METHODOLOGICAL PRINCIPLES OF INSURANCE STRESS TESTING – CLIMATE CHANGE COMPONENT

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Contents

List of tables

List of figures

Abbreviations

BCBS	Basel Committee for Banking Supervision
BE	best estimate
BS	balance sheet
CIC	complementary identification code
CQS	credit quality step
D&A	deduction and aggregation
DTA	deferred tax asset
DTL	deferred tax liability
EBA	European Banking Authority
EIOPA	European Insurance and Occupational Pensions Authority
ESRB	European Systemic Risk Board
GDP	gross domestic product
GWP	gross written premium
IAIS	International Association of Insurance Supervisors
ICP	(IAIS) insurance core principles
EU	European Union
LTG	long-term guarantees
NACE	nomenclature of economic activities
Nat-Cat	natural catastrophe
NCA	national competent authority
NGFS	Network of Central Banks and Supervisors for Greening the Financial System
OF	own funds
ORSA	own risk and solvency assessment
RFR	risk-free rate
RM	risk margin
SII	Solvency II
SCR	solvency capital requirement
ST	stress test
TA	total assets
TP	technical provisions
UL/IL	unit-linked and index-linked

1 Introduction

1. The main purpose of this paper is to set out methodological principles to incorporate climate change-related risks in a stress testing framework, which can be used when developing future EIOPA bottom-up stress test (ST) on climate change risks. As such, it can be seen as a methodological tool-box which can inform the design and calibration of future supervisory climate STs and is part of EIOPA's broader strategy on integrating sustainability and climate-related assessment into its various supervisory processes and framework[1][2].

2. While there are clear similarities between traditional stress testing in the financial sector and climate change stress testing, several specific challenges related to assessing climate change vulnerabilities exist. While being a relatively **new risk** compared to other traditional insurance specific and financial risks, climate change risk rapidly gained a high priority in the agendas of supervisors and policymakers. The specificity of the topic and of the events to be assessed require expertise that go beyond the usual financial / insurance perimeter, hence a close cooperation among different disciplines and the combination of various different tools and data sources to understand the potential implications of climate change for the financial sector and insurer is needed. Additionally, the long term nature of the climate change related events exceeds the time horizons used in traditional stress testing requiring a general reassessment of this element. Not only that climate change has a long time horizon, it is a process that has already started and has an impact today. Against this background, a consensus on standardized methodologies has not been reached yet and the topic is in rapid evolution.

3. Also the **long term nature** of the climate change related events[3] have a relevant effect on the **uncertainty, nature and time horizon** of any climate change scenario, as the impact of climate change is likely to be structural, irreversible and non-linear and the impacts may only manifest themselves beyond the typical short term time horizon for stress testing.[4] Against this, considerations on exogenous elements such as adaptation strategies, technological advances and responses (management actions) to climate change become relevant (see Table 1-1 for an overview of several key assumptions and uncertainties that can affect climate scenarios).

TABLE 1-1 KEY ASSUMPTIONS AND UNCERTAINTIES SURROUNDING CLIMATE CHANGE SCENARIOS

Key assumptions and uncertainties	Macroeconomic physical	Macroeconomic transition	Financial stability physical	Financial stability transition
Future climate policy	Determine the extent of warming	Determine the speed and timing of transition	Determine the extent of warming	Determines the speed and timing of transition, and also may have diffuse impacts on different sectors (for

[1] This paper is part of EIOPA's broader sustainability agenda to integrate environmental, social and governance (ESG) risk assessment in the regulatory and supervisory framework. EIOPA is committed to supporting the European insurance and occupational pension sectors in their transition to climate neutrality and to deliver on the 'Green Deal' initiated by the European Commission.

[2] Taking into account that similar work are currently carried out in various international fora (IAIS, NGFS, GFIA, etc.), this paper has a provisional nature and there is a possibility that it will be updated in the coming years in the light of new developments given the current discussions taking place worldwide.

[3] Climate change has long term impacts but it has also impacts already today. For example, the recent extreme events in 2021 can be linked to climate change.

