Philipp Haenle (Bundesbank), David Gayle (Bank of England), Samuel Hurtado (BdE), Chiara Lelli (ECB), Iana Liadze (NiESR), Federico Lubello (Banque Centrale du Luxembourg), Laura Nowzohour (ECB), Miroslav Petkov (BIS), Nadezda Sinenko (Bank of Latvia), Azusa Takeyama (Bank of Japan), Robert Vermeulen (DNB), Pascal Weel (FRB), and Sha Yu (IMF).

The authors would like to thank Jean Boissinot (NGFS Secretariat), Theresa Lober (BoE; Chair's team of NGFS Workstream on Monetary Policy), Michelle Van der Merwe (BoE; Chair's team of NGFS Workstream on Monetary policy), and the members of NGFS Workstream on Scenario Design and Analysis for their helpful inputs and comments.

Executive Summary

Policymakers, regulators and financial institutions are keenly interested in analysing the short-term impact of climate change and mitigation policies on the real economy, individual financial institutions, and the broader financial system. This is particularly important amid heightened uncertainties stemming from fossil energy supply on the one hand and the mounting scientific evidence that the world might surpass an increase in global temperatures compared to pre-industrial times of 1.5 Celcius degrees[1] within the next five years, fuelled by heat-trapping greenhouse gases and a naturally occurring El Niño event. While recognizing the diverse user base of NGFS scenarios, the materialization of transition and physical impacts that are already taking place within the monetary policy and supervisory assessment horizon make short-term scenarios especially worthy of the attention of central banks and banking supervisors. In this context, short-term scenarios are a potentially significant step forward for them to better understand the near-term macro-financial impacts of the green transition and physical risks, owing to an improved understanding of adversity and non-linearities at business cycle frequency, including interdependencies between climate risks and macro-financial developments.

By covering a time horizon of three to five years, short-term scenarios can overcome limitations in macroeconomic and financial risk analysis stemming from the focus on long-term climate-economy relationships as captured in the current NGFS climate scenarios. Specifically, short-term scenarios can account for shocks that have a short-term impact and subside in the medium term (e.g., confidence shocks), allow for a more dynamic translation of shocks to near-term impacts (e.g., non-linearities) and could provide insights into the economic transmission channels (e.g., sectoral shifts). Specifically in the context of supervisory and financial stability focused exercises, their shorter time horizon could allow for the construction of a more realistic baseline, the inclusion of adverse near-term shocks and a sounder use of constant balance sheet or loan portfolio assumptions.[2]

Five different climate scenario narratives are proposed to underpin the short-term dynamics associated with different transition and physical impacts.[3] Three scenarios focus on mitigation efforts and exhibit significant transition risk. Underlying these scenarios is the current environment of elevated uncertainty related to future fossil energy supply, possibly driven by geopolitical tensions, which could lead to an acceleration or a delayed implementation of climate policies, depending on the evolution of public opinion. These scenarios feature stringent climate policy or regulation with different timings and combinations of macro-financial and technology shocks, reflecting their adversity. They are envisaged to be aligned with long-run scenarios that lead to an effective limitation of global warming. Furthermore, one scenario that exhibits high physical risks in the short-term is proposed. Since physical risk is pre-determined in the short-run due to a time lag between climate policy stringency and physical risk impacts, there is no connection between the climate policy stringency assumed in the short-term scenario and the level of physical risk impacts. Rather, this scenario should be interpreted as reflecting the short-run implications of living in a Hot House World (Trust et al., 2023). Lastly, one scenario that exhibits significant transition as well as physical risk is considered. In such a world, only some countries pursue an ambitious climate mitigation policy and thus face transition risks. The realization that mitigation efforts are uneven then leads to a sudden re-assessment of future physical risk impacts globally, due to the overall ineffectiveness of the transition. Such a narrative could be driven by a surge in geopolitical tensions and/or some

1 This does not imply breaching the Paris goal of limiting average global temperature increase to 1.5C, as that goal is commonly interpreted as referring to long-term warming attributable to human influence, and not the added effect of natural climate variability.

2 Note that the term "baseline" here refers to projections of the macro-financial environment in the absence of additional shocks (e.g., a shock-less current policies scenario) with the purpose of providing a reasonable reference to which other scenarios can be compared. No statement as regards its "likelihood" is intended.

3 Since the past is an inaccurate predictor of the future, a key challenge going forward will be the calibration of shocks within the chosen modelling framework. The usual linear relationships may not hold any longer when considering historically unprecedented events, which is an especially relevant point for capturing physical risk.

countries being caught in a recovery trap following severe disasters amid elevated levels of debt.

The narratives not only differ in the source of shocks but could also shed light on different channels, the importance of key model parameters as well as of accompanying fiscal and monetary policy choices. Specifically, while the energy sector and associated prices will play a key role in transmitting the impact of policies to the macro-financial system, food and real estate prices could transmit physical impacts. The size, volatility and persistence of these price effects will depend on the availability of low-carbon substitutes and could thus be an important sensitivity for monetary policy responses. In addition, the choice of fiscal revenue recycling could play an important role here.[4] Given the global nature of NGFS scenarios, there could be substantial geographical and sectoral heterogeneity in these assumptions, depending on the economic structure and level of economic development.

The narratives proposed here have been developed with their primary applications in mind: climate stress testing related to prudential/financial stability and macroeconomic impact assessments related to monetary policy.[5] While both applications require slightly different levels of adversity reflected in the scenarios and different though overlapping sets of output variables, they both require a high level of sectoral and spatial granularity of the output data, which has so far been challenging. A key question going forward is whether NGFS short-term scenarios can provide a one-size-fits-all solution to both applications and whether adapted versions of the scenarios would need to be developed.

The discussion on potential modelling frameworks touches upon the key features of several well-known frameworks, including their advantages and disadvantages with regard to the needs of climate stress testing and macroeconomic impact assessment applications. These models differ from one another in terms of their sectoral detail, their inclusion of key mechanisms from economic theory reflecting the behaviour of economic agents, their closeness to statistical data, and/or the presence or absence of environmental variables. Finally, inclusion of extreme weather events into short-term scenarios via Natural Catastrophe models is discussed.

The purpose of this note is to inform the public on the conceptual framework reflecting the NGFS's thinking on short-term scenarios, ahead of their analytical implementation. It introduces the types of scenario narratives the NGFS intends to work through, followed by a brief commentary on modelling options. The final section contains a practical guide for central banks and supervisors on how to get from a short-term scenario to a climate stress test. In this sense, the note is a hybrid between an *informative* notice on short-term scenarios and a *roadmap* of the analytical work the NGFS will carry out in this vein. It is based on a broad-based effort by members of the NGFS workstream on "Scenario Design and Analysis".

4 While this note proposes a conceptual framework for thinking through the narratives along those lines, the analytical work on macro-financial channels, impacts and interactions with policies currently taking place in NGFS WS3 on Monetary Policy will further inform this work going forward.

5 On monetary policy applications, NGFS Workstream on Monetary Policy views have been considered in this note and a closer collaboration is envisaged for the implementation phase of the short-term scenarios.

Exploring upcoming climate risks: the NGFS's journey towards short-term climate scenarios

Identifying Key Applications

- Climate Stress Testing
- Macroeconomic Impact
- Assessment (eg monetary policy)

Developing Narratives

IN LINE with reaching net zero by 2050

Highway to Paris

Implementation of an ambitious mitigation pathway

Green bubble

Glut of green private investment

Sudden wake-up call

Sudden change in public opinion and accelerated transition

NOT IN LINE with reaching net zero by 2050

Low policy ambition and disasters

Severe acute physical disasters and higher risk premia

Diverging realities

> Severe natural disasters in EMDEs and LICs and lack of external financing

> Disruption of transition-critical mineral supply chains hampering global transition

Translating Stories Into Quantitative Models

- Types of shocks (climate, policy, macroeconomic, financial)
- Timing and compounding of shocks
- Calibration

Assessing Possible Modelling Frameworks

- Spatial and sectoral granularity
- Dynamics and sudden shifts
- Capture second-round effects

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Publication of NGFS conceptual note and preparation of analytical implementation of short-term scenarios

1. Introduction

Why do we need short-term climate scenarios?

Policy makers, regulators and financial institutions are keenly interested in analysing the impact of climate change and mitigation policies on the real economy, individual financial institutions, and the broader financial system.[6] The NGFS long-term climate scenarios, developed by the NGFS together with a modelling consortium, represent an important element of the current analytical toolkit. These scenarios – and the underlying Integrated Assessment Models (IAM) – have been developed to investigate long-term relationships between emissions, carbon prices and global economic variables.[7] The long-term horizon – covering the period up to 2050 in steps of five years[8] – is key to understanding both the costs of the transition as well as the long-term benefits stemming from a reduction of physical risks and devise transition strategies. However, by emphasizing low-frequency long-term dynamics, these scenarios only provide a limited picture of possible transition and acute physical risks in the near-term, their unfolding at higher frequency (typically, on a quarterly basis) and their interaction with business cycle shocks that are important, for example, for central banks in producing macroeconomic analysis in support of their financial stability monitoring and supervisory responsibilities, e.g. via stress tests, but also to inform their monetary policy-making. The lack of variation at business cycle frequency makes the analysis of interdependencies between climate risks and macro-financial developments challenging.

By covering a time horizon of three to five years, short-term scenarios can overcome challenges in macroeconomic and financial risk analysis stemming from the focus on long-term climate-economy relationships as currently captured in the existing NGFS climate scenarios.[9] Specifically, the contrast between short- and long-term scenarios consists not only in the length of the horizon under study but, more importantly, in varying the type of shocks and the timing of plausible events. This is obtained, for example, by considering shocks and implied impacts that are less relevant over longer time periods (e.g., short-term reactions of financial markets or temporary changes in agents' response to policy changes) or by paying more attention to the unfolding of some events which are unlikely to play out progressively and/or smoothly (e.g., sudden changes in the perception of climate risks, materialization of physical risk hazards).

Short-term scenarios are a significant step forward for central banks and supervisors to better understanding the near-term macro-financial impacts of the transition toward a net zero global economy and of severe but already likely physical risks over the next three to five years. Specifically, they can:

- **Account for shocks that have a short-term impact and subside in the medium/long term**, including cyclical factors, like changes in business and consumer confidence, compound shocks and feedback loops.
- **Allow for a more dynamic translation of shocks to near-term impacts** that incorporates the role of expectations and preparedness of the financial system vis-a-vis mitigation policies and climate change itself.
- **Could provide insights into the economic transmission channels**, balance of risks around economic forecasts and projections and potential trade-offs that are relevant for central banks in the context of setting monetary policy and pursuing other objectives.

6 While the NGFS focuses on the needs of its members, which represent a large group of central banks and supervisors, its climate scenarios are used by a much more diverse group of institutions, including governments, firms and financial institutions. The framing of "we" intends to reflect the diversity of the potential user base of NGFS short-term scenarios.

7 Such IAMs are usually solved endogenously in the long run. Either the modeller sets a temperature target – such as 1.5 or 2 degrees – and the model finds an emission price that reduces emissions in such a way that the target is achieved, or the modeller restricts the policy ambition level and thus limits the price for emissions. In such a case, the model solves for the global increase in temperature that can be expected in the long run. Since climate scenarios are solved endogenously for the emission prices when restricting the temperature or for the temperature when restricting the policy ambition level, these scenarios are not a prediction of the future, but rather plausible projections (if-then relationships) given a broad variety of assumptions.

8 The macro-financial variables based on the NiGEM model are available until 2050 (outputs from IAM go out until 2100).

9 The NGFS scenarios portal can be found here.

Specifically in the context of supervisory and financial stability focused exercises, they could:

- **Allow for the construction of a more realistic baseline**, anchored to more accurate projections of the macro-financial environment owing to the shorter time horizon over which the development of economic variables and policies can then be better extrapolated.
- **Allow for the inclusion of plausible and adverse shocks**, which could hamper the safety and soundness of individual firms, financial institutions, and the financial system in the short-term, as well as lead to structural changes in the economy.[10]
- **Allow for a sounder use of constant balance sheet or loan portfolio assumptions in stress testing applications**, which are strong assumptions if applied over long time horizons but substantially reduce complexity for the modeller (and thus are widely used in supervisory bottom-up exercises, financial institutions' internal risk management or corporates' transition planning).
- **Provide an internally consistent international benchmark** to enable regulators, financial institutions, and industry to conduct climate scenario analyses for risk surveillance and climate stress tests in a comparable manner.[11]

There are strong synergies from using short-term scenarios in combination with long-term scenarios. Long-term scenarios provide projections up until climate goals are achieved (or not) and thus provide a necessary anchor for considering the potential impact of a range of global transition plans and whether they meet international targets. In addition, they allow for a more complete assessment of the consequences from past, current and future emissions, particularly in the context of physical risk. In a nutshell, long-term scenarios are indispensable to frame any shorter term scenarios. On the other hand, short-term scenarios allow for the incorporation of tensions in the near term and, relatedly, the exploration of *unexpected* deviations from what is otherwise a typically assumed smooth policy pathway over the longer run. Thus, short-term scenarios offer a glimpse into the possible implications of climate-related *disruptions* in the macro-financial system, which are the main concern from a financial risk perspective.

Finally, the materialisation of transition and physical impacts unfolding within the next few years (i.e. taking place within the monetary policy horizon) make short-term scenarios worthy of central banks' attention beyond risk surveillance and monitoring. This includes studying key interactions between risk drivers (e.g. physical and transition risks), transmission channels as well as feedback loops (e.g. between the real economy and the financial system).

Beyond the central bank and supervisory community, we recognise that there are a range of other beneficiaries from the development of NGFS short-term scenarios. In keeping with the global public good nature of NGFS scenarios, these use cases are recognized and continuously monitored[12] to make sure they are considered in the work of the NGFS and could be accommodated in the design of the scenarios to the extent possible.

What this note contains and the work it reflects

The purpose of this note is to inform about the conceptual framework reflecting the NGFS's thinking on short-term scenarios, ahead of their analytical implementation. It introduces the types of scenario narratives the NGFS intends to work up followed by a brief commentary on modelling options. In this sense, the note is a hybrid between an *informative* notice on short-term scenarios and a *roadmap* of the analytical work the NGFS will carry out in this vein.

Five different climate scenario narratives are proposed to underpin the short-term dynamics associated with different transition and physical impacts. These narratives

10 Specifically, the integration of short-term climate scenarios into capital planning exercises would prepare financial entities for near-future climate-related risks, supporting financial stability and informed decision-making.

11 The increased comparability comes from the fact that users no longer have to derive short-term scenarios themselves (e.g., by compressing the current NGFS scenarios or adding arbitrary shocks). However, differences might still come from the need to complement the scenarios with other data sources and/or downscale them, depending on the level of sectoral/spatial granularity that will be provided.

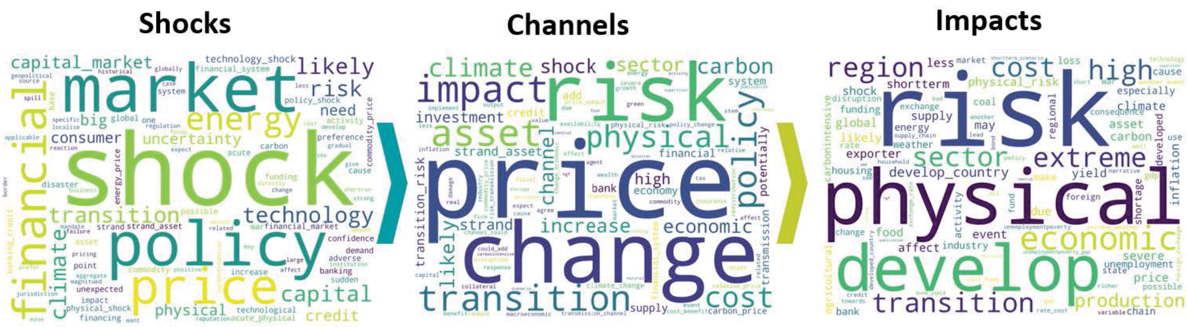
12 For instance, see the NGFS survey results published in Q2 2023 here.

capture the climate and macro-financial risks that have been deemed most relevant by NGFS members both in the context of their applicability to climate stress testing and, as a more emerging field, monetary policy analysis.[13] The use of narratives in this context allows for a mapping between real world risk scenarios and a combination of shocks, transmission channels and expected macroeconomic impacts. The narratives provide a guide for modellers, who will need to translate these scenarios into quantitative model outputs by means of assumptions and shocks.[14] In turn, this yields a set of policy-relevant scenarios grounded in real-life developments.

The proposed narratives differ in their implied level of transition and physical risks.[15] Three scenarios focus on mitigation efforts and are more informative of transition risks. These scenarios feature stringent climate policy with different combinations of macro-financial and technology shocks, reflecting their disorderliness. They are envisaged to be aligned with long-run scenarios that lead to an effective limitation of global warming. Furthermore, one scenario that exhibits high physical risks in the short-term is proposed. This scenario might be especially useful to analyse the implications of unambitious *past* climate policy, reflecting repercussions of higher-than-expected physical risk impacts for the real economy and, as such, for the financial system. Lastly, one scenario that exhibits significant transition as well as physical risks is considered. In such a world, only some countries pursue an ambitious climate mitigation policy and thus face transition risks. The realization that mitigation efforts are uneven then leads to a sudden re-assessment of future physical risk impacts globally, due to the overall ineffectiveness of the transition.

This note[16] is based on a broad-based effort to better understand which shocks, transmission channels and impacts are relevant for short-term scenarios. An internal survey allowed the identification of the main shocks, channels and impacts deemed more relevant (see Figure 1, more results are in Appendix 1). It was complemented by a careful examination of lessons learnt by NGFS Members who had experience developing their own short-term scenarios. The work further focused on the interrelated issues on applications, narratives, shocks and calibration and modelling frameworks (see Figure 2; the arrows represent the logical chain of how the four issues were connected,

Figure 1 **Word clouds from survey for members**



Source: Survey for members of NGFS WS 2 SS2 on short-term scenarios from December 2022.

13 While these five narratives capture a wide array of adverse but plausible futures, they are not claimed to be exhaustive. Feedback regarding blind spots is very much welcome.

14 A modelling team/modelling teams to implement the NGFS short-term scenarios will be selected in Q3 2023.

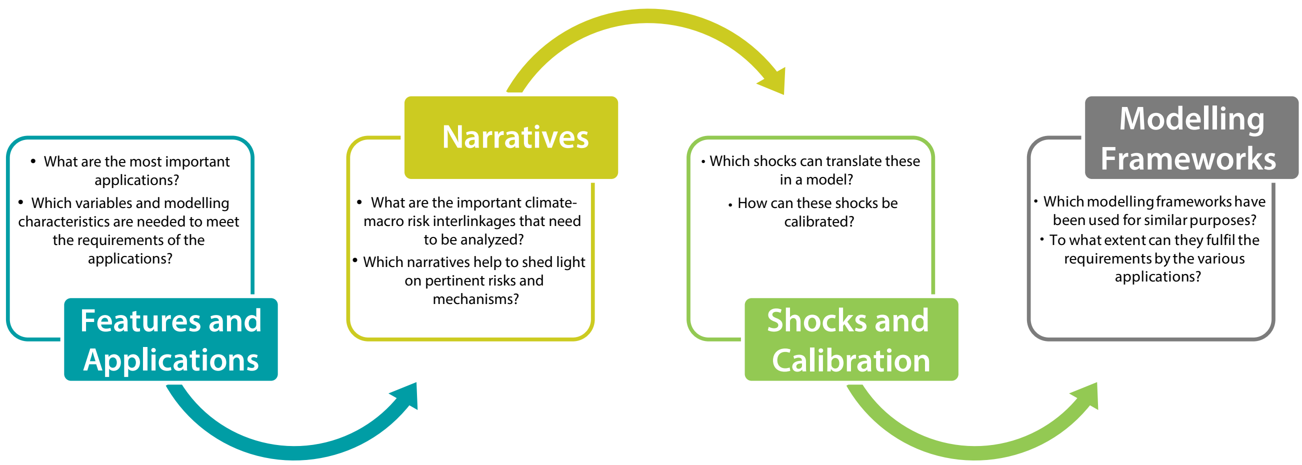
15 Note that physical risk is pre-determined in the short-run due to a time lag between climate policy stringency and physical risk impacts. Thus, there is no connection between the climate policy stringency assumed in the short-term scenario and the level of physical risk impacts. Rather, each scenario is assumed to describe a deviation from a long-term scenario path (e.g. NGFS long-term scenarios) that drives the level of physical risk.

16 The note was prepared by the "short-term scenarios" sub-group of the NGFS Workstream on "Scenario Design and Analysis".

rather than implying a direct dependence).[17] While this note takes stock of the work to date and mainly focused on the framing of short-term scenarios, their analytical implementation will start in the fall of 2023, following an open call for expression of interest to modelling teams and a selection procedure.[18]

The remainder of this note is structured as follows. Section 2 details the five proposed narratives for short-term scenarios, including related shocks, channels, and some conjectures on the macro-financial impacts. Section 3 covers potential applications of short-term climate scenarios and discusses the various requirements they would ideally need to fulfil, such as needed output variables, required levels of disaggregation as well as the characteristics of a potential baseline scenario.[19] Section 4 gives an overview over the various possible modelling approaches that can be used for implementing the short-term scenarios, including how they fare vis-à-vis the requirements identified in the applications section. Section 5 offers a preliminary, high-level guide on how to conduct a climate stress test starting from a short-term scenario.[20] The note concludes by laying out the way forward. In the Appendix, some additional Tables as well as case studies that have already investigated climate-related risks in the short run are presented.[21] This section is designed to be a stock-take with initial experiences that provided the foundation for our work.

Figure 2 **Design process of short-term climate scenarios**



17 For instance, having a clear idea of the most important applications guided out thinking on which narratives would usefully cater to these applications. The narratives underpinned our thinking on shocks and how these might be reasonably calibrated, while the modelling frameworks brainstorming was, among other things, based on the type of narratives and shocks it would need to be able to capture.

18 The NGFS press release and the Call for Expression of Interest can be found here.

19 Note that the term "baseline" here refers to projections of the macro-financial environment in the absence of additional shocks (e.g., a shock-less current policies scenario) with the purpose of providing a reasonable reference to which other scenarios can be compared. No statement as regards its "likelihood" is intended.

20 A more comprehensive guide is envisaged for after scenario publication.

21 Case studies were provided by NGFS Members. NIESR has also been included in this exercise since they are already a member of the current NGFS modelling consortium.

2. Narratives

The narratives envisaged for the NGFS short-term scenarios entail not only climate-related shocks but also additional short-run shocks in the macro-economy that interact with climate shocks. In fact, this is their main value-added compared to the existing NGFS long-term scenarios, which are more geared to capturing long-term relationships and trade-offs.

2.1 What is a short-term climate scenario narrative?

A scenario is a description of a possible path into the future under a given set of assumptions, encompassing both quantitative and qualitative elements (Foster, 1993). Such a description requires "a story with plausible cause and effect links that connects a future condition with the present, while illustrating key decisions, events, and consequences throughout the narrative" (Glenn, 2000). Scenarios are not predictions but reflect possible and often adverse future outcomes based on "internally consistent and challenging narrative descriptions of possible futures" (van der Heijden, 2005). Scenarios are also often designed with different purposes in mind, with some seeking to provide an advice to decision makers by describing the best course of actions toward a given objective (i.e. normative scenarios) and others are mainly trying to describe various possible futures irrespective if their desirability (i.e. positive scenarios, Boissinot and Heller, 2020).

An individual scenario without a baseline is less informative. However, taken together, a set of scenarios allows for useful comparative analyses of the future under different assumptions. This is extremely useful in analyzing (tail) risks and especially adverse outcomes, which standard economic models fail to capture. Moreover, it also helps policymakers better understand the balance of risks around their central forecasts and the extent to which the crystallization of certain risks might change the projected outlook. In the case of short-term climate scenarios, each individual narrative is therefore an alternative description of how the future may unfold associated with a combination of changes in socio-economic, policy, technological, and climate assumptions (Mallampalli et al., 2016) and their impact on the future state of key climate, macro-financial variables.

Short-term climate scenarios first require specifying the timing of shocks as well the horizon over which they unfold, likely reflecting time spans relevant to central banks, supervisors, and financial institutions. For instance, for inflation-targeting central banks, this reflects the time horizon over which the primary objective of price stability should be pursued.[22] For financial stability, stress-testing exercises usually use a three-to-five-year horizon. For the purpose of NGFS short-term scenarios, the narratives will span a horizon of three to five years, reflecting the shock impact as well the subsequent years when key variables return to their pre-shock, long-term reference scenario.[23] Each narrative is based on selected key drivers: a policy decision or lack thereof (e.g. increase in carbon pricing, implementation of environmental regulation), and the associated response by households (e.g. preference for green goods, higher savings due to uncertainty), firms (innovation in green technologies that fosters productivity), and the financial system (e.g. repricing of assets which strand or the bursting of a green bubble). Alternatively, some scenarios feature the climate as a key driver (e.g. increased incidence and severity of acute physical risk). When narratives combine several drivers in the same storyline (which might be useful to better understand correlations and the compounding impact of shocks), consistency across drivers is essential, to avoid implausible outcomes (e.g., a disorderly transition with low risk premia in financial markets). Given that these changes occur in the short term, the chronology of events is also critical to the narrative. For instance, an immediate policy-related event could be followed by a change in behavior with some delay. In contrast to the long-term scenarios, short-term scenarios make the interactions between the various drivers and cause-effect links more explicit.

22 In line with NGFS Workstream on Monetary Policy, a 2- to 3-year horizon would be most appropriate for such applications. However, in practice, this horizon is not clearly defined by central banks and can vary across jurisdiction as it depends on the structure of the economy, the weight of price stability in the society's objective function, the degree of "forward-lookingness" in the economy or the slope of the Phillips curve (see Smets, Frank, 2000. "What horizon for price stability," Working Paper Series 24, European Central Bank).

23 Note that shocks might differ in their persistence. For instance, acute physical impacts in AEs are expected to be resolved faster than in EMDEs. The narratives aim to account for this heterogeneity.

Another challenge when it comes to climate change is that the past is an inaccurate predictor of the future and usual linear relationships may not hold any longer when considering historically unprecedented events. To account for such non-linearities, additional shocks are sometimes included. These may lead to a deviation of key variables from their historical relationship and generate additional stress. In doing so, the aim is to reflect future uncertainties and cater to the needs of climate stress testing applications – a type of exercise that requires narratives to err on the side of caution in the face of substantial uncertainty.

Although primarily qualitative, the description of a scenario can also provide insights into the severity of events. For example, the assumption that a scenario remains consistent with climate targets induces some degree of carbon price increase; conversely, deviating from climate targets affects the potential severity of longer-term physical risks (as the long-term tradeoff between climate policy ambition and physical risk is not present within a 3-5 year horizon). In all cases, the plausibility of the short-term scenarios must be compatible with credible references that take the interaction between economic and climate systems into account. If short-term scenarios deviate from the long-term pathways over shorter horizons, all macro-financial variables should nevertheless converge again towards a credible long-term baseline once the shocks have been absorbed by standard attenuation mechanisms (policy reactions or agents' behavior). The contrast between short- and long-term scenarios consists therefore of varying the timing of plausible events, making some events more frontloaded or considering likely additional effects that are ignored over longer time periods (e.g., short-term reactions of financial markets or temporary changes in agents' response to policy changes).

Finally, one way to address the large degree of uncertainty surrounding the macro-financial impacts of climate-related risks under different transition paths is to consider several short-term scenarios. This diversity mainly reflects the different nature of the key drivers, some of which primarily affect the supply side of the economy (e.g., carbon prices which increases production costs or technological innovation), while others may be associated with demand-side drivers (e.g., public spending on green infrastructure or reduced consumption due to uncertainty in transition policies). Such diversity covers multiple use-cases and provides a range of macro-financial outcomes that can be useful in assessing the macroeconomic and financial stability implications of climate-related risks.

2.2 Five narratives to sketch out plausible adverse futures

This note proposes five short-term scenarios[24] with a three to five-year horizon[25] capturing a mix of transition and physical impacts and their interaction with the macroeconomy and financial sector[26]. The scenarios capture the main sources of downside risks to an effective and timely transition (see Table 1). Note that a key difference to the framework of long-term scenarios is that there is no tradeoff between transition and physical risk *in the short run*, in the sense that physical risk is pre-determined within the 3-5 year horizon we envisage for the short-term scenarios. Still, they can be seen as describing short-run fluctuations around the NGFS long-term scenarios within the known quadrants reflecting an "orderly" transition, a "disorderly" transition, a "hot-house-world" long-term equilibrium or an ineffective "too-little-too-late" adjustment path, as shown in Figure 3. The novelty of these short-term scenarios is that they combine a given climate mitigation stringency with relevant short-run business cycle shocks and dynamics, enabling financial actors to properly assess the resilience of the financial sector to climate-related financial risks.[27]

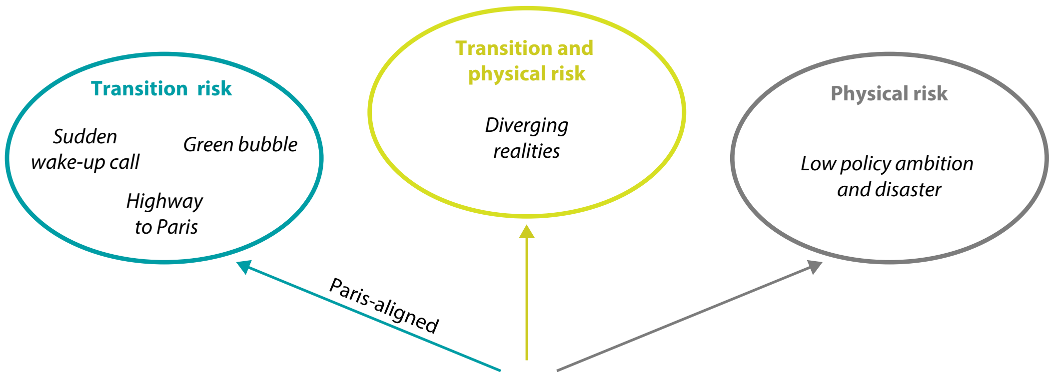
24 Five different narratives might be too many, also given the numerical features of each scenario, and there is a risk of both complicating the user's understanding and undermining their effective usability. The possibility of combining some scenarios or prioritizing their production based on user needs might be considered in the future.

25 This horizon was chosen based on the survey that was conducted with members of Workstream on "Climate scenario design and analysis" and reflects the needs of stress testing applications. However, for other applications, a longer or shorter horizon might be useful. Users could either alter the scenario to adjust its length – for instance, given that time horizons typical in monetary policy applications are 2-3 years, the first 2-3 years of the scenario could simply be used – or alternative scenarios would have to be developed altogether – for instance, for trading book stress testing.

26 Although, in the span of 5 years, baseline physical risk will be virtually indistinguishable from physical risks in the short-term narratives (concentrations of GHG are nearly equal over 5 years), short-term scenarios could consider including selected acute physical risks drawn for distribution tails of future extreme weather events or rely on projections from physical climate models.

27 A caveat of these narratives is that they do not address the topic of a 'just transition' or allow for a comparative analysis in terms of the effectiveness of different climate policy tools (e.g., green subsidies versus carbon taxes). However, we could at a later stage provide a sensitivity analysis of a selected scenario with different revenue recycling schemes and different combinations of policy tools to shed some light on these questions.

Figure 3 **Overview of NGFS short-term scenarios**



2.2.1 Three transition scenarios

The Highway to Paris, Green Bubble and Sudden wake-up call scenarios shed light on possible avenues for reaching net zero by 2050 with different assumptions regarding climate policy stringency, the extent to which transition policies are expected, technology and the resilience of the financial sector. Underlying these scenarios is the current environment of elevated uncertainty related to future fossil energy supply, possibly driven by geopolitical tensions, which could lead to an acceleration or a delayed implementation of climate policies, depending on the evolution of public opinion. They contain different but generally elevated levels of transition risks, reflecting the gap between actions currently in place and efforts needed to reach net zero by 2050.[28]

The Highway to Paris scenario reflects an immediate and technology-driven transition, in which the private sector develops and adopts green technologies faster than expected, inducing a rapid shift on the supply side. Elevated levels of uncertainty related to fossil energy supply leads governments to implement carbon prices to reach net zero by 2050 in a widely anticipated fashion. The resulting fossil-fuel demand reductions are in line with reaching the Paris goals. Revenues from carbon policies are partially recycled in the form of green public investments, which induces a rapid re-allocation of private capital away from emission-intensive activities, both across sectors and internationally. The speed of the transition may lead to initial demand-supply mismatches in some sectors. Cross-country capital flows and lending patterns adjust accordingly. On the regulatory side, green prudential policies reinforce the credibility of transition paths laid out by governments and, as a result, the financial disruption is contained. This scenario captures one of many possible short-term pathways around the NGFS net zero by 2050 long-term scenario, additionally including transition-related business cycle fluctuations.

In the Green bubble scenario, generous fiscal policy incentives in the form of subsidies lead to a glut of green private investment and expenditure. Investors pour money into green sectors and the transition becomes finance-driven. Short of matching policy incentives, adjustment frictions in the real economy prevent value-creation at pace with financial flows, thereby fueling a credit bubble in green sectors. A sunspot, i.e., an unrelated random event, leads to the burst of the bubble, inducing a confidence crisis and a sharp increase in risk premia. Although, the rise and bursting of the bubble may take longer than the 5-year horizon considered, the idea here is to focus on a short time span around the peak and the beginning of the market downturn – e.g., a year before the bubble bursts and a couple of years of financial turmoil – and its macro-financial consequences. This scenario is a variant of the Highway to Paris scenario but adds business

28 To make these scenarios fully compatible, they could all reflect the same level of physical risk so that that the only differentiating feature would be the source of transition impacts. This would be accurate in the short-term since physical risk is pre-determined within a 3-5 year horizon. However, it should be noted that at longer time horizons, different transition paths (even if they are compatible with the same long-term warming limit) might not bear the same physical risk because they might imply different emission pathways and thus different peak warming temperatures, which are a key determinant of long-term physical risk.

cycle shocks that could emerge in the presence of generous but poorly targeted subsidy schemes. Consequently, it entails a sub-optimal allocation of investment and a more expensive low-carbon transition than the Highway to Paris scenario.

The Sudden wake-up call scenario describes an abrupt and unanticipated transition, in which policy makers initially procrastinate on strengthening climate policies, essentially ignoring the need to accelerate the transition, until an event (e.g., a severe natural disaster) triggers a sudden change in policy stance.[29] Governments hastily implement carbon policies to still reach net zero by 2050. This *unanticipated* change in mitigation policy sets off shock waves through the global economy and financial system, leading to a climate Minsky moment, including asset stranding, an abrupt devaluation of polluting firms and the general tightening of financial conditions. This scenario illustrates how the NGFS Delayed Transition long-term scenario could behave in the short term.[30]

2.2.2 Hot house world

Before delving into narratives that entail physical risks, it should be noted that physical risk is pre-determined in the short-run due to a time lag between climate policy stringency and physical risk impacts. Thus, there is no connection between the climate policy stringency assumed in the short-term scenario and the level of physical risk impacts. Rather, each scenario is assumed to describe a deviation from a long-term scenario path (e.g., NGFS long-term scenarios) that drives the level of physical risk. Moreover, because the most severe physical impacts can materialize already in the short term but would more probably only happen beyond our five-year horizon, a key question is how to incorporate these within the short-term narratives. One way to address this challenge is to model a change in the perception of physical risks via a shock to expectations, whereby agents incorporate future damages into their choices today. Alternatively, to increase adversity, one may frontload future physical risk, when damages from natural disasters are likely to become much more severe. In this way, the scenario would reflect the idea that baseline physical risks in the future could very well reflect tail physical risks today. This is explored further in section 3.3.1.2 on shocks.

The Low Policy Ambition and Disasters scenario is a 'Hot House World' scenario, where extreme physical risk impacts are analyzed. This scenario reflects the short-run repercussions of insufficient long-term policy ambition globally – and therefore bears high physical risks. Large parts of the world continue to rely on fossil fuel. Investors price in a hefty risk premium, which freezes private investment, and reduce their exposure to jurisdictions and sectors, whose assets are at greatest risk of disaster losses. Households consume less and save more due to the increase in uncertainty, and insurance costs increase markedly.[31] This narrative could be combined with severe acute and or chronic physical impacts and their consequences on the global economy and financial system.[32]

2.2.3 Too little too late

The Diverging Realities scenario maps out possible futures with severe divergences across countries in the extent to which economies transition to net zero. The transition entails both strong transition risks in the countries which do transition and strong physical risks globally, in line with a broader long-term narrative of an ineffective transition globally.

The Diverging realities scenario reflects the risk of a lack of external financing from advanced economies (AEs) and local circumstances in emerging markets and developing economies (EMDEs) and low-income countries (LICs) limiting the ability to transition globally in a timeline fashion. For example, this can stem

29 Note that there is no economic impact of the trigger event. It is purely an exogenous shock (a "sunspot"), which acts as a trigger for the policy shock. A precedent for such a sunspot-triggered policy shock is the 180-degree turn in Germany's nuclear energy policy under former chancellor Angela Merkel following the Fukushima disaster.