[4] The structural, non-linear and irreversible impact of climate change in the long run has also been referred to as the Tragedy of the Horizons (Mark Carney, Breaking the Tragedy of the Horizon – Climate Change and Financial Stability, 2015): while the physical impacts of climate change will be felt over a long-term horizon, the time horizon in which financial, economic and political players plan and act is much shorter.

				example, a widespread carbon tax)
Rate of progress in carbon-neutral technology	Determine the extent of warming	Could reduce costs or actually result in an increase in GDP	Determine the extent of warming	Key technologies (for example carbon capture and storage) will be particularly important for some sectors, and result in less disruption to existing business models
Feedback loops within the model	Key assumptions (e.g. about GDP) are often taken as external in the model	Economy may be affected indirectly through second-round effects	Financial stability risks could be exacerbated by second-round impacts	Financial stability risks could be exacerbated by second-round impacts
Level of adaption and adaptive capacity	Higher level of adaption could lower the long-term physical damages but might entail higher adaption costs in the short-term	More diversified economies, adaptive firms, and resilient financial systems could reduce transition costs	Higher level of adaption could lower the long-term physical damages but might entail higher adaption costs in the short-term	More diversified economies, adaptive firms, and resilient financial systems could reduce transition costs
Non-linear impacts / uncertainties in climate modelling	Damages may be higher than expected, either through direct losses to particular sectors or through general macroeconomic channels	Higher-than-expected damages could impacts the speed and timing of climate policy	Damages may be higher than expected, either through direct losses to particular sectors or through general macroeconomic channels	Higher-than-expected damages could impacts the speed and timing of climate policy

Source: NGFS (2019)

4. Moreover, **historical data and experience are building up**, which means that climate change scenarios are inherently more forward-looking and rely heavily on assumptions about possible future equilibria and interactions between physical, transition and liability risks. In light of these challenges, EIOPA acknowledges that any EU-wide climate change ST should be at this stage seen as an important learning process with a more explorative nature, where each ST exercise will evolve as expertise and capacity is built over time. An important element of climate stress testing is therefore about raising awareness, enhancing risk management capabilities and understanding how insurers assess climate related risks themselves and evaluate potential spillover effects to other financial sectors and the real economy.

5. Finally, it should be noted that this paper focuses solely on climate change related risks and does not consider other environmental and sustainability risks for insurers. This is in line with the current focus within the global supervisory community on climate change as a wide-ranging and potentially large-scale transformation compared with other aspects of sustainability. Furthermore, this paper is mainly concerned with the financial impact of climate change related risks and does not look at specific liquidity risk stemming from climate change (approaches to liquidity stress testing for insurers in general are discussed in the Methodological Principles of Insurance Stress Testing – Liquidity component[5]).

1.1 Climate change risk and transmission channels

6. Climate change is by now widely recognized as an important source of financial risk for the financial sector and for insurers in particular.[6] Climate change related risks can not only adversely affect the safety and soundness of individual firms and the wider financial sector,

[5] The Methodological Principles of Insurance Stress Testing – Liquidity is available at https://www.eiopa.europa.eu/sites/default/files/financial_stability/insurance_stress_test/methodological-principles-liquidity.pdf

[6] See for instance SIF-IAIS Issues Paper on Climate Risk (2018) or NGFS Comprehensive Report (2019), NGFS reports in 2020 and 2021 among many others.

but also affect the insurability of risks, impacting the affordability and availability of insurance products with potential implications for the insurance protection gap (difference between total economic losses and insured losses[7]). It is therefore increasingly relevant to EIOPA's mandate to monitor and assess the resilience of the European insurance sector to adverse climate developments. In particular, stress testing and scenario analysis are seen as important tools to better understand and assess potential financial and economic risks stemming from climate change given the high-level of uncertainty involved and the more forward-looking nature of climate scenarios, to ensure that the financial system is resilient to these risks.

7. The financial risks stemming from climate change for insurers are typically divided into two different channels: physical risks and transition risk[8].

8. **Physical risk** refers to the risk faced by financial institutions due to the economic costs and financial losses resulting from the direct physical impact of increasing severity and frequency of extreme climate change-related weather events (such as heat waves, landslides, floods, wildfires and storms) as well as longer term progressive shifts of the climate (such as changes in precipitation, extreme weather variability, ocean acidification, and rising sea levels and average temperatures). For insurers, this could not only affect their own physical assets and investments, but also their insurance liabilities (through higher claims). For life insurers, increased morbidity (ill-health and specifically the rate of incidence of ill-health) and mortality from severe heat waves and other indirect impacts of rising temperatures may affect life insurance liabilities.