30 Note that this scenario does not necessarily imply the implementation of a global carbon price but rather regionally-differentiated carbon prices (depending on real-world policy pledges) such that the world as a whole reaches net zero by 2050. For instance, this could be calibrated using the same approach as in the NGFS scenarios.

31 For instance, these could be factored into the modelling as a downward pressure on household consumption, as a downward pressure on asset prices, as a driver of higher loss-given defaults (LGDs) due to an absence of collateral coverage, or all three.

32 The specification and shape of the damage function, reflecting GDP impacts from physical risk impacts, will be important here. Ideally, it would reflect a broader set of physical drivers (i.e., not just temperature effects, but rainfall quantity and intensity, storms/cyclones, ocean heatwaves, increasing ocean acidity and thermohaline circulation effects), although some of these may fall outside the 3-5 year timeframe.

from severe natural disasters leading to a sharp economic contraction.[33] Local labour productivity drops, and migration flows from disaster-prone regions to less affected areas. In an attempt to aid the recovery, governments expand fiscal spending, possibly compounding high pre-existing levels of public debt and leading to a rise in risk premia. The resulting stagflation in EMDEs and LICs disrupts supply chains in transition-critical minerals limiting the ability of the global economy to transition.[34] The sudden realisation that a timely global transition is no longer feasible leads to a sudden re-assessment of future physical impacts globally. As a result, risk premia rise sharply. This scenario captures a key feature of the green transition, namely the extent of global interlinkages and that the unavailability of external financing from AEs poses an important risk for the ability of the world as a whole to transition. In essence, the scenario intends to reflect the global nature of climate change and that all economies need to work together when it comes to achieving climate goals.

An alternative formulation of a narrative reflecting international divergences and focusing on disruptions in supply chains and elevated food, energy and commodity prices could be considered. Such an international frictions scenario could instead be justified by elevated geopolitical tensions and fragmentation of economies that could be modeled globally, i.e., relevant price spikes *in general* without having to specify particular countries. The advantage would

Table 1 **Overview of narratives**

Scenario	Narrative
Highway to Paris	Elevated levels of uncertainty related to fossil energy supply lead governments to implement an ambitious mitigation pathway in a timely and anticipated fashion. There is a boom in green public investment leading to a rapid reallocation of capital and across sectors as well as internationally via cross-country capital flows and lending patterns. Technology shocks lead to a faster-than-anticipated transition, inducing disorderliness. Green prudential policies prevent financial turmoil albeit with losses in some sectors due to stranded assets. In line with reaching net zero by 2050.
Green bubble	Elevated levels of uncertainty related to fossil energy supply limits governments in their ability to implement ambitious mitigation policy. Green regulation overtakes government policies in driving the transition, leading to a glut of green private investment and the build-up of a green credit bubble. A sunspot (i.e., an unrelated random event) leads to the burst of the bubble, a sharp rise in risk premia and a confidence crisis. In line with reaching net zero by 2050.
Sudden wake-up call	Elevated levels of uncertainty related to fossil energy supply limits governments in their ability to implement ambitious mitigation policy. Driven by an event that triggers a sudden change in public opinion (e.g. a severe natural disaster), an unanticipated and accelerated transition occurs.[1] The abrupt policy change sets off shock waves through the economy and financial system: stranded assets in polluting sectors cause severe financial stress which propagates internationally via capital, trade and financial flows. In line with reaching net zero by 2050.
Low Policy Ambition and Disasters	Severe acute physical disasters hit exposed jurisdictions. Investors price in a sizeable risk premium, which freezes private investment, and reduce their exposure to the jurisdictions and sectors whose assets are at greatest risk of disaster losses. Households consume less and save more due to the increase in uncertainty and insurance costs increase. **NOT** in line with reaching net zero by 2050.
Diverging realities	The world as a whole aims to avoid the worst impacts of global warming. However, severe natural disasters in the EMDEs and LICs and a lack of external financing lead to recovery traps, i.e., a lack of fiscal space for affected regions to transition. Meanwhile, the disruption of transition-critical mineral supply chains originating in disaster-prone regions hampers the speed of the global transition.[2] The sudden realization that the global transition is too slow to avoid a Hot House World leads to a sudden re-assessment of future physical impacts globally. As a result, risk premia rise sharply. **NOT** in line with reaching net zero by 2050.

1 For instance, the natural disaster in Fukushima lead to a 180-degree turn-around in Germany's nuclear energy policy under Chancellor Merkel.

2 An alternative narrative would be that geopolitical tensions instead of natural disasters clog up supply chains. However, the impacts might be observationally equivalent – leading to a spike in commodity prices and a sharp increase in risk premia once the realization that the transition is ineffective hits investors.

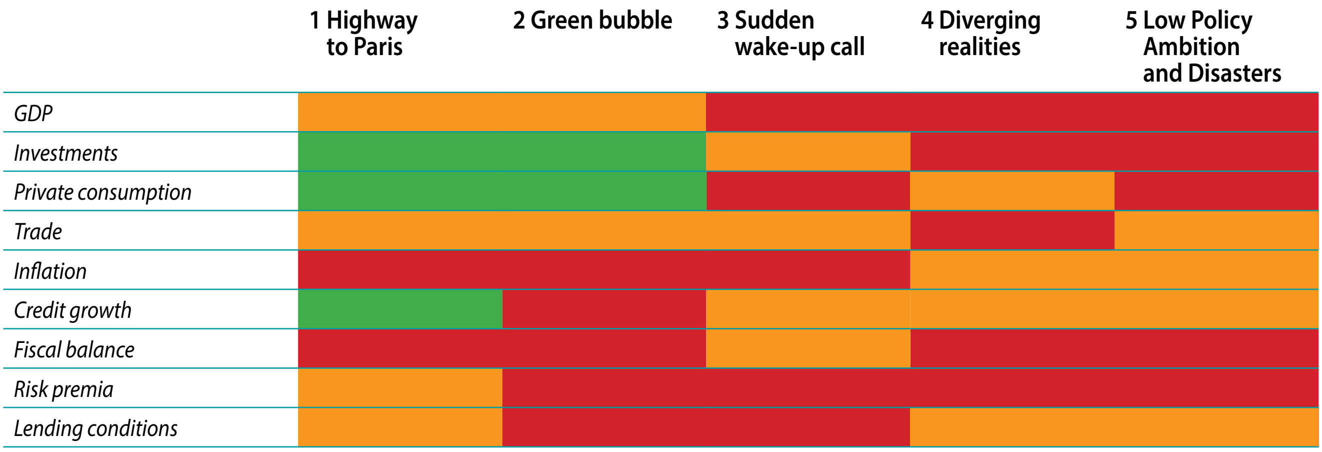
33 These shocks should be country- and sector-specific depending on the local exposure to various natural disasters.

34 Although the macro impact of supply chain disruptions in transition-critical minerals is likely to be limited (depending on the model used), it is an important potential source of adversity.

be a simpler implementation. The disadvantage is that it might be less relevant for jurisdictions in EMDEs and LICs who may see their material risks better reflected in the Diverging realities narrative featuring physical risk and how this might transmit globally.

Figure 4 contains a high-level overview of the sources of stress for each scenario. It should not be taken as precise forecasts of what *will happen* but as an example for how one might *think through* these narratives. Red refers to a "high" level of stress, yellow to "medium" and green to "low". Economic activity would be affected under all scenarios, except in the Highway to Paris and Green bubble scenario as investments and private consumption support overall GDP. The source of adversity originates relatively more from the household side in the Sudden wake-up call scenario while the negative investment and trade effects are at the core of the Diverging realities scenario. The transition scenarios are expected to be more inflationary than the scenarios involving physical risks. Financing conditions are likely to be under stress in all scenarios but the Highway to Paris.

Figure 4 **Sources of stress for each scenario**

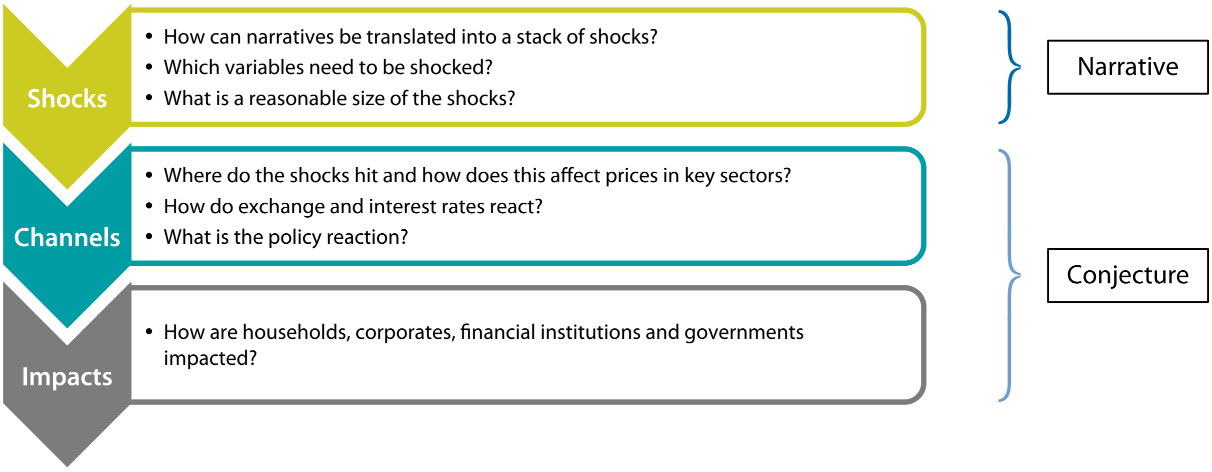


Note: Colours indicate the levels of stress. Red refers to high, orange to medium and green to low levels of stress.

2.3 Conceptual framework for thinking through the narratives

This subsection details the expected impact of each scenario on some key macro-financial variables. Although these depend on the modelling framework, choices of key parameters and policy assumptions, and feature substantial sectoral and geographical heterogeneity, it might be useful to classify scenarios based on expected impacts. Where the adversity of each scenario comes from (source of the shock), how it transmits (channels) and where the expected impacts manifest (impacts) are key differentiating features of the narratives. Their identification is also important to make sure that the narratives cater to the needs of climate stress testing and other applications. The conceptual framework is visually represented in Figure 5. Note the distinction between "narrative", i.e., the elements given by the previous sub-section, and "conjecture", i.e. the expected impacts that *could* happen as a result of the narrative under certain circumstances. There is also ongoing analytical work – both on conceptual macroeconomic frameworks and development of macroeconomic modelling toolkits – more specifically in relation with monetary policy. At a later stage, this parallel work may inform the work on short-term scenarios.

Figure 5 **Conceptual framework for thinking through short-term scenario narratives**



2.3.1 Shocks

Each scenario features a mix of climate and macro-financial shocks (more details on this are provided in the next section). While climate shocks can reflect transition risks (e.g. stemming from rapid climate policy implementation, preference adjustments, or technological innovation) or physical risks (e.g. acute natural disasters or chronic changes in the natural system), macro-financial shocks reflect short-term and often short-lived fluctuations driven by e.g. confidence or uncertainty shocks. The novelty of short-term scenarios is that they combine both, i.e. climate shocks together with standard financial stress.

Firstly, a set of high-level, non-specific shocks that are relevant for thinking about possible adverse future states of the world was identified. These shocks were then mapped to variables that can usefully capture them in a modelling framework. When identifying shocks and variables, several criteria were applied: (i) they could be modelled within existing climate or economic models, (ii) they are comparable across geographies and across time[35], and (iii) they are available at a high enough level of aggregation to provide some flexibility in their model implementation while being sufficiently granular to distinguish effects between geographies and sectors. For instance, one could prescribe a certain intensity for a peril that is relevant for each region (consistent with SSP5-8.5), rather than applying an aggregate global physical risk shock (that might be too high-level to be useful). Finally, shock variables were defined as those that reflect the origination of a shock (e.g., related to a flood event), rather than the effects of a shock (e.g., GDP – which is an impact rather than a shock variable). Finally, the narratives for the NGFS short-term scenarios were mapped to a set of proposed shocks to guide the eventual modelling process for generating the package of short-term scenarios.

Then, a set of eight high-level shocks with corresponding variables to capture these was extracted. A key question here is the calibration methodology as many of these shocks have not yet occurred in history and even if they have, are likely to change in magnitude and impacts due to the non-linear evolution of climate change and intensifying vulnerabilities. Some suggestions and references are included here where possible with the caveat that this is an ongoing scientific discussion and ongoing work across the NGFS will shed light on the key macro variables and channels over the short-term horizon across different sources of physical and transition impacts going forward.

35 Although the judgement as to where a scenario falls in the distribution of outcomes may vary across geographies, geophysical exposition, and stages of economic development.

(a) Transition shocks

A policy stringency shock (#1, a) could be captured by a price on greenhouse gases or CO_2, possibly taken from and calibrated using the *shadow* carbon taxes from the NGFS long-term scenarios. The variable capturing the shock could also include other forms of regulatory restrictions on emissions (e.g., the price of Emissions Trading System (ETS) permits).[36] The Integrated Assessment Models (IAMs) derive carbon prices for certain policy ambitions (e.g. Net Zero by 2050) with a varying degree of smoothness as well as global and sectoral divergence, depending on the narrative. An example of this is described in IMF (2021), which suggests different carbon pricing for blocks of countries, to reach varying climate goals, subject to different abatement costs, or a global carbon price floor.

Another key feature is the extent of international coordination (#1, b), which is usually captured again via CO_2 prices but with regional or sectoral variation to reflect differences in the stringency of policies across different jurisdictions. Carbon border adjustment mechanisms (CBAM[37]) or "climate clubs" could also be modelled in specific regions but not others to simulate the idea of regional policy fragmentation and to observe the effects of this on the global economy. A CBAM could be captured via an additional tax on imports on certain regions in the world that do not adopt the adjustment mechanism. It should be noted that regional initiatives such as CBAMs may actually lead to convergence in climate policies (in fact, this is one of its goals, besides creating a level playing field for domestic producers). The calibration of these shocks or level differences could be done again by using NGFS long-term scenarios. For instance, one could assume that some regions set a Paris-aligned price (e.g., form the NGFS Net Zero by 2050 scenario), while others do not raise their price over the time horizon (e.g. from the NGFS Current Policies scenario).

A technology or technological progress shock (#2) could be captured using aggregate or sector-specific efficiency improvements captured by total factor productivity or the elasticity of substitution between highly polluting vs. other technologies. For instance, the elasticity of substitution in the energy sector is often considered a key variable in climate-economy models as it indicates the ease (or difficulty) of switching from fossil fuels to renewable energy sources. The difficulty of calibrating these shocks is that there is substantial uncertainty surrounding the size and probability of technological breakthroughs and the speed of technological progress, which generally occurs over longer horizons. 'Learning by doing' effects are also difficult to capture. In the context of short-term scenarios, expectations of changes could be modeled. Ausubel (1994) discusses the role of technology in combating climate change in greater detail. In addition, carbon sequestration could be considered as a technology shock to help lower emissions.

Preference shocks (#3) could be captured via changes in the parametrization of households' consumption decisions. Although this depends on the model specification of consumption equations, preference shocks generally represent shifts in the utility function or the intertemporal trade-offs households make between present and future consumptions. According to the scenario, these shocks can be translated into changes in the elasticity of substitution between emission-intensive and other consumption goods, shifts in time preferences or intertemporal substitution or changes in habit formation.

(b) Physical shocks

The incorporation of physical shocks poses challenges along at least two dimensions. First, there is the question on whether only acute (i.e. natural disasters) or also chronic (i.e. slower-moving changes in the natural system such as sea level rise, temperature variability, etc.) physical risk should be incorporated in the narratives. While the case for studying the interaction between natural disasters with macro-financial shocks is quite clear, it is more challenging to think about the relationship between chronic risks and business cycle shocks. Thus, chronic physical risk is currently not considered in this note, but the door is open for it to be included at a later stage should this be

36 While different policy tools might have very different macro-financial impacts, they are grouped in one category here as the options for what policies could be captured will depend on the final modelling framework.

37 See, for example, the scheme agreed by the EU on 10 May 2023.

warranted. Second, the implementation of physical risk, which is pre-determined and at a horizon of 3-5 years, is not straightforward. On the one hand, one can model the actual impact of a disaster occurring today.[38] Alternatively, this could be modelled via a shock to the expectations of future physical risk impacts (as agents know that current climate action or the lack thereof determine future physical risk impacts). This is captured in Table 2.

Natural disasters (#4, a), i.e. the materialization of acute physical risk, manifesting as a weather event to be specified depending on the geography under consideration could be captured via a variety of variables, including an impact on sectoral gross value added (due to destroyed firm assets and business disruptions), the total supply (deaths or migration) or productivity of labor (people affected), arable land (destroyed land) and/or indirect impact on GDP (e.g. via production and services disruption). The appropriate impact variables depend on the type of shock (e.g., a drought or a storm). The proper calibration of these shocks is especially tricky due to the strong non-linearities in the intensity and frequency of climate change impacts going forward. While it is commonly known that the past is not a good predictor of the future, the future magnitude of these shocks is subject to an ongoing scientific debate. Nonetheless, there are several sources to find some orientation. For instance, EM-DAT is a database for historical damages from disasters that could be multiplied to account for increasing severity in an ad-hoc fashion. In addition, the NGFS Climate Impact Explorer offers the possibility to peak into future expected damages from several different disaster types under various warming scenarios at a granular level. Finally, because the most severe natural disasters are expected to occur beyond our short time horizon, one may consider either incorporating future shocks (that are due to a current lack of abatement) in current scenarios or utilize a shock to expectations to bring this forward in time.

Increased expectation of natural disasters (#4, b), i.e., the sudden re-assessment of the likelihood of acute physical risk materializing in the future, manifesting as a shock to expectations on any of the above-mentioned variables and reduced investment spending.

Table 2 **Options for incorporating physical risk into short-term scenarios**

	Acute	Chronic
Actual impact	Considered (#4, a)	Less relevant over 3-5 years
Shock to expectations of future impacts	Considered (#4, b)	Relevant and could be additionally considered

(c) Business cycle shocks

A confidence shock (#5) could be captured via a shock to expectations. In a setting where current choices depend on the expectations of an unknown future, this might manifest as increasing the weight of a more pessimistic outlook in current choices. Alternatively, it could manifest directly as a drop in consumption. To calibrate this shock, one could use the confidence crisis following the Global Financial Crisis as a precedent for the magnitude of changes.

An uncertainty shock (#6) could be captured via an increase in the equity and/or sovereign risk premium or via increasing the second moment of the distribution from which key parameters are being drawn. Alternatively, it could manifest directly as a drop in investment.

An energy price shock (#7) could be captured via a shock to energy volumes or prices, i.e., a decrease in the supply of major fossil fuels (oil and gas) or an increase in their price, respectively. High uncertainty in the production of fossil fuels coming from geopolitical tensions could

38 For instance, the impact of a disaster in t+x years, where x is the number of years until when more severe physical risk impacts are expected (e.g.., taken from NGFS long-term scenarios), could be modelled.

also leads to an acute energy shortage and clogs up supply chains. The calibration of such a shock regrettably now has seen a precedent with the 2022 Russian war in Ukraine, which caused a shock to commodity prices and the availability of fossil fuel. An important point to note here is the strong connection between energy price shocks and policy shocks in the form of carbon prices.[39]

(d) Other relevant shocks

As an illustration, restrictions in the supply of transition critical minerals in the near term (#8) could be captured via a proxy variable such as in the cost of capital for green technologies, given that such metals are key to building many low-carbon technologies (e.g., in the production of electric cars or offshore wind). This is necessary because most climate-economy models do not include critical minerals (lithium, cobalt, nickel, graphite or manganese) as a specific resource. Supply constraints could be calibrated by raising the cost of capital for the sectors most acutely impacted by a shortage of critical minerals (particularly low-carbon transportation). Alternatively, price spikes of the final good relying on rare earths could be modelled to capture restrictions in the supply – however, this would not capture any knock-on supply chain effects that might have an important bearing on global production networks or cost pressures.

(e) Pairing shocks with the short-term scenario narratives

Having devised a list of high-level shocks and the means to capture and calibrate these with specific variables, an interesting question is how to map these shocks to the narratives. There are many possibly ways to do this, also depending on the modelling framework. Table 3 below shows an example for how the five narratives *could* be translated into shocks of the types presented above for the first three years of each scenario. D+ (D-) and S+ (S-) refer to a positive (negative) demand and supply shock, respectively. Note that the characterization of shocks below is one interpretation of many, and the economic literature has not established a clear consensus yet on some of them.[40] Moreover, the diverging realities scenario features different shocks for advanced economies and others. In addition, while the diverging realities scenario looks very similar to the current policy scenario, the narrative is very different. Specifically, while the latter is meant to reflect the realization of severe natural disasters *globally*, the former only features these impacts in emerging and developing economies as well as low income countries. The content of Table 3 is described in greater detail in the section on impacts below.

39 On the one hand, high energy prices require a lower carbon price to achieve emission reductions in line with any given target. At the same time, carbon price shocks can also trigger energy price shocks.

40 For instance, while sudden carbon prices are usually modelled as negative supply shocks, their nature is less clear when these are signalled ahead of time, implemented gradually and thus anticipated by households and firms, in that, agents could foresee a persistent drop in output and income and thus lower their consumption and investment, respectively (October 2020 World Economic Outlook, Chapter 3). On the contrary, such anticipated changes could lead to innovation responses that might culminate in a positive supply shock. Thus, the balance of supply and demand effects will greatly depend on model parameters and ancillary policies governments undertake.

Table 3 **Sequence of shocks by scenario**

Scenario	**Shocks** (sketched-out example for the first three years)			
		t1	*t2*	*t3*
1 Highway to Paris	*Climate Shocks*	[S-] Carbon tax (anticipated)	[S-] Carbon tax	[S-] Carbon tax
	Macro-financial Shocks	[D+] Boom in green public investment financed by carbon taxation	[S+] Green Innovation boosts aggregate productivity	
2 Green bubble	*Climate Shocks*	[S+] Green subsidies equivalent to a carbon tax financed by sovereign debt	[S+] Green subsidies equivalent to a carbon tax financed by sovereign debt	[S+] Green subsidies equivalent to a carbon tax financed by sovereign debt
	Macro-financial Shocks	[D+] Boom in green private expenditures coupled with a green bubble due to fiscal-led incentives to alter consumer behaviour [S+] Large green private investment co-financed by higher debt	[D-] Confidence crisis due to bubble bursting leading to increased risk premia	
3 Sudden wake-up call	*Climate Shocks*	[S-] Carbon tax (unanticipated)	[S-] Carbon tax	[S-] Carbon tax
	Macro-financial Shocks	[D-] Shock to expectations of physical risks raising risk premia [D-] Confidence crisis due to financial turmoil as a consequence of stranded assets		
4 Diverging realities (advanced economies top; others Bottom)	*Climate Shocks*	[S-] Carbon tax (anticipated)	[S-] Carbon tax	[S-] Carbon tax
	Macro-financial Shocks	[D+] Boom in green public investment financed by carbon taxation	[S-] Supply constraints from the global south [D-] Heightened risk premia due to higher perception of physical risks	
	Climate Shocks	[S-] Severe hazard-specific disaster leading to supply chain disruptions		
	Macro-financial Shocks	[S-/D-] Cross-country migration from disaster-prone regions to less affected areas [D-] Heightened risk premia due to high physical risks	[D-] Post-disaster spending leading to a worsening of the fiscal balance and higher sovereign risk premia	
5 Low Policy Ambition and Disasters	*Climate Shocks*	[S-] Severe hazard-specific disaster leading to supply chain disruptions		
	Macro-financial Shocks	[D-] Heightened risk premia due to high physical risks	[D-] Post-disaster spending leading to a worsening of the fiscal balance and higher sovereign risk premia	

2.3.2 Channels of transmission to the macro-financial environment

The question of how the above-mentioned shocks impact key macro-financial variables is not straightforward, not least because the green transition is likely to cause cross-sectoral shifts in production and consumption patterns with knock-on effects on sectoral prices and an unclear sign of the overall effect. Table 4 reflects the type of channels, amplification mechanisms and feedback loops under consideration here, split in: (i) climate-economy direct impacts, (ii) macro-financial second-round effects, and (iii) intra-finance amplification (Reinders et al., 2023). These mechanisms constitute a relevant but non-comprehensive list of potential channels. Ongoing work ongoing to better understand the transmission from physical and transition impacts to the economy and financial sector from a monetary policy perspective will also to inform work on short-term scenarios at a later stage.

In general, the low-carbon transition is likely to affect prices in ways that lead to both substitution as well as wealth effects in uneven ways across sectors and households. For instance, households who live in cities may be able to rapidly substitute cars for low-carbon transport options, whereas households in more rural areas might find themselves in a position where their only choice is to reduce consumption of more expensive fossil-fuel intensive goods. The social ramifications are key in designing policies that are credible and compatible with a just transition.

A key channel associated with the transition is via energy prices and capital obsolescence. The energy sector is the one where the biggest changes are envisaged to reach net zero in a timely fashion. On the one hand, energy prices are directly impacted by climate mitigation policies targeting the price of fossil fuels and are a key input for virtually all production technologies and home appliances and therefore directly affects firm and household balance sheets.[41] In addition, it is a highly capital-intensive sector at the risk of premature loss of value. Whether these are ring-fenced or macro-relevant phenomena would likely depend on the level of preparedness and regulation in place.

There is a salient feedback loop between carbon and energy prices. First, carbon price shocks are likely to trigger an energy price shock due to the direct impact of carbon prices on the price of fossil fuels, which is still an important source of energy. On the other hand, when a persistent pre-existing energy price shock is already priced into the present (i.e. when fossil fuel prices are already high at baseline), then the size of the necessary carbon price to achieve climate targets could be reduced in a narrow emission-reduction sense because higher fossil fuel prices already incentivize a reduction. However, from an innovation perspective, active policy support for emission-reducing innovation is still key due to intertemporal knowledge spillovers as well as prevalent financial constraints of new and innovative green market entrants. This is an important tension that could play a role.

Moreover, the economic impact of severe natural disasters could lead to local economic scarring and migration via the destruction of physical capital, part of the labor force (via deaths) and lower labor force productivity or agricultural yields. Depending on the local economic structure, food and commodity prices might be an important channel for shock transmission whose effects might be propagated internationally via exchange rate or terms-of-trade fluctuations.

Finally, fiscal, and monetary policy responses play a key role in how climate shocks transmit to the real economy. First, government spending might act as a first shock absorber, although stress could also be amplified if this leads to or happens on top of pre-existing excessive sovereign debt. Moreover, interest rates reflecting the central bank's response to shocks are a key mitigating or amplifying factor. Further second-round effects and intra-finance amplification mechanisms are sketched out in Table 4.

41 The distinction between producer and consumer price here might be relevant for countries reliant on energy trade.

Table 4 **Short-term amplification of climate risk materialization and feedback loops**

	Climate-economy direct impacts	Macro-financial second-round effects	Intra-finance amplification
Transition risk *(climate policies and regulation, preference shocks or green technological breakthroughs)*	**Energy** prices **Capital obsolescence** **Labour market mismatch** (unemployment) **Consumption** and **Investment** **Innovation**	**Policy responses, accompanying policies** (fiscal, regulatory and monetary) and **pre-existing levels of sovereign debt** are key mitigating or amplifying factors for the impact on: • **Firm and household balance sheets** • **Asset prices** (e.g. via green fin. flows or a deterioration of real estate values) • **Sovereign debt** sustainability (lack of fiscal space could push economies into poverty traps) • **Sudden stops** in capital flows – Exchange rates – Corporate defaults (esp with high in foreign-currency debt levels)	**Expectation** adjustment about the future of climate change and associated value of exposed assets (Climate Minsky moment) • **Asset stranding** • **Corporate defaults** • **Financial institution solvency** (possible amplification via non-bank sectors) • **Access to and affordability of insurance** (rapid re-pricing) **Fire sales** and liquidity shortages **Doom loop** (i.e. a toxic sovereign-bank nexus), whereby runs on banks risk sovereign default due to excessive holdings of domestic bank bonds
Acute physical risk *(climate disasters)*	**Physical capital** destruction **Labour force** size and productivity/agricultural yields **Food and commodity** prices **Business continuity** (e.g. via disruptions in global value chains) **Cost of disaster insurance** **Migration**		

2.3.3 Impacts

This section discusses conjectures about expected impacts of each scenario, after reflecting on two key parameters – the elasticity of substitution between emission-intensive and other energy in production and the revenue recycling scheme of potential revenues from climate policies – driving these impacts and how they might differ across scenarios.

(a) Key Parameters

There are some well-known parameters and policy choices, which drive the macroeconomic impacts of transition policies, namely the elasticity of substitution between emission-intensive and other energy and the revenue recycling option of potential revenues from climate policies. A high elasticity of substitution implies that production processes have the *internal technical feasibility* to easily switch from high-emission to lower-emission technologies and/or that the latter can easily be *scaled and delivered owing to production-external factors* (e.g., ability to scale supply chains, navigate competition, associated infrastructure lead times and delays), both of which ease initial supply bottlenecks fast.[42] This parameter varies substantially across sectors. For instance, some sectors (such as cement) rely on technologies that are much harder to decarbonize than others (such as electricity). On the other hand, the more revenue is rebated to households, the less demand falls and therefore the more prices will rise in response to the negative supply shock stemming from climate policies. Usually, governments care more about perceptions of fairness and political acceptability of their policies than the inflationary impacts. It is thus likely that a politically feasible climate policy would entail some form of revenue recycling to households.

From a central bank and supervisory perspective, it is thus important to understand that the pursuit of price (and possibly financial) stability will be much harder if the economy is ill-prepared for the transition (i.e. the lower is the elasticity of substitution). This is because a disorderly transition raises the probability of greater price and output volatility across sectors and regions. A reasonable working assumption is that the elasticity of substitution is high in scenarios where climate policy action was widely anticipated (low otherwise) because of the

42 This favourable development may not necessarily imply limited financial risks. The latter depends on the ability of firms using the high-emission technologies to transition (which is driven, inter alia, by the value of the productive capital tied to high-emission technologies and to the existence of financial frictions).

Table 5 **Description of key parameters**

Short-run impact on inflation from transition policies		Elasticity of substitution between emission-intensive and other energy	
		Low	*High*
Percentage of climate policy revenue rebated to households	*Low*	Medium	Low
	High	High	Medium

response in innovation to the policy signal.[43] Generally, one can think of the combined role of these two key parameters in affecting price volatility in a highly stylized way as shown in Table 5.

(b) Scenarios

So far, several potential climate and macro-financial shocks have been discussed and mapped to each narrative. Next, the channels through which these shocks may transmit to the macroeconomy have been laid out. Next, some conjectures about the potential impacts that could materialize within each narrative are presented. This is a glimpse of what *could happen* as a result of each scenario and not what *will or should happen*, as the actual impacts will depend on the chosen modelling framework.

Highway to Paris

The Highway to Paris scenario is the most optimistic narrative featuring a broad-based transition, which is implemented by private sector behaviors, partly incentivized by carbon price and public investment policies. On the policy side, the Paris alignment implies a steep carbon price but its anticipation avoids financial turmoil. The carbon price acts as a negative supply shock. This is because energy is a key input to most production processes and energy prices are likely to rise initially due to the carbon price inducing a costly shift from current technology based on fossil fuels to more expensive renewable-based alternatives. On the other hand, there is a boom in green public investment financed by carbon price revenue, acting as a positive demand shock. Depending on the relative size of these shocks, the central bank might face a tradeoff between limiting inflation and spurring output in the short-run.

On the private sector side, enterprises launch green innovation projects and invest massively in low-emission technologies. If, in the short-term, this may put some pressures on supply, the expansion in green capital helps alleviate partly supply-side bottlenecks in the medium term. Private sector reaction is also incentivized by public policy, as carbon prices and green public investment in the form of subsidies not only induce green innovation because of the direct price incentive they put in place, but also because they help create a larger market for green goods and technologies (if taxes are implemented widely), which makes them more profitable due to scale effects. Thus, while there is likely some energy-driven "fossilflation" (Schnabel, 2022) in the short-run, these price pressures should not last long in this scenario.

Households and corporates might have a lower energy demand due to higher prices. Moreover, consumption is likely to drop because of the negative income effect caused by carbon prices. On the supply side, firm profits are squeezed due to higher production costs in the short-term, while they may pass it on to consumers in the medium-term. Financial institutions might face some interest rate risk if the central bank reacts by raising interest rates as well as credit risk due to the negative effect of carbon prices on corporate profits, especially polluting firms. Sovereign risk might also increase, especially in indebted economies with a sizeable fossil-fuel sector.

Green Bubble

When carbon prices are politically difficult to implement, governments may rely more on subsidy schemes (e.g. IRA[44]). Instead of taxing the main source of emissions, they foster sectors who innovate and make processes less carbon-intensive. While the literature is quite clear that both

43 Although local anticipation is unlikely to directly translate into a high elasticity of substitution if the transition inputs are contingent on external factors (e.g., competing with other countries for limited solar PV output, inability to roll out supporting infrastructure in a timely manner).

44 The Inflation Reduction Act (IRA) is a major US Federal law, which aims to release large investments into clean energy and emission-reduction technologies. For more details, see here.

instruments are needed in combination (AABH, 2012) – taxes to lower emissions immediately and green innovation subsidies to lower emissions in the future – they will be considered separately for the sake of this exercise.

Green (innovation) subsidies, if debt-financed, might lead to a boom in green private investment with the risk of a green bubble emerging in financial markets.[45] Depending on the specific policy design and sector, energy prices might increase or decrease. Importantly, relative prices of different energy sources might change dramatically reflecting e.g. an expansion of renewables. Producer prices might shift immediately, while consumer prices might respond with a delay, depending on the local market structure. Risk free rates are expected to rise reflecting the central bank's objective to counter the increase in prices stemming from the uptick in green investment.

A crisis of confidence caused by a sunspot, that is, a fluctuation in investor sentiment that is not related to economic fundamentals and yet may, via herding behavior in financial markets, have strong and widespread repercussions, may pop the green bubble. The risk premium spikes in response with possible international contagion via exchange rates reflecting sudden stops to heavily exposed jurisdictions and sectors as well as via terms of trade adjustments.

Households initially increase their consumption due to higher income and profits from green sectors, while corporates increase their investment reflecting lower production costs stemming from the green subsidy. Once the bubble pops, household consumption drops sharply and so does corporate investment. Financial institutions face market risk because the bubble popping could lead to a stark correction of equity and bond prices with possible negative second-round effects on liquidity risk via fire sales and contagion. Moreover, financial institutions might face some credit risk as loans in green sectors might no longer perform. There is also the possibility of a sovereign debt crisis in some vulnerable countries (where governments hold excessive domestic bank debt) due to the confidence crisis.

Sudden Wake-up Call

The sudden wake-up call scenario reflects a world of widespread climate ignorance, which is challenged by a sudden change in policy preferences. Markets do not price in climate risks and the energy sector relies heavily on fossil fuels. A sudden change in policy preferences, triggered by for instance a surprise election result favoring green parties or a natural disaster (e.g. nuclear disaster in Fukushima triggering a 180-degree turnaround in German nuclear policy), leads governments to hastily implementing a stringent mitigation pathway, leading to a speedy re-allocation of capital from polluting to green sectors. The sudden and unanticipated nature of climate policies means that this re-allocation process leads to a climate Minsky moment is the most unprepared jurisdictions and asset stranding in polluting sectors. The ensuing financial turmoil leads to a crisis of confidence.

Energy prices rise sharply because of the sudden implementation of climate policy. Differences in producer and consumer prices of fossil fuel could lead to sharp terms-of-trade adjustments for exporters and importers. Risk-free rates drop in response to financial turmoil and depressed demand. The risk premium spikes reflecting the confidence crisis. In especially fossil-fuel reliant economies, sudden stops might trigger sharp exchange rate and terms-of-trade adjustments.

The real economy is severely affected. Household consumption drops due to higher precautionary savings following the confidence crisis. Corporates reduce their investments, and, in polluting sectors, stock values deteriorate and loans become non-performing. As a result, financial institutions face elevated credit, market and liquidity risks. Moreover, highly indebted governments might face sovereign debt crises.

Diverging Realities

This scenario reflects how a lack of external financing from advanced economies can lead to global divergences. Emerging markets and developing economies, as well as low income countries, experiences repeated severe

45 Subsidies that are broadly directed at green activities could be subject to a Lemon's problem, i.e. the risk of financing unviable green projects, which go bust, especially when large sums of money are deployed in little time and competition is fierce. Banks and financial institutions might be more inclined to grant credit to a burgeoning green industry. If credit growth exceeds value creation in the real economy, a credit bubble develops, which, in turn, could burst once animal spirits turn pessimistic. A trigger could be a prominent default of a green firm (e.g. Solyndra bankruptcy in 2011).

natural disasters and gets trapped in perpetual state of recovery. This not only leads to severe local disruptions in the form of deaths, capital destruction, migration and labor productivity drops, but also to global knock-on effects on food and commodity prices and on the supply of critical minerals. Short of external support from advanced economies, this renders the global transition ineffective.[46] Risk premia rise globally as it becomes clear that the overall ineffectiveness of the transition makes future damages from natural disasters highly likely. Specifically, this sudden change in the perception of future acute physical risk could lead to a run on emission-intensive equities and bonds in the financial system. Moreover, post-disaster spending in EMDEs and LICs leads to a worsening of the fiscal balance and to higher sovereign risk premia there.

In advanced economies, energy prices rise initially due to ambitious climate policies being implemented and reflecting a shift from clean fossil fuels to more expensive renewables. Risk-free rates rise due to the increase in investment in green public spending. Once the natural disaster in the EMDEs and LICs hits, exchange rates appreciate via EMDEs and LICs reflecting the local economic deterioration. As it becomes clear that post-disaster scarring in EMDEs and LICs affects supply chains of advanced economies and limits its ability to transition, risk premia rise and real estate prices in exposed regions drop due to a greater perception of looming physical risks. Energy prices drop due to the contractionary impact of supply chain disruptions and the rise in risk premia. Meanwhile, risk-free rates drop, households and corporates demand less energy, consume less and face higher production costs. Financial institutions face credit and interest rate risks and sovereigns which are exposed to physical risks are challenged by higher debt-servicing fees due to elevated risk premia.

In EMDEs and LICs, energy prices and risk-free rates drop due to the contractionary impact of the disaster. Risk premia rise reflecting a greater perception of physical risk. Exchange rates drop vis-à-vis advanced economies. Real estate prices drop in vulnerable areas, while food prices (and possibly other prices such as construction materials) rise sharply. The informal economy collapses amid destroyed public infrastructure and houses. Households are hit hard by the loss of (the value of) housing, while corporates suffer from loss of labor supply and productive capital destruction, which takes time to rebuild. As a result, financial institutions face elevated credit, market and liquidity risks, while sovereigns face a higher sovereign risk premium making it challenging for governments to finance the transition undertaken in advanced economies, let alone meaningfully invest in rebuilding efforts.

Low Policy Ambition and Disasters

The Low Policy Ambition and Disasters scenario reflects the short-run repercussions of insufficient long-term climate ambition and thus a continued reliance on fossil fuel. Severe hazard-specific disasters, such as a battery of different but related disaster types driven by El Niño or otherwise compounding disasters, hit in exposed regions leading to a spike in risk premia due to an elevated fear of a deteriorating climate.[47] Energy prices drop due to the contractionary impact of disasters, especially in the most affected regions in EMDEs and LICs. The global response to key import/export commodities, likely affected by physical damages (e.g., food prices), could reflect cross-country spillovers in the form of supply chain disruptions. Risk-free rates drop due to the globally contractionary impact of higher risk premia and disaster losses. Exchange rates may adjust reflecting an elevated fear of default vis-à-vis countries exposed to physical hazards. Real estate prices drop sharply in exposed areas affecting particularly vulnerable communities.

46 There is no connection between transition and physical risk in the short-run. This scenario is rather an example of how the combination of high vulnerability, geophysical exposition and getting "unlucky" (i.e., EMDEs and LICs being hit by a severe natural disaster that leads to a lock-in to a state of reconstruction) can lead to global divergences.

47 A non-exhaustive overview of physical risk hazards and their potential impact on firms, depending on their exposure, vulnerability and mitigating factors (e.g. insurance coverage) can be found in Table 2 of the Data Supplement of the ATC/FSC report on "Climate-related risk and financial stability" here. The JRC Risk Data Hub hosts publicly available granular data on these categories.

An important consideration here is the response of the insurance and reinsurance sectors to acute natural catastrophe events. Specifically, severe natural catastrophes can lead to contagion from one part of the world to insurance pricing globally (via reinsurance) and to chilling effects via the impact of increased insurance premia on economic activity (i.e., decreased consumption, reduced insurance coverage over collateral for existing financial institution exposures, thereby increasing lending losses, and delayed/abandoned new investment due to higher/unavailable insurance).

Households demand less energy, consume less, and save more in response to the increase in risk premia and direct disaster losses. Corporates face a shortage of production inputs due to a lack of productive capital and labor, which takes time to rebuild. In the short run, this reconstruction phase may trigger an increase in import demand and investment, where private and/or public financing is available. However, overall, there is a lower energy demand due to depressed consumption and lower investment due to higher risk premia. Financial institutions face elevated credit, market, and liquidity risk, while some governments may struggle with sovereign debt crises if previous debt vulnerabilities have been exacerbated by severe disaster losses and/or sudden stops in capital flows.

3. Features and applications

In this section, the main applications of short-term climate scenarios are identified. In addition, their main features, representing the basis for the selection of modelling frameworks to calibrate the narratives presented above, are extracted.

NGFS members have expressed the need for tools more fit-for-purpose to analyse the immediate impact of climate-related risks together with more standard business cycle developments. While the existing NGFS scenarios are useful for assessing climate-related financial risks over longer time horizons, they do not incorporate macro-financial impacts at business cycle frequency (Takeyama, 2023). So far, NGFS scenarios have been adapted by adding stress in the short-run via additional frictions and shocks (see the Appendix on case studies). While such individual exercises are welcome and important, there is a key need for improving the consistency of these efforts.

Providing an NGFS package of internally consistent global short-term scenarios would enable relevant actors to assess risks over policy relevant horizons in a sounder and more comparable way. It could be applied by users for many different types of analysis. In the following sections, two applications with central bank and supervisory responsibilities in focus are presented to help identify the requirements of the scenario outputs for these key applications, though there may be more as this remains an emerging field.

3.1 Climate Stress Testing

From a supervisory and financial stability perspective, the primary application of short-term scenarios is climate stress testing, as shown by recent analytical efforts undertaken by central banks, supervisors and financial firms.[48] The very nature of stress-testing exercises, i.e. its focus on short-run spikes or collapses in key macro-financial variables, calls for reference scenarios to capture shorter time horizons between 3-5 years (usually at a quarterly frequency). As several central banks and supervisors mentioned in their scenarios analyses (Banque de France, 2021; Bundesbank, 2021; FSA and BOJ, 2022; FSB-NGFS, 2022), the current set of long-term scenarios are not sufficiently adverse for stress tests, even those in the disorderly quadrant. Moreover, the often-used static balance sheet assumption (e.g. EBA EU-wide stress test) makes the analysis of longer time horizons difficult and subject to substantial uncertainty.[49]

To-date, a number of exercises have crafted "condensed" (i.e. more stressed and shortened) climate risk scenarios based on NGFS long-term scenarios, in order to try and better capture some of the important short-term dynamics over the near term (Vermeulen et al., 2018; EIOPA, 2022; Guth et al., 2021; ECB, 2022, 2023; ESRB, 2022).[50] Abe et al. (2023) develop short-term climate scenarios for the Japanese economy, while the European Central Bank (ECB) and the European Systemic Risk Board (ESRB) published a joint report on how climate shocks can affect the European financial system, considering three short to medium-term (i.e. 5-year) horizon scenarios (ESRB, 2022). Banco Central do Brasil (2022, 2023) conducted climate scenario analyses on extreme droughts and heavy rains at the municipal level in the short and long term. In addition, the International Monetary Fund has conducted several Financial Sector Assessment Programs including climate risks and transition risk in several jurisdictions (IMF 2021, 2022).

48 The FSB-NGFS note on climate scenario analysis published at the end of 2022 is here and the NGFS survey results published in Q2 2023 are here.

49 Even if this assumption was relaxed, challenges associated with the risk identification and the modelling of the loan portfolio dynamics would further increase the uncertainty of credit risk projections. This creates challenges when assessing banks solvency, both, due to different approaches and modelling techniques banks might apply and due to the general uncertainty of the results. Furthermore, the relaxation of the static balance sheet assumption and the incorporation of a dynamic balance sheet introduce complexities that impede the identification of pure related risks. This calls for short-term analyses, which in turn require short-term scenarios.

50 Vermeulen et al. (2018) provided seminal work on short-term transition risk scenarios. EIOPA developed a climate scenario for their EU-wide pension fund stress test in 2022 (EIOPA, 2022), where a cumulative shock from the first three years of NGFS Disorderly Transition scenario was condensed to one year. The Austrian National Bank developed a transition risk scenario with a 5-year time horizon (Guth et al., 2021) and the ECB produced their own short-term climate scenarios for their 2022 SSM climate stress test (ECB, 2022) as well as the ECB's second economy-wide stress test (ECB, 2023). Moreover, the ECB and the ESRB published a joint report (ESRB, 2022) on how climate shocks can affect the European financial system, considering three short-term (i.e. 5-year) horizon scenarios: a scenario for an immediate and disorderly transition with a sharp increase in carbon prices and two physical risk scenarios (extreme flood events and a long heatwave period).

3.2 Macroeconomic impact assessment

Short-term scenarios will also enable central banks to deepen their understanding of the macroeconomic impacts associated with physical and/or transition shocks, including different transmission channels, the materiality of the effects, and the balance of risks around the central path for the economic outlook. Aggregate impacts will be sensitive to fiscal policy mixes and assumptions e.g., the choice of instruments, revenue recycling and the monetary policy reaction. An analysis of macroeconomic effects, channels and potential trade-offs could then be used as inputs into monetary policy decision making and/or to explore the implications of different monetary policy reaction functions. Conversely, it could also inform the sensitivity analysis in financial stability and stress testing exercises via assumptions used for monetary policy rules.

An important distinction between stress testing applications and macroeconomic scenarios in the context of monetary policy is the adversity of the scenarios in focus. Specifically, in a monetary policy context, central banks are focused on the balance of upside and downside risks that reflect only moderate deviations from the central projection. In contrast, stress testing applications consider plausible yet highly adverse shocks, including tail risks that reflect large deviations from the baseline.[51]

3.3 Output variables

A broad set of variables are required for climate stress testing and macroeconomic/ monetary policy analysis applications. Tables (A)-(C) in the Appendix contain the "wish-list" of output variables labelled as either "high importance" or "low importance". For climate stress testing, the list comprises mostly standard macro-financial variables used in stress tests to date (e.g., GDP, unemployment, inflation, real estate prices, exchange rates, interest rates, share prices, sovereign bond rates). Given the heterogeneous nature of climate risks across firms, stress testing applications will also require a higher degree of granularity for some key variables, i.e., at sector level (e.g., changes in profit, asset prices, lending conditions, share of buildings by Energy Performance Certificates). For macroeconomic impact assessments with links to monetary policy analysis, the list includes further details on macroeconomic variables that characterize the key channels and transmission mechanisms from climate change and the low-carbon transition. Across both applications, climate-related variables would ideally include (shadow) carbon prices, emissions, fossil fuel prices and investment (by technology).

The needs of central banks and supervisors might vary depending on their national circumstances and country characteristics. Thus, the variables listed are very much a starting point that can be refined over time. For example, work on monetary policy is currently ongoing in the NGFS seeking to inform central bank understanding of the key channels and variables that policy makers should consider in the context of climate change and the transition. As this work develops, it will provide useful input and cross-check to the short-term scenarios being developed.[52] Countries could also consider refining the list of variables further to make the scenarios specific to their jurisdictions.

3.4 Granularity

Both applications require a greater degree of granularity of output variables than is typically used for stress tests and/or macroeconomic impact assessments. This is especially the case for climate stress tests. When assessing transition risks, the greatest impacts from policy changes are expected in emission-intensive sectors so aggregate analyses are not very instructive. Furthermore, differences between firms within the same (adversely impacted) sector might be significant and thus require additional granular information. Assessments of acute physical risks in stress testing applications also require granular data as usual regional splits do not adequately capture hazard incidence, vulnerability and exposures

51 As the short-term scenarios are developed, it will be important to consider whether they can serve both climate stress testing and monetary policy applications, i.e. whether a one-size-fits-all set of scenarios will be feasible, or whether adjustments would be necessary. This discussion is not only about the degree of adversity imposed, but also the time horizon in view, with monetary policy typically focused on the 2-3 year horizon, while stress testing is around 3-5 years. However, to the extent that there are large shocks in an economy that will take time to be resolved, it is not uncommon for central banks to look beyond the standard monetary policy horizon to understand when the economy is expected to reach a (possibly new) steady state.

52 The NGFS Workstream on Monetary Policy survey report can be found here.

in a localized area (e.g. floods, droughts or forest fires). Ideally, regional geographical high-resolution physical risk maps would be matched with financial institutions' exposure (scaling down to firm-level data).

However, while greater granularity is useful in some cases, there is a "curse of dimensionality", reflecting the high number of output variables that would be produced from excessive details. Therefore, the extent of sectoral breakdown should depend on the structure of the economy under study and its financial-sector exposure towards different industries. Cost-benefit thinking should guide the choice of the degree of granularity (i.e. focus on key economic sectors relevant for stress testing; sectoral details necessary for understanding the transmission channels for impacts of climate on the macroeconomy). For example, in the 2023 EBA EU-wide stress test scenario, gross value added was reported by industry for each EU country for the first time. While the manufacturing sector was split into two sub-sectors by energy intensity, less important sectors (to which the financial sector was less exposed) were aggregated. Moreover, different risk drivers call for different granularity levels of output variables (see Table D in the Appendix).

3.5 Baseline scenario[53]

As climate scenario analysis (CSA) is an exercise to explore macro-financial impacts under adverse but plausible future paths, it is usually conducted vis-à-vis a counterfactual. This could be either another climate scenario (i.e. in response to a question "what are the differences (positive and/or negative) of a transition that looks like this versus one that looks like that?") or a baseline scenario (i.e. in response to a question "what are the effects of a transition that looks like this versus our expectations regarding the near future in absence of shocks?"). The choice of the baseline scenario depends on the objective of CSA among the two identified applications of short-term scenarios. Once NGFS short-term scenarios are available, existing long-term NGFS scenarios could be calibrated to the modelling framework of the short-term scenarios and be used as a baseline.

For the assessment of price stability over the medium term, the NGFS Current Policies or NDC scenarios are relevant candidates for a baseline. Climate policies proxied by a shadow carbon price[54] could raise fossil energy and other goods prices relying on carbon-intensive industries, which could trigger an overall price rise. The Current Policies or Nationally Determined Contributions scenarios, which represent currently lax or planned (although highly uncertain) more ambitious climate policy, respectively, are conceivable baselines to assess the transmission of a strengthening in climate policy.[55] For macroeconomic impact assessments, it will be important to consider the baseline to observe whether the modelled disruption is short-term (i.e., purely cyclical) or whether a longer-term structural shift (i.e., reflecting supply-side changes or demand-side scarring) has occurred.

For the assessment of transition risks implied by a delayed or divergent transition as well as for the assessments of physical risks, an NGFS orderly transition scenario may be a useful baseline.[56] As the NGFS Net Zero by 2050 scenario entails immediate but relatively smooth carbon prices, losses due to inefficiently fast-increasing carbon prices (e.g., implied by policy delays or a lack of coordination) and the macro-financial repercussions could be analysed. Moreover, because of the speedy emission reductions, this scenario avoids the worst physical damages and could therefore be a useful baseline for assessing damages in less ambitious scenarios.

53 Note that the term "baseline" here refers to projections of the macro-financial environment in the absence of additional shocks (e.g., a shock-less current policies scenario) with the purpose of providing a reasonable reference to which other scenarios can be compared. No statement as regards its "likelihood" is intended.

54 Climate policy instruments are relying either on an explicit pricing mechanism or on norms. By mandating changes, the latter approach also implies an increase in costs which can be understood as an implicit carbon price. Eventually, the stringency of the instruments can be described with a (shadow) carbon price.

55 While particularly suited to assess the impact of an increase in carbon pricing, an increase in the shadow carbon price can also capture the impact of the introduction or strengthening of other non-pricing measures (e.g. regulatory approaches) with some additional work.

56 In Phase III, this could be for instance the NGFS Net Zero by 2050 scenario.

3.6 Criteria for designing and implementing short-term climate scenarios

The analytical implementation of NGFS short-term climate scenarios is oriented towards the needs of central banks and supervisors in fulfilling their financial stability, supervisory as well as monetary policy responsibilities. The below are guiding principles for the implementation of NGFS short-term climate scenarios:

- **Scenario narratives will be translated into calibrated shocks** or a stack of shocks and paths for exogenous variables to be simulated by a model.
- **A model whose features are best-able to capture features needed by the identified applications will be chosen.** This includes, inter alia, time steps, simulation horizon, the degree of sectoral and spatial decomposition.
- **The modelling infrastructure should be able to account for climate-related** shocks (i.e. related to transition and physical risk), as well as capture short-term amplification mechanisms, cross-sectoral substitution and granular impacts.
- **A meaningful baseline or reference scenario(s) need(s) will need to be calibrated within the modelling framework.** This could be a set of different baselines for each scenario or one reference scenario.
- **The results should be collected for a set of macro-financial and climate variables** (see Tables (a)-(c) in the Appendix containing a list of variables) into a template.

Tables (a) – (f) in the Appendix provide more details about the output variables (macroeconomic, financial and climate variables) required for each application type, their corresponding level of disaggregation and the key features of the models to be selected. Finally, further details are provided about the choice of the baseline/reference scenarios.

4. Modelling approaches

After having proposed narratives to map out adverse but plausible futures that include both, climate risk and standard macro financial stress, and discussed the most popular applications of short-term climate scenarios, the note now turns to existing modelling frameworks, which could be capable of calibrating the proposed scenarios, without claiming to be exhaustive.

Several modelling frameworks can be used for the calibration of short-term climate scenarios, depending on the requirements of the application these scenarios should be used for.[57] For instance, such requirements may include analytical tractability, reasonable modelling assumptions, output data availability and regional/sectoral granularity. The most common frameworks for calibrating short-term scenarios include input-output (I-O) models, computable general equilibrium (CGE) models, semi-structural models, (Environmental) Dynamic Stochastic General Equilibrium (E-DSGE) models, and dynamic integrated assessment models (IAM). These models are not mutually exclusive and may be coupled with one another as ancillary tools as they do not necessarily cater to the required criteria individually, e.g., to couple some of them together or with ancillary tools that could, for instance, add sectoral details or dynamic features to a static framework.

Input-output (I-O) frameworks represent sectoral interdependencies through the interaction of the flow of goods and services between different sectors of the economy. The models can be extended to integrate environmental considerations by linking economic variables and environmental variables to account for the degree of natural resource utilization and pollution incorporated in the goods and services consumed in the economy. Input-output frameworks are integrated into static environmental multi-sector models with international trade (Devulder and Lisack, 2020; Aguilar et al., 2022).[58] They can be used to analyse the effects of changes in government policies, technology, and changes in consumer behaviour on the economy (Guilhoto, J. J., 2021).

Current climate-related I-O models are well-equipped to deal with several key features of short-term scenarios (see Table e) in Appendix 2), such as international relationships, greenhouse gas emissions and sectoral granularity. However, they are less well suited with respect to capturing dynamic interactions between shocks and agents' reactions, both at the household and firm level.

Computable general equilibrium (CGE) models seek to capture the behaviour of economic agents. A key advantage of this framework is the possibility to simulate the impact of changes in different types of climate policies on the behaviour of agents and their welfare. However, due to their computational complexity, CGE models often make use of assumptions and simplifications to render them tractable. This limits their ability to fully capture the complex interactions among agents (Chateau et al., 2014; Capros et al., 2013; Brandsma et al., 2015).

CGE approaches perform well in capturing international linkages together with sectoral granularity that accounts for the energy sector and elasticities of substitution across fossil fuels, which is key for transition dynamics[59]. However, they generally focus on the medium or the long run, perform less well with capturing climate related features[60], dynamic and forward-looking dynamics, abstract from relevant nominal, real and financial frictions and leave out the financial sector, which present important limitations for short-term scenario analysis.

57 Notably, this is a different exercise than the models taking the calibrated short-term climate scenarios as an input to run scenario analysis exercises (which is beyond the scope of this note).

58 These models all build on the state-of-the-art multi-sector macro model with production networks developed by Baqaee and Farhi (2019).

59 The OECD's ENV-Linkages model, the World Bank's ENVISAGE model and the IMF-ENV model (see Chateau et al., 2022) are examples of GCE models used in international organizations to analyse the economic effects of climate policy options. They all feature a detailed representation of sectors and world trade.

60 The behaviour of the carbon price is assumed to be exogenous and there is no explicit accounting for the carbon budget.

Structural and semi-structural models define how outcomes relate to preferences and to relevant factors in the economic environment in the context of analysing counterfactual policies (Low and Meghir, 2017). Both structural and non-structural frameworks describe the economy as a system of dynamic equations, whose parameters are estimated econometrically using historical observations.

Structural modelling frameworks consist of a set of dynamic stochastic equations typically featuring aggregate exogenous shocks and several frictions (Kydland and Prescott, 1982; Galí, 1999; Smets and Wouters, 2003).[61] More recently, several environmental DSGE models have been developed with the aim of capturing the interaction between climate-related shocks and the monetary, regulatory and fiscal policy mix.[62] However, several caveats limit their usefulness for short-term scenario analysis, including the lack of: feedbacks between climate and macro-financial variables, of endogenous innovation, of an open-economy lens[63], of a sufficient sectoral breakdown, of a scientific consensus on the calibration of climate-related parameters, of a bank transmission channel, of adaptation[64] and of heterogenous impacts on households due to transition and physical risks, depending on their income and wealth profiles.[65]

Prominent examples of semi-structural frameworks that account for climate considerations are the National Institute Global Econometric Model (NiGEM) and the Oxford Economics Global Economy Model (GEM), which both cover a wide range of socio-economic variables, have a rich geographical granularity, and capture international linkages via trade and capital flows.[66] However, they currently lack sufficient sectoral granularity. A closely related semi-structural, global, open-economy model with dynamic general equilibrium properties is the G-cubed model. It features substantial sectoral details and can reflect a broad array of climate policies (e.g., country-specific economy-wide carbon taxes or cap-and-trade schemes). Moreover, countries/regions are linked both temporally and inter-temporally through trade and financial markets, including feedbacks between the real economy and the energy sector (McKibbin and Wilcoxen, 2015), which is a desirable feature in assessing climate scenarios.[67] The IMF's novel Global Macroeconomic Model for the Energy Transition (GMMET), as a multi-country, micro founded, nonlinear dynamic general equilibrium model used to simulate the transition, can also be associated with this type of modelling approach (IMF, 2022c).

Finally, dynamic integrated assessment models (IAM) combine a climate module with an aggregate economic module to capture the relationship between emissions and economic activity. While they have been used extensively to provide economic assessments of climate change policies (IPCC, 2014; Stern, 2007; NGFS 2022b), they present several shortcomings related in particular to: (i) the high sensitivity of the social cost of carbon to small changes in the discount rate[68], to assumptions/parameters on climate variables[69] and to different functional forms of the damage function, (ii) their inability to capture

61 These frictions can be real rigidities such as habits in household consumption behaviour, nominal rigidities and financial frictions.

62 These models are built to study questions related to optimal taxation on fossil fuels (Golosov et al., 2014), the implications of stranded assets in the transition to a low-carbon economy (Van der Ploeg and Rezai, 2021), and how the performance of optimal environmental policy regimes are influenced by the presence of nominal rigidities and the response of monetary policy (Annicchiarico and Di Dio, 2015), inter alia. All these models introduce energy and related emissions both in the production and in the consumption side. To different degrees, most models distinguish between "dirty" and "clean" energy in production and use.

63 Notable exceptions include: Hinterlang et al. (2021), Ernst et al. (2022), Varga et al. (2022), IMF (2022c) and Coenen et al. (2023). These structural models allow for the analysis of cross-border spill overs from climate policies and sectoral disaggregation, albeit to different degrees.

64 In a very stylized model, Ferrari and Nispi-Landi (2022) show that depending on agents' expectations being more or less myopic, transition policies may have completely different macroeconomic implications.

65 Pieroni (2022) represents one of the first attempts to include energy consumption both at the household and firm level in a Heterogeneous Agents New Keynesian (HANK) model.

66 For more details on both models see Hantzsche et al. (2018) and Oxford Economics GEM (2023). Although NiGEM lacks the desirable sectoral detail, it could be considered as a possible model to be complemented by ancillary tools. It has recently been used to provide more macro-financial variables for the NGFS scenarios as well as a sensitivity analysis of these depending on policy parameters/rules (Darracq-Pariès et al., 2022).

67 While current NGFS scenarios only account for a unidirectional link between the energy sector and the aggregate real economy, a model such as G-Cubed has the potential to produce its own projections for many of the variables already included in the NGFS scenarios.

68 The social cost of carbon represents the economic cost caused by an additional ton of carbon dioxide emissions or its equivalent (Nordhaus, 2017).

69 However, second-generation IAM models have also been produced to account for parameter uncertainty in the attempt to overcome the shortcomings of earlier IAMs. For instance, Cai et al. (2012) build a dynamic stochastic integrated model of climate and economy (DSICE) to demonstrate that adding uncertainty and risk to basic IAM models is feasible.

rapid technological advances[70], (iii) their long-term view, (iv) their limited macroeconomic and sectoral breakdown, and, (v) the lack of standard monetary and fiscal policy blocks. There exist however also dynamic versions of IAMs which can also be used for monetary and fiscal policy analysis (Abiry et al., 2022).

While the previous modelling frameworks are more or less well adapted to account for transition risk drivers in short-term scenarios, including physical risk impacts may be particularly challenging. Short of off-the-shelf macro tools to account for these, modellers sometimes rely on highly aggregate (and thus likely inaccurate) damage functions. A sounder way would be to consider pairing a macroeconomic model with a NatCat model. Box 1 elaborates on this option. As a wide range of potential future physical events are conceivable, the modelling approach may rely not only on deterministic scenarios but should also account for a stochastic catalogue of events.[71]

Overall, notwithstanding the above-mentioned shortcomings, at the current stage structural and semi-structural models are well-equipped for calibrating short-term scenarios as they meet most of the identified key desirable features reported in Table e) of Appendix 2. While they generally assume an exogenous process for the carbon price and do not account explicitly for the carbon budget, they can account for international linkages (needed to capture cross-country heterogeneities in the transmission of climate-related shocks), GHG emissions, sectoral granularity, and the endogenous response of agents to both transition and physical risk shocks (via their dynamic setup and the adoption of some form of rational expectations). They can also be particularly useful for monetary policy applications as they explicitly incorporate demand-side effects. Moreover, these models are mostly calibrated/estimated at business cycle frequency on quarterly data and thus enable users to analyse the short-term impact of different shock combinations on a variety of macroeconomic and financial variables under different fiscal and monetary policy rules. Finally, the output data can easily be integrated into central banks' modelling frameworks used for forecasting and policy analysis and used by financial institutions (e.g. to augment their models for the estimation of default probabilities and, more generally, the quality of the assets in their portfolios).

Across many central banks, work is currently underway to further improve the modelling of interactions between physical and transition impacts and the macroeconomy to answer key policy questions. As set out in NGFS 2023 (link to publication), one of the aims of the future work of the NGFS monetary policy is to work towards addressing some of the key challenges facing central banks in their near-term modelling of climate-macro effects. This work could help improve the short-term scenarios that will likely face similar challenges.

70 While IAMs are generally able to account for the technological change leading to a shift to low-carbon alternatives, they fail to provide a quantification of the changes occurring in the affected sectors (such as steel production, building and transport sectors).

71 See, for instance, Lloyd's (2014), "Catastrophe Modelling and Climate Change".

Box 1

How to include extreme weather (acute physical) risk into short-term climate scenarios?

There are broadly two distinct ways to model extreme weather risks: statistical models based on historical data and simulation models, typically known as Natural Catastrophe (NatCat) models.

What is a NatCat Model?

Natural catastrophe (NatCat) models are simulation models and produce the physical characteristics of a wide range of potential natural catastrophe events, their likelihoods and financial impact. The event set also includes events that are possible but have never been observed.

A NatCat model consists of:

- Hazard component – geophysical meteorological models, which represent the physical forces causing the loss and their effects on physical assets
- Vulnerability component – the event intensity metrics, simulated by the hazard component, are applied to the properties within the footprint of the simulated event to determine the property damages, which consider the vulnerability characteristics of individual properties to the simulated hazard, such as construction type, height, age
- Financial component – the physical damage to buildings is translated into financial loss, considering the terms of insurance protection in place

NatCat models have been used by the insurance industry for more than two decades. Insurers use them for risk pricing, underwriting, reserving, risk management and setting capital requirements for natural catastrophe risks. NatCat models have started being used more widely, particularly within the financial and public sector to understand the potential financial impact of natural catastrophes on their exposures.

The main advantage of NatCat models over statistical models is that they can represent events, which are possible but have not occurred recently. Such events are unlikely to be reflected in statistical models based on recent historical records. Such records are often too short for capturing infrequent events such as natural catastrophes and may no longer be fully representative of future risks. Given the strong non-linearities in projected climate change impacts going forward, this feature is highly relevant.

Moreover, the simulation process used in a NatCat model can be adjusted to incorporate the latest science on the characteristics of extreme weather events and the impact of climate change more broadly. While it is also possible to adjust historical records to capture the expected impact of climate change, this can only be done approximately and on a judgement basis.

In addition, NatCat models can explicitly account for the impact of other longer-term trends such as inflation, changes in exposures, building standards and adaption measures. This could be important even in the context of short-term climate scenarios if they entail asset repricing in response to the expected longer-term impact of climate change over the lifetime of the asset. For instance, the current pricing of real estate already reflects the expected future impact of climate change on property prices and the associated increases in insurance premiums.

…/…

The spatial nature of NatCat models is an important advantage as it allows financial institutions to incorporate the impact of acute physical risk not only at a macroeconomic level but at the asset exposure level, based on their specific geographic footprint. In contrast to typical statistical models, NatCat models provide location-specific loss estimates, which explicitly reflect property-specific vulnerabilities and insurance coverage. This is useful for developing physical risk climate scenarios (e.g. Low Policy Ambition and Disasters) as NatCat models can account for the specific intensity, geographic footprint and return period. For example, it can allow banks to incorporate the impact of the following variables in the credit risk models of their mortgage books:

- Drop in loan-to-value (LTV) ratios because of damages to real estate collateral.
- Wider drop in house prices in the impacted areas, even for properties which are not damaged due to possible deterioration in the local economy.
- House price fluctuations in any high-risk area reflecting the financial impact of the increased physical risk due to higher insurance premiums or the risk of uninsurability, and the reduced attractiveness of living/operating in high-risk areas.

As NatCat models can provide economy-wide loss estimates, they can be used for estimating impacts on aggregate macroeconomic variables such as GDP, inflation and house prices. This can be done by using, for instance, an empirically observed relationship between the size of NatCat losses and the impact on macroeconomic metrics. Moreover, NatCat models can provide useful inputs for more detailed macroeconomic impacts of extreme weather events, including second-round effects. For example, the models can estimate the size of damaged production facilities to help estimate any reductions in supply. They can also help to estimate the consequent increase in demand for the reconstruction of the destroyed assets. On the downside, NatCat models are more complex to develop, calibrate and validate than models based on historical experience.

5. From short-term scenarios to a climate stress test: some preliminary consideration

The short-term scenarios sketched out in this report reflect the impact of transition and physical risks on key macro-financial variables over short time horizons. They are not forecasts but map out plausible futures. Deliberately adverse, these scenarios can be used to test the resilience of economic or financial systems to such negative developments and promote better preparation before they occur. In turn, this could motivate policy makers and private actors to facilitate and support the transition to a net-zero economy while there is still time.

The use of short-term scenarios for such climate stress testing applications warrants a comprehensive guide once, which is envisaged for after the scenarios will have been published. In the meantime, we provide some preliminary thoughts about a few adaptation steps to be considered:

1. **Choice of starting point:** Although the starting point matters when dealing with transition paths, the short-term scenarios refer to a combination of shocks that could be relevant irrespective of the year they are implemented. Thus, the 3 to 5-year horizon can be moved over time and be applied to any starting year. For example, the start of the transition in the "Disorderly transition" scenario can be frontloaded to model a sudden start of the transition.
2. **Choice of baseline:** There is no "right" or "wrong" baseline per se as the choice of the baseline depends on the focus of the analysis.[72] Scenarios are usually quantified as deviations from a baseline (e.g., as *percentage* deviations for the main aggregates like GDP or *absolute* deviations for ratios like the unemployment rate). If the baseline is available, the results can be translated into levels and the deviation from any other baseline (e.g., a current policy baseline or an orderly transition one) can be calculated. This transformation can also be used to update scenario variables with more recent data. For instance, the impact of a scenario on current or forecasted GDP can be derived by applying the percentage deviation from any baseline to an updated/forecasted one.
3. **What if my country is not represented in the geographical breakdown of the scenario outputs?** While unfortunate, this does not have to be a limiting factor for using the data.[73] For instance, the use of results for similar countries – in terms of location, size and/or sectoral specialisation – is recommended in applying deviations from scenario baseline to a country-specific baseline. Alternatively, the user could refer to more aggregate data for the same geography (e.g., EU instead of Germany) and downscale this to the country level based on an informed judgement. For instance, if the development of a variable in each country doesn't seem realistic, the user could use the pathway of that variable at regional level applying the country-specific starting point.
4. **What if the NGFS scenarios do not capture all shocks relevant to my jurisdiction?** NGFS short-term scenarios could be combined to other existing scenarios to complement the combination of shocks that the users want to cover. The goal could be to include a climate-related risk driver to a regular stress-testing exercise. For instance, the ATC/FSC project team on climate risks combined an EBA stress-test scenario with shocks from the NGFS long-term scenarios[74] (ESRB/ECB, forthcoming). If the climate shocks considered are independent from the existing stress test risk drivers, climate-related deviations for all output variables could be added to the stress test scenario to compute combined effects. However, in case the user expects feedback loops or spill over effects from a climate shock to the stress test scenario drivers, using a model could be warranted to ensure consistency and obtain realistic aggregate effects.

72 For instance, to zoom into the impacts of transition policies on GDP, it would make sense to compare an ambitious with a less ambitious scenario (e.g.., NGFS Net zero by 2050 compared to NGFS Current Policies scenario).

73 The country granularity is related to the model used and, due to the curse of dimensionality issue, trade-offs have to be made between the richness of the model in terms of variables, country coverage and sectoral details. A criteria for model selection includes country details but also the diversity of countries modelled.

74 The NGFS scenarios have been disaggregated using a sectoral model developed by the Bundesbank, with additional shocks related to uncertainty in transition policy designed by Banque de France.

5. **What if the NGFS scenarios data do not include all variables necessary for my exercise?** NGFS short-term scenario output will depend on the modelling framework chosen. For some specific applications (e.g., climate stress tests), the level of details may not be sufficient to provide all necessary information to financial firms. In that case, other ancillary tools could be used to complete the information set. This method is close to a suite-of-model approach, as the one used for instance by the Banque de France which combines two macroeconomic models, a sectoral model, and financial modules to derive firm-level PDs, as well as sectoral credit spreads and equity valuations (Allen et al., 2021). An alternative for how to address missing variables could be to use the pathways of another variable that is expected to behave in a similar way and is available in the NGFS scenarios.

6. Conclusions and way forward

This note discusses important conceptual questions around the design and calibration of short-term scenarios. A key objective of introducing short-term scenarios is to better capture the adverse implications of a disorderly transition and severe natural disasters in the near future. By proposing five different climate scenario narratives, this note also gives a detailed account of the diversity of shocks that could arise over time horizons of three to five years with different transition and physical impacts. We therefore envisage three disorderly transition scenarios, including abrupt implementation of carbon prices, financial turmoil due to stranded assets and uncertainty shocks, a scenario representing a fragmentation in transition policies across groups of countries and a scenario with extreme physical hazards.

The note also gives detailed recommendations in terms of scenario design, shocks and calibration and model implementation. It is a preparatory step for the analytical work that will follow in 2023-2024, leading to the development of short-term climate scenarios to complement the NGFS existing scenario framework of long-term climate scenarios. This preparation of the analytical phase has started with the launch, on 23 March 2023, of a Call for Expression of Interest for the Analytical Implementation of Short-term Climate Scenarios in order to select a modelling team and a macroeconomic model that could simulate various shocks related to transition and physical risks. The analytical implementation of the short-term scenarios will then imply adapting scenario narratives based on the conceptual work detailed in this note and simulate the short-term scenarios. The scenario data will then be reported in the NGFS scenario portal and publicly available.

With these short-term scenarios, we aim to overcome the challenges of macroeconomic and financial risk analysis that arise from the focus on long-term relationships between climate and the economy, as reflected in the current NGFS climate scenarios. More concretely, the short-term scenario data to be provided could be used for climate stress-testing exercises, including more adverse effects that could potentially create systemic risk, and more generally for a better understanding of the macroeconomic impacts of various transition paths, their channels and potential trade-offs that could be useful in the monetary policy decision-making process.

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8. Appendix

8.1 Appendix 1: Case studies – stock-take from members' experiences

Several NGFS members as well as NIESR have developed short-term scenarios either for analytical purposes or in a context of specific exercises, such as climate stress-tests or initiatives to understand the relationship between macroeconomic factors and climate-related risks. These experiences are useful for the NGFS as they provide insights regarding specifications of climate-related shocks over short periods of time and modelling approaches to simulate them. This stock-take exercise was meant to kick-start the work of this group by facilitating a learning based on previous experiences.

Exploring a sudden rise in carbon prices for financial actors with macroeconomic models (NiESR)

To have a full understanding of the climate risks that the financial sector is facing, it is essential to use long-term as well as short-term scenarios in climate risk assessments. In the spring of 2022, UNEP-FI and NIESR developed several short-term macroeconomic scenarios with the purpose of increasing the financial sector's awareness of their nature and utility (UNEP-FI & NIESR, 2021). One of the scenarios explored the impact of a sudden and sharp rise in global carbon prices stemming from the need for aggressive and rapid change. Carbon prices were assumed to rise by between \$130–\$700 per tonne of CO_2 in the next 5 years. Advanced economies were expected to introduce more ambitious pricing policies. The higher price in advanced economies was indicative of the policy efforts that would be required to advance much-needed behavioral changes in countries, where much of the "low-hanging fruits" of emission reductions have already been absorbed.

The expected short-term impact of a sudden rise in carbon taxes on key macroeconomic variables were a drop in GDP growth by about 1-4 percentage points and an increase in inflation by about 1-3 percentage points compared to a Current Policies scenario that involved no sudden increase in carbon prices. The impact on GDP growth was expected to be somewhat smaller than the loss experienced during the Global Financial Crisis or the first year of the Covid-19 pandemic, but larger compared to other shocks experienced in recent decades. Inflation was expected to rise well above central bank targets in most countries, but to remain contained compared to the surge in inflation experienced by many countries during the oil crises of the 1970s.

In regions such as the Euro Area, which is less energy and carbon intensive than other parts of the world, the net impact on inflation and GDP growth were relatively subdued compared to other countries. The Euro Area, as well as countries such as Japan, were expected to benefit from improvements in their terms of trade in response to the shock, as their fossil fuel consumption is largely imported. Energy-intensive countries such as Russia, on the other hand, were expected to suffer terms of trade losses on top of the domestic pressures, amplifying the impact on both GDP growth and inflation.

Table 6 **Overview of members' experience**

Application	Jurisdiction	Shocks	Time horizon	Scenarios	Modelling approaches	Key features
[NIESR] Exploring a sudden rise in carbon prices for financial actors with macroeconomic models	World	The carbon price rises to between $130-$700 per tonne of CO_2 by the end of 5 year horizon, depending on the country	5 years	Sudden, unexpected hike in the carbon price with the advanced economies expected to introduce more ambitious pricing	NiGEM climate model	This project coupled the climate extensions and shocks of NiGEM with the standard short-term policy analysis
[ECB] Short-term scenarios for the Euro Area economy-wide climate stress test	Euro area	EBA + climate shocks	2022-2030	Accelerated Transition, late-push transition, delayed transition	NGFS combined with EBA shocks	Sectoral granularity, short-term scenarios
[IMF] Financial Stability at the Climate Minsky point: Transition risk in the UK financial sector assessment program (FSAP)	UK	1.5°C Transition	2020-2025	NDCs, Net-Zero 2050	Integrated macro-micro modeling	Climate Minsky Moment
[Banque de France] Price and financial stability assessment	France and euro area	Carbon tax, public/private investment, financial shocks, uncertainty shocks, productivity shocks	5 years	8 transition scenarios (disorderly implementation of policies, abrupt changes in behaviours,…)	NiGEM, FR-BDF and BdF Sectoral Model (Devulder, Lisack)	Assess the diversity of climate-related scenarios in business cycle frequency/monetary policy horizons
[Banco de Espana] Banking sector stress test	Spain	Increases in price and/or coverage of ETS	3 years	Disorderly: sharp increase in ETS price and energy prices; Orderly: increase in price and coverage of ETS; Draughts and heatwaves: based on the ECB/ESRB scenario	CATS: model based on Baquaee-Fahri, with 51 non-energy sectors and 2 energy sectors, detail on emissions and ETS	Production networks, full detail of the input-output structure in the Spanish economy
[DNB] An energy transition risk stress test for the financial system of the Netherlands	The Netherlands	i) USD 100 CO_2 price increase on impact, ii) share of renewables in energy mix doubles in 5 years, iii) confidence shocks depressing private consumption & investment and equity premium shock	5 years	Policy shock scenario, Technological shock scenario, Double shock scenario and Uncertainty shock scenario	NiGEM (with production function adjustment), Input-Output tables for sectoral disaggration and Pricing functions for individual bond price shocks and sectoral equity price shocks	Sectoral granularity, multiple short term scenarios, four step climate stress test framework

Short-term climate scenarios for the euro area economy-wide climate stress test (ECB)

The ECB has developed three short-term scenarios, over the time-horizon 2023-2030, combining NGFS scenarios and macroeconomic projections underlying the 2023 EU-wide stress test, as well as latest data on energy. While the first economy-wide climate stress test (2021) has shown the importance of a timely and effective transition directly using NGFS long-term scenarios, the objective of the second exercise was to use short(er)-term scenarios to assess the impact of three different transition pathways on the real economy and the financial system. The following transition scenarios have been designed and calibrated for the purpose of this exercise:

- The "accelerated transition" scenario is implemented as an NGFS-style Disorderly transition starting immediately. For the years 2023-2025, this scenario combines the EBA baseline scenario[75] with the NGFS Delayed transition scenario frontloaded from 2030 to 2023 for the macroeconomic variables available in the EBA stress test and only the frontloaded NGFS Delayed transition for all other variables. After 2025, all variables follow the NGFS Delayed transition frontloaded from 2034 to 2026.
- The "late-push" scenario is an abrupt but effective transition that starts later – around 2026 – it is intense enough to ensure a comparable emission reduction as the accelerated transition scenario by 2030. For the years 2023-2025, the EBA baseline scenario is used for the variables available in the EBA stress test, while the NGFS Current Policies scenario is considered for the other variables. Starting in 2026, all variables follow the NGFS Delayed transition frontloaded from 2034 to 2026.
- The "delayed transition" foresees a smooth but ineffective transition. New climate policies are introduced starting from 2025, but these are assumed to be milder and hence less effective compared to the abrupt but effective transition. Emission reductions are more sluggish than in the other two scenarios. For the years 2023-2025, the EBA baseline scenario is used for the variables available in the EBA stress test, while the NGFS Current Policies scenario is considered for the other variables. Starting in 2026, all variables follow the NGFS Net Zero by 2050 scenario postponed from 2024 to 2026.

Financial Stability at the Climate Minsky Point: Transition Risk in the U.K. Financial Sector Assessment Program (IMF)

The IMF's Financial Sector Assessment Program (FSAP) piloted the assessment of macroeconomic and financial criticality of physical and transition risks.[76] Here, an approach used in the UK FSAP, which assessed the implications of a "climate Minsky moment" for financial system stability (International Monetary Fund, 2022b), is highlighted. The "climate Minsky moment" is a sudden reassessment of asset values, prompted by a drastic change in market expectations that triggers a crystallization of losses. In the "climate Minsky moment", agents price in upfront the change in companies' prospects caused by shocks associated with technology and/or policy and incorporate the new expected cash flows in the valuations of assets, leading to market and credit losses for financial institutions (see Figure 2).

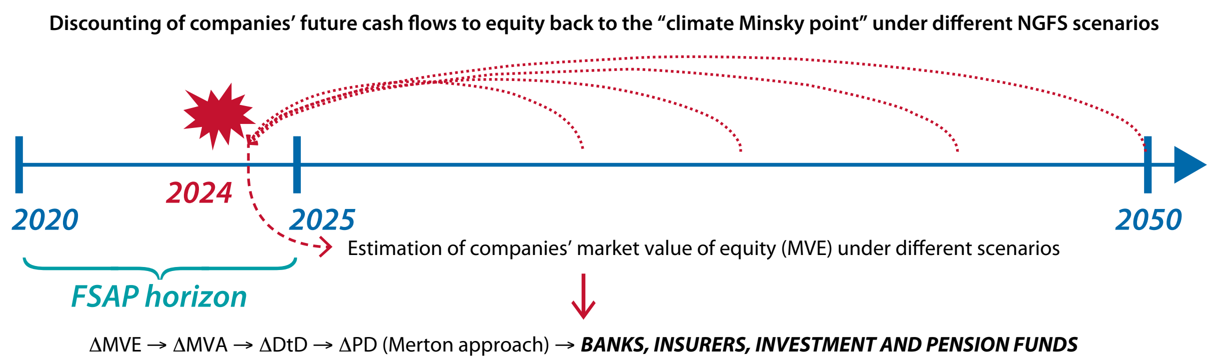
This exercise used the following NGFS scenarios: (1) "National determined contributions" (NDCs) as the business-as-usual scenario and (2) "1.5°C with Carbon Dioxide Removal" (1.5°C+CDR) from Phase I and "Net Zero 2050" (NZ2050) from Phase II as orderly transition scenarios. The simulation horizon is 2020-50 and the risk horizon is 2020-25. Cash flows are projected over the simulation horizon to capture the impact of transition risks over the whole relevant time span. However, risks are evaluated at the "climate Minsky point," which is assumed to occur within the shorter five-year risk horizon.

The initial shock is defined as a drastic change in expected global decarbonization policies, from "business as usual" to "orderly 1.5°C transition to a low carbon economy." This entails a sharp steepening of the expected carbon price path, which, in turn, leads to changes in expected costs and revenues across sectors and countries.

75 The EBA baseline scenario is based on the projections from the national central banks of December 2022. "EBA 2023 EU-wide stress test", January 2023.

76 Climate risk analysis has been piloted in recent FSAPs, for example, in Chile (International Monetary Fund, 2021), Colombia (Sever and Perez-Archila, 2021), Mexico (International Monetary Fund, 2022a), Norway (Grippa and Mann, 2020), Philippines (Hallegatte et al., 2022; International Monetary Fund and World Bank, 2022), and the United Kingdom (International Monetary Fund, 2022b).

Figure 6 **The Logic of the "Climate Minsky Moment"**



The analysis is conducted in an integrated macro-micro modelling framework. A computational general equilibrium model (CGE), GTAP-E (Corong et al., 2017), was used to assess the sectoral impact in terms of the change in the expected paths for sectoral gross value added. The output from the CGE model was then used to assess the impacts on companies within each sector. The change in expected cash flows of each firm was simulated via a suite of climate-related financial models. The shock to expected cash flows leads to a generalized revision of corporate asset valuations via discounting and recalculation of their market value of equity (MVE). This directly impacts equity holdings of financial institutions. Loan and bond portfolios are affected by companies' defaults, and for "surviving" firms, by changes in their probability of default and credit rating as a function of change in MVE and distance to default and consequently in credit spreads and price of their bonds. Changes in valuation are mapped to losses on financial institutions' holdings of securities (at the individual security level, when the information is available) and banks' loans (at the sectoral level).

This exercise found that a switch from NGFS NDCs scenario to NZ2050 scenario would generate credit losses of 3.6 percent, on average, on banks' corporate loan portfolio[77] and market losses of more than 4 percent, on average, on their equity and corporate bond holdings. Pension funds would experience losses of 3.5 percent on equity and corporate bond holdings and insurers would endure losses of 11 percent on equity, and 4 percent on corporate bonds.

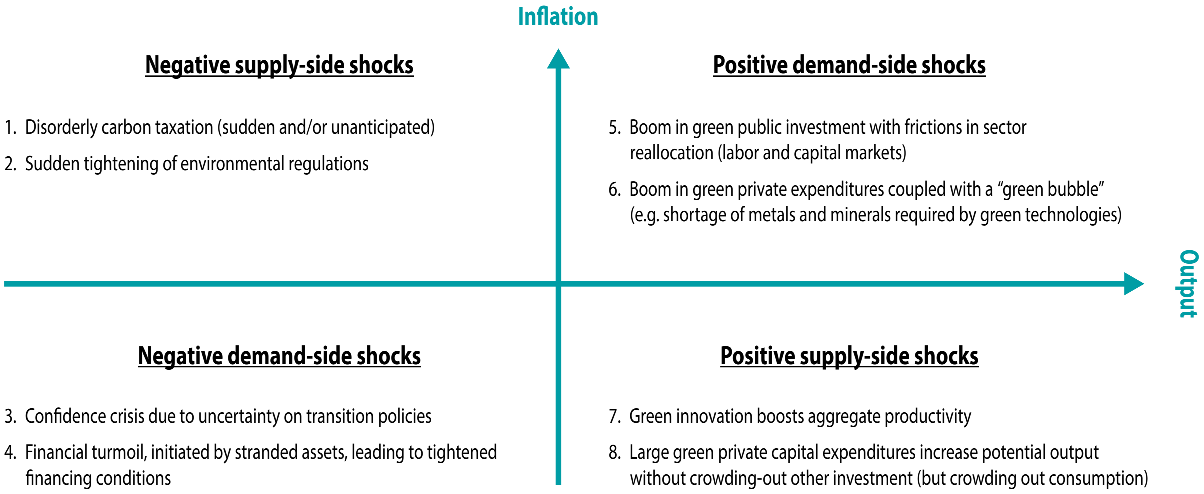
Short-term climate scenarios for France and the Euro Area by Banque de France (BdF)

Banque de France has used a suite-of-model approach (see Allen et al., 2021) to simulate eight short-term scenarios corresponding to representative cases of a "family of shocks" linked to the transition (policy shock, market shock, technology shock, etc.). These scenarios illustrate the diversity of macro-financial impacts of transition-related narratives. In practice, some scenarios could be combined, although attributing probabilities to their occurrence would be a complex endeavor. Each scenario can nevertheless mobilize different macroeconomic transmission channels, with effects that can sometimes be amplifying or, on the contrary, compensating.

One can classify the scenarios according to supply or demand shocks, which can be both positive and negative. A positive demand shock – the one usually presented in the ordered/optimistic scenarios - could have a positive effect on economic activity but also inflationary implications. In contrast, negative demand shocks – triggered by uncertainty or financial market turbulence – could be disinflationary and recessionary. On the supply side, positive shocks could stimulate economic growth and reduce inflation if they stimulate innovation and productivity. On the contrary, if they are negative, triggered for example by higher costs due to carbon taxation or stranded assets, stagflationary episodes could appear. Figure 7 below gives more details on the narratives of the various scenarios envisaged.

77 Credit losses on corporate loans would total around GBP 79 billion at the 'Climate Minsky Point', an amount comparable to the credit impairments of more than GBP 70 billion that the same eight banks in scope of the exercise would incur under the Bank of England 2021 solvency stress – but over two years (2021 and 2022) and on all their loan portfolios (not only corporate exposures). This amount corresponds, on average, to ~560 bp of Common Equity Tier 1 (CET1) capital in 2020 and ~490 bp of CET1 capital at the assumed time of the shock (2024), using the capital projections under the baseline.

Figure 7 **Impacts of short-term climate transition shocks on output and inflation**



An application of 4 of these scenarios (#1, #3, #5, #8,) has been proposed to evaluate the risks to price stability (Dees et al. 2023). The results show very different short- and medium-term impacts on economic activity and prices, depending on the transition strategies chosen (carbon pricing, subsidies for green innovations, public spending on infrastructure, etc.). The effects on inflation could range from -0.8 percentage points to +0.6 percentage points after five years, while the effects in GDP range from -1.2% to +1.6%. In particular, a "disorderly" increase in the carbon tax, i.e. sudden and unanticipated (scenario #1), would lead to a rapid increase in inflation linked to the rise in energy prices (up to 1.75 percentage points after one year, and 0.6 percentage points after five years). Initially, the effect on growth would be neutral, but it would become negative after two years, leading to a decline in GDP of about 1.2% after five years. Further details on the eight short-term scenarios, their calibration, implementation and results are available in Allen et al. (2023).

Short-term climate scenarios for the banking sector stress test in Spain (BdE)

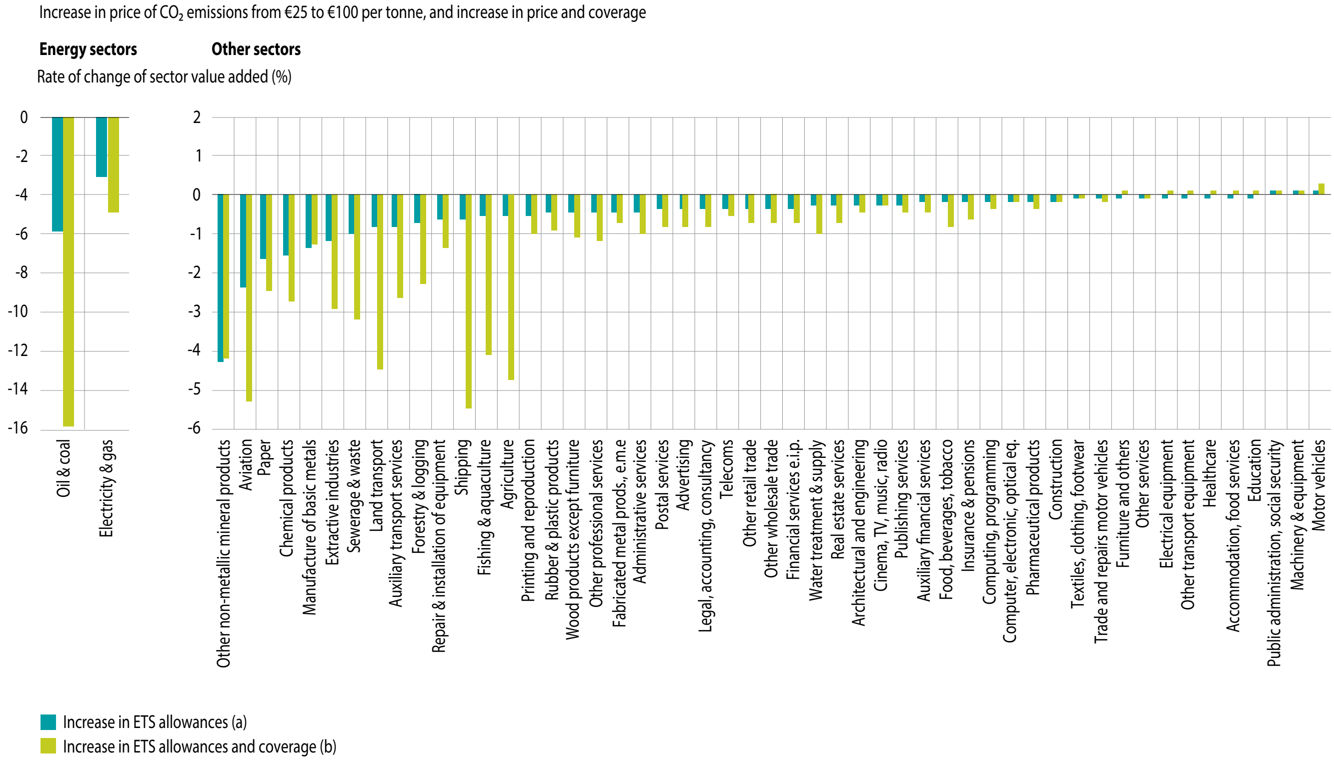
Banco de España has used its Carbon Tax Sectoral Model (CATS) to produce macroeconomic scenarios that incorporate transition risks associated with green policies (Aguilar et al., 2022). These scenarios have subsequently been employed in climate stress test exercises for the banking sector.

The model has a structure à la Baqaee and Fahri (2019), with 51 non-energy sectors and two energy sectors (fuel and electricity). It includes the cross-sectoral relationships contained in the input-output matrix, plus added detail regarding sectoral asymmetries arising from (i) the energy intensity of each industry, (ii) the source of that energy and the associated emissions, and (iii) the interdependencies with other industries. With this model, calibrated to the Spanish economy, it is possible to identify the substitution and general equilibrium effects stemming from changes in the relative prices of sectoral outputs in response to different shocks, including changes in the price and coverage of greenhouse gas emission allowances.

Figure 8 shows the impact of two climate policy shock combinations on sectoral value added. First, the red bars reflect an increase in the price of emission allowances, similar to what was observed in recent years (from approximately €25 per ton of CO_2 in 2019 to almost €100 per ton in early February 2022). The second shock adds to this increase in price an extension of ETS coverage to include all productive sectors' emissions. The model predicts a cumulative decline in Spanish GDP after three years of 0.6% in the first simulation and 1.3% in the second one. Beyond these aggregate effects, Figure 1 also shows striking sectoral asymmetries resulting from these policies. An increase in the price of ETS emissions reduces activity much more in sectors that are currently covered by the system, or in those trading heavily with sectors that are directly affected, underlining the importance of indirect policy exposures. For instance, this is the case for the printing and recorded media sector, which buys a lot of inputs from paper manufacturers, and for the repair and installation of machinery and equipment sector, that sells a lot of their products and services to various chemical and metal manufacturing sectors.

In the simulation where ETS coverage is also extended, agriculture and fishing is one of the sectors most affected, together with transport sectors. For a more detailed description of the methodology and results, please refer to Aguilar et al. (2022).

Figure 8 **Sectoral impact of environmental emission policies after 3 years**



Source: See Aguilar et al. (2022).
a. Increase in price of CO_2 emissions, from €25 to €100 per tonne.
b. Increase in price of CO_2 emissions, from €25 to €100 per tonne, and extension of coverage of EU-ETS to include all the emissions all the productive sectors.

An energy transition risk stress test for the financial system of the Netherlands (DNB)

The stress test is conducted by analyzing four severe but plausible energy transition scenarios. The scenarios revolve around the two risk factors that emerge from the literature as the main drivers of energy transition risk: government policy and technological developments (Figure 9). In addition, we consider a drop in consumer and investor confidence in a scenario where the energy transition is postponed and technological breakthroughs are absent. Furthermore, the scenarios are defined in such a way that they materialize within five years, thus ensuring that the stress test results are relevant to financial institutions, decision makers and other stakeholders, today.

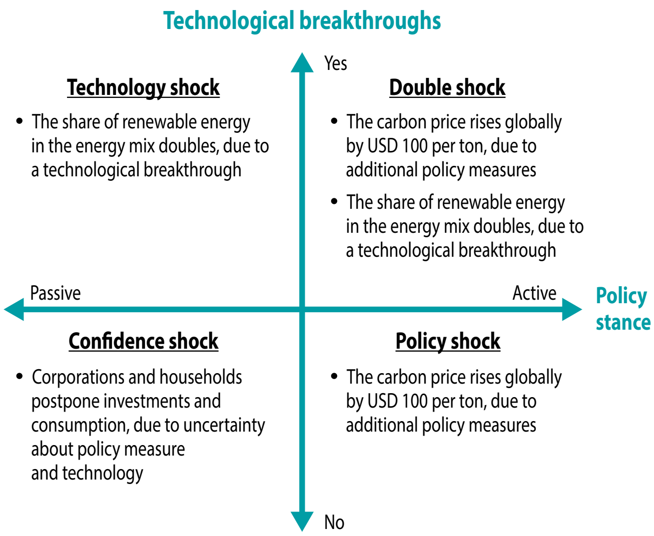
The four scenarios have the following narratives:

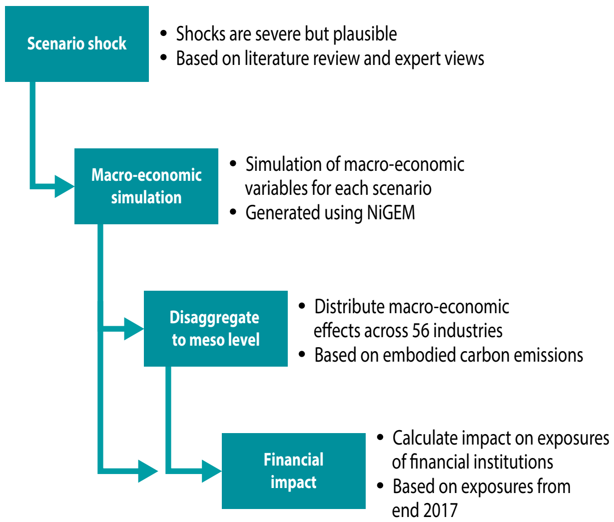
- In the policy shock scenario, it is assumed that a set of policies pushes the effective global carbon price up by \$100 per ton of CO_2 emissions. As the shock is modelled as a global quota, there are no tax receipts. The resulting cost increase leads to a general economic slowdown, while interest rates rise as the central bank attempts to curb inflation.
- In the technology shock scenario, unanticipated technological breakthroughs allow the share of renewable energy in the energy mix to double in five years. The lower cost of energy, which is assumed to be accessible worldwide, increases the potential output of the economy. In the short run, however, losses for fossil fuel producers and adjustment costs incurred by firms that need to replace equipment lead to an economic slowdown.

- In the double shock scenario, strong climate change mitigation policies are abruptly implemented while simultaneous unanticipated technological breakthroughs allow the share of renewable energy in the energy mix to grow faster than expected. This is a combination of the policy and technology push scenarios, which means that the carbon price increases by $100 per ton while at the same time, the cost of energy falls and a process of creative destruction takes place.
- In the confidence shock scenario, uncertainty regarding government policies to combat climate change causes a sudden drop in the confidence of consumers, producers, and investors. In this scenario, it is assumed that policy uncertainty triggers a sudden drop in confidence, such that consumers delay their purchases, producers invest more cautiously, and investors demand higher risk premiums. As a result, there is a setback in GDP, stock prices fall and lower inflation leads to lower interest rates.

Each scenario is first translated into an impact on key macroeconomic variables and then disaggregated to a meso level (Figure 10). Defining a stress test scenario in terms of macroeconomic variables is standard practice in macroprudential stress testing. To translate each scenario into a set of macroeconomic impacts we used NiGEM, a multi-country macroeconometric model.

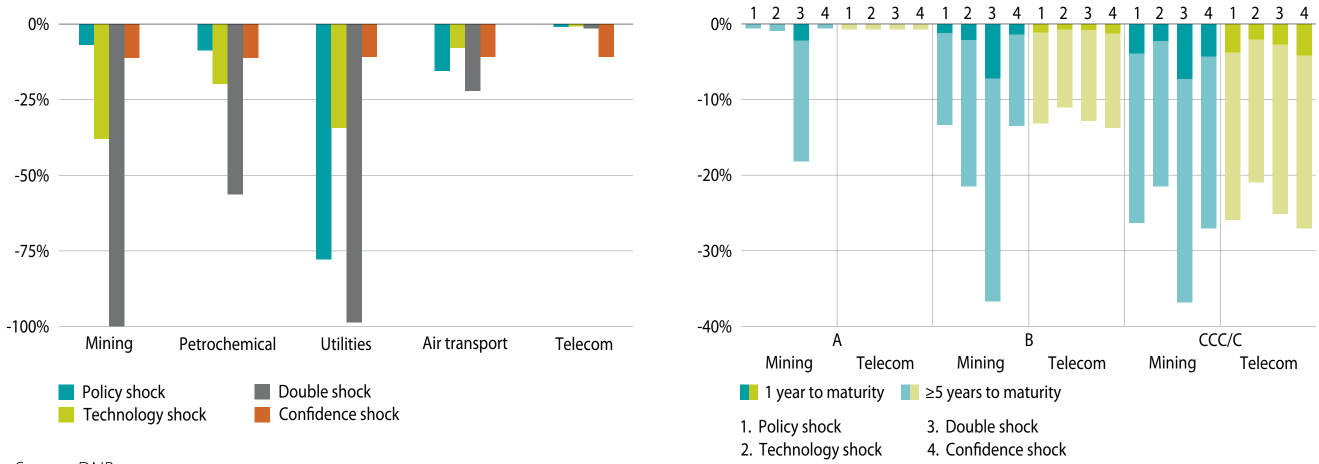
Figure 9 and 10 **Four disruptive energy transition scenarios (left) / Four step methodological approach (right)**





The stress test discriminates between exposures to 56 industries based on each industry's relative vulnerability to energy transition risks. Intuitively, energy transition risks will be more impactful for industries that rely heavily on fossil fuels. Hence, financial institutions may be more or less vulnerable to energy transition risks depending on their exposure to more or less vulnerable industries. In this study, this effect is captured by calculating a transition vulnerability factor for each industry. This transition vulnerability factor is based on the amount of CO_2 emitted to produce the final goods and services of each industry. It takes into account both each industry's own emissions and the emissions of its suppliers, yielding so-called "embodied CO_2 emissions". Since the risk channels are different in each scenario, the transition vulnerability factors vary across the scenarios as well. The total impact on financial institutions' exposures thus depends on the combined effect of the macroeconomic impact in each scenario and the industry-specific vulnerability factors. Figure 11 presents the price shocks for a selection of equities and bonds, respectively. The results are presented in Vermeulen et al. (2018).

Figure 11 **Equity price shocks (left panel) and bond price shocks (right panel) for a section of industries**



Source: DNB.

8.2 Appendix 2: Output variables and key features

(a) Output variables (i) : macroeconomic variables

Variable	Climate stress test	Macroeconomic impact assessment
GDP (and gross value added by sectors)	High importance	High importance
Unemployment	High importance	High importance
Investment (by technology)	Medium importance	High importance
Private Consumption		High importance
Export/import		
Inflation/Core inflation	High importance	High importance
Inflation (by component)		High importance
Compensation per employees		High importance
Credit Growth		High importance
Productivity		High importance
Sovereign debt/Fiscal balance	Medium importance	High importance
Real Effective exchange rate		High importance
Household disposable Income and indebtedness indicator	High importance	
Commercial/Residential Real Estate price	High importance	

(b) Output variables (ii): financial variables

Variable	Climate stress test	Macroeconomic impact assessment
Interest rates at various maturities (short, medium and long term)	High importance	High importance
Sovereign bond prices	High importance	High importance
Exchange rates	High importance	
Equity prices	High importance	High importance
Asset prices for relevant sectors	High importance	High importance
Credit spread (sovereign/corporate)	High importance	High importance
Risk premia	High importance	High importance
Lending conditions	High importance	High importance

(c) Output variables (iii): climate variables

Variable	Climate stress test	Macroeconomic impact assessment
Oil price	High importance	High importance
Gas price	High importance	High importance
Electricity price	High importance	High importance
Electricity mix	Medium importance	High importance
Energy mix	Medium importance	High importance
(Shadow) Carbon price	High importance	High importance
Emissions	Medium importance	High importance
Share of building by Energy Performance Certificate (EPC)	Medium importance	High importance
Final Energy Consumption	High importance	High importance
Primary and secondary manufacturing by sector	Medium importance	
Final Energy consumption by EPC	Medium importance	
Final Energy Consumption by sector	High importance	High importance
Quantity of available fossil fuels	Medium importance	
Land cover by sector	Medium importance	

(d) Disaggregating variables

Type of scenario	Sectoral details				Geographical details			Main trade-offs*		
	One representative sector	Key sectors	Multiple sectors	Firm-level	Regional	Country-level	International regions	Feasibility	Complexity	Usefulness
Transition risks										
Energy price repricing		x				x		Medium	High Dimensional models	High
Repricing of assets			x			x		Low	Merging with financial institution data	High
International coordination		x	x			x		Medium	Choice between sectors-geography	High
Consumer preferences	X					x	x	High	Stylized model	
Acute physical risks		x	x	x	x	x	x	High[1]	Need details on location	High
Macrofinancial risks										
Confidence	X					x	x	High	Off-model calibration	
Fiscal budget	X				x	x		High	Off-model calibration	
Productivity			x			x	x	Medium	Choice between sectors-geography	High

Note: * "Feasibility" refers to the practical implementation of defined shocks in a modelling tool; "complexity" depends on the model structure, data availability, shock types and calibration; "usefulness" refers to evaluating the extent to which the output provides valuable insights, supports decision-making or contributes to the scenario objectives.

1 Aggregate exposures could be computed by applying relevant weights such as population or different land use types.

(e) Key modelling features

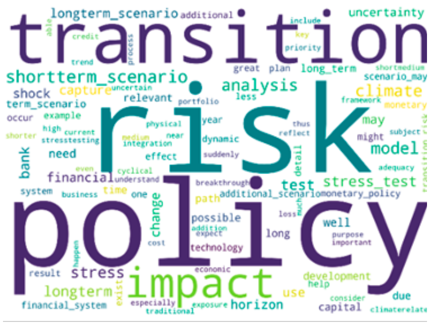
Features	Criteria to be considered	Model frameworks meeting the criteria	Relevant examples
International relationships	Multi-country approach	Multi-country CGE models or semi-structural models, which capture economic effects of Carbon Border Adjustment Mechanisms (CBAMs), international capital follows and currency movements	IMF's Financial Sector Assessment Program of XXX (including a CBAM with a CGE structure) Country-specific for trade variables and structures including in a multi-country setting McKibbin et al. (2017) on CBAM NiGEM, G-Cubed
Climate-related features	GHG emissions Climate policy instruments	Dynamic IAMs, macro models with exogenous policy instruments (e.g. taxes) and emission equations	Cai et al. (2012) NiGEM, G-Cubed Bovari, Giraud & Mc Isaac (2018)
Sectoral granularity	Energy intensive vs. Non-intensive	CGEs or IO models with details on the energy sector. Elasticity of substitution across fossil fuels	G-Cubed BdF model
Dynamic relationships	Portfolio relocation from "polluting" to green sectors and loans to "green" economy	Models with two sectors (green and non-green), including financial frictions	E-DSGE
Relevant frictions	Supply-chain disruptions, labour market frictions, financial frictions, key non-linearities	Dynamic NK models with sectoral details	Park, Hong & Roh (2013)
Shocks to quantities	Role of shortage in transmission of shocks		
Anticipated/unanticipated shocks	Forward-lookingness	Models with RE	DSGE, semi-structural models with forward-looking features (e.g. NiGEM)

(f) Baseline scenario choices

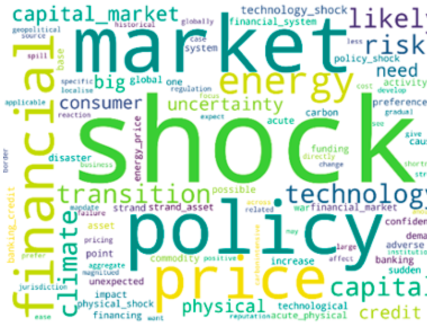
Scenarios	Description	Pros and cons	Relevance for each type of application
Business as Usual scenario	Technical baseline without climate	Neutral baseline-requires projections that exclude climate policies	Assess climate change risks
NGFS Current Policies/NDC scenario	Announced or pledged policies	To assess transition costs-should include physical consequences	Assess the cost of implementing transition policies
NGFS Orderly Transition scenario	Less adverse scenarios (close to low-carbon government strategies)	To be considered as the most desirable (likely?) scenario-risks of being unreachable	Assess resilience of financial sector compared to a desirable path
NGFS Delayed Transition scenario	Delayed Transition, as 1.5°C scenario, is not feasible anymore	Most likely scenario? Allows to compare scenarios with the same temperature target-already among the most adverse	Assess resilience of financial sector compared to a more probable path

8.3 Appendix 3: Additional survey results

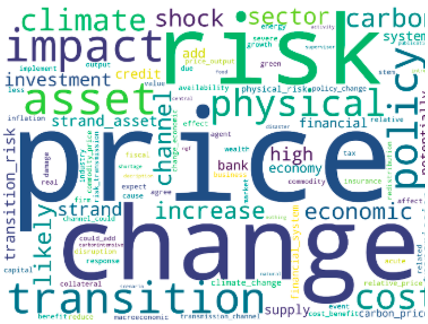
Why do we need additional scenarios to look at the short-term?



Which shocks are relevant for the short-run transition?



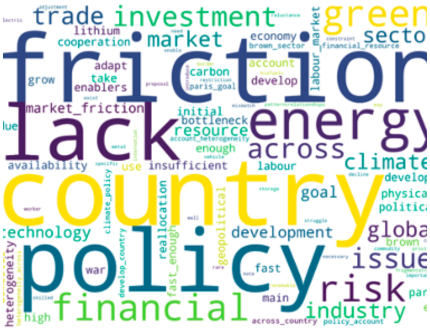
Through which channels do you expect climate to impact the economy?



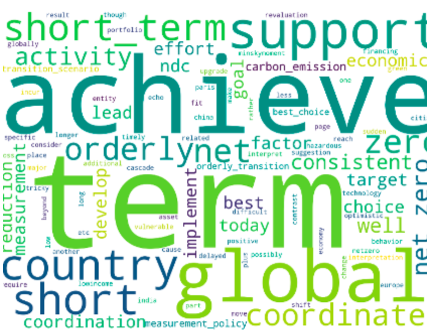
What short-term impacts do you expect on the macroeconomy?

Which risks should be considered?

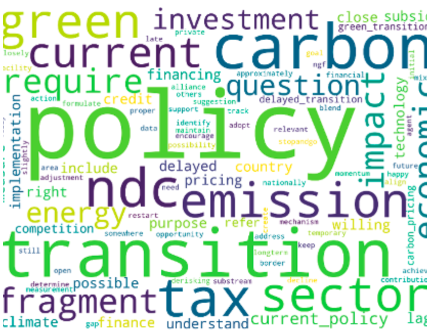
What are possible bottlenecks or enablers to reach the Paris goals?



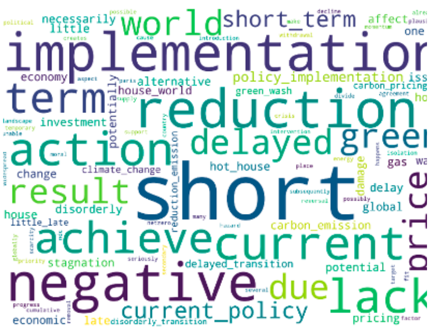
What is an optimistic climate policy scenario?



What can we expect as our best guess of climate policies within the close future?



What is a pessimistic climate policy scenario?



NGFS
Secretariat