9. **Transition risk** refers to the risk related to the process of adjustment towards a low-carbon economy to meet the objectives of the Paris climate agreement, which may lead to a reassessment of a wide range of asset values, in particular for climate-sensitive sectors (for instance carbon/GHG intensive sectors such as fossil fuels). The transition to a carbon-neutral economy also presents some opportunities for the financial sector, for example, financing investments in building energy efficiency, renewable energy and carbon-neutral transportation. A range of factors influence the adjustment process to a low-carbon economy, including: climate change-related developments in policy and regulation, the emergence of disruptive technology or business models, shifting sentiment and societal preferences. Transition risks are particularly pronounced for abrupt and disorderly transitions to a low-carbon economy. Legal liability/litigation risk refers to the risk of climate-related claims under legal liability policies, as well as direct claims against insurers for failing to manage climate risks. Liability risk may arise when parties who have suffered losses from climate change seek compensation from those they believe may have been responsible (for instance through failure to mitigate, adapt or disclose climate change-related risks). Liability risks are of particular relevance to insurance undertakings as these risks can be transferred by means of third-party liability protection, such as professional indemnity or directors' and officers' insurance.

10. **This paper considers only climate change-related risks stemming from physical and transition risks (excluding legal liability risk).** While *legal liability/litigation risk* is also

[7] See for instance EIOPA papers: Report on non-life underwriting and pricing in light of climate change | Eiopa (europa.eu), The pilot dashboard on insurance protection gap for natural catastrophes | Eiopa (europa.eu)

[8] In 2021, EIOPA issued a second opinion related to climate change scenario in the ORSA Opinion on the supervision of the use of climate change risk scenarios in ORSA | Eiopa (europa.eu). There it was decided to use the definition from the European Commission's Guidelines on non-financial reporting – Supplement on reporting climate-related information, Communication from the Commission, OJ C 209, 20.06.2019, p. 1. where only physical and transition risks are mentioned (litigation risk is under transition risk).

important in the context of climate change, it is not addressed further in the paper as there is currently very little evidences and information available in the literature on methodologies to incorporate this in stress testing frameworks (also in the absence of jurisprudence and/or settlements related to climate change lawsuits).[9]

11. The paper also excludes consideration on the impact on the asset-pricing stemming from the application of newly developed technologies whose impact is expected over long time horizons and so far subject to incomplete and non-conclusive assessment.

12. Many studies have found that climate change-related risks can have a significant impact on the economy, in particular in the medium to long term, and is likely to affect different economic sectors and geographic regions differently.[10] Climate change risks also have direct implications for both the asset side and liability side of insurers. Table 1-2 provides an overview of the main transmission channels for insurers and highlights which ones are covered in this paper. It is worth noting that if a transmission channel listed in table is not covered in this paper, it does not imply that it will not be included in future stress test exercises. EIOPA will keep working on these aspects and consider their inclusion in the stress test framework once deemed as sufficiently mature.

TABLE 1-2 OVERVIEW OF MAIN TRANSMISSION CHANNELS FOR CLIMATE CHANGE-RELATED RISKS

Type of risk	Transmission channel	Balance sheet impact	Example	Covered in this paper?
Physical risk	Underwriting risk	Liabilities	Higher than expected insurance claims on damaged insured assets (non-life) or higher than expected mortality or morbidity rates (life/health)	Yes
	Market risk	Assets	Impairing of asset values due to financial losses affecting profitability of firms, due to for instance business interruptions, or damage to real estate. Specific example: equity price shocks	Yes
	Credit risk	Assets	Deteriorating creditworthiness of borrowers/bonds/counterparties/reinsurers due to financial losses stemming from climate change Specific example: bond price/yield shock	Yes
	Operational risk	Assets	Disruption of own insurance activities and/or assets, such as damage to own property	No
	Liquidity risk[11]	Assets / Liabilities	Unexpected higher payouts and/or lapses as broader economic environment deteriorates	No (not as part of climate ST)
Transition	Market risk	Assets	Impairment of financial asset values due to low-carbon transition, for instance stranded assets, 'brown' real estate and/or decrease in value of carbon/GHG intensive sectors. Specific example: equity price shock	Yes

[9] This does not mean that insurers and supervisors should ignore potential legal liability risks within their risk management and supervisory frameworks beyond stress testing.

[10] See for instance OECD Economic Consequence of Climate Change (2015), The Cost of Inaction (The Economist Intelligence Unit 2015), NGFS First Comprehensive Report: A Call for Action (2019) or The Green Swan: Central banking and financial stability in the age of climate change (BIS/Banque de France 2020).

[11] This concerns liquidity risk specifically stemming from climate change related risks, which is not considered further in this chapter. However, please note that The Methodological Principles of Insurance Stress Testing – Liquidity component discusses the general approach to liquidity risk stress testing for insurers.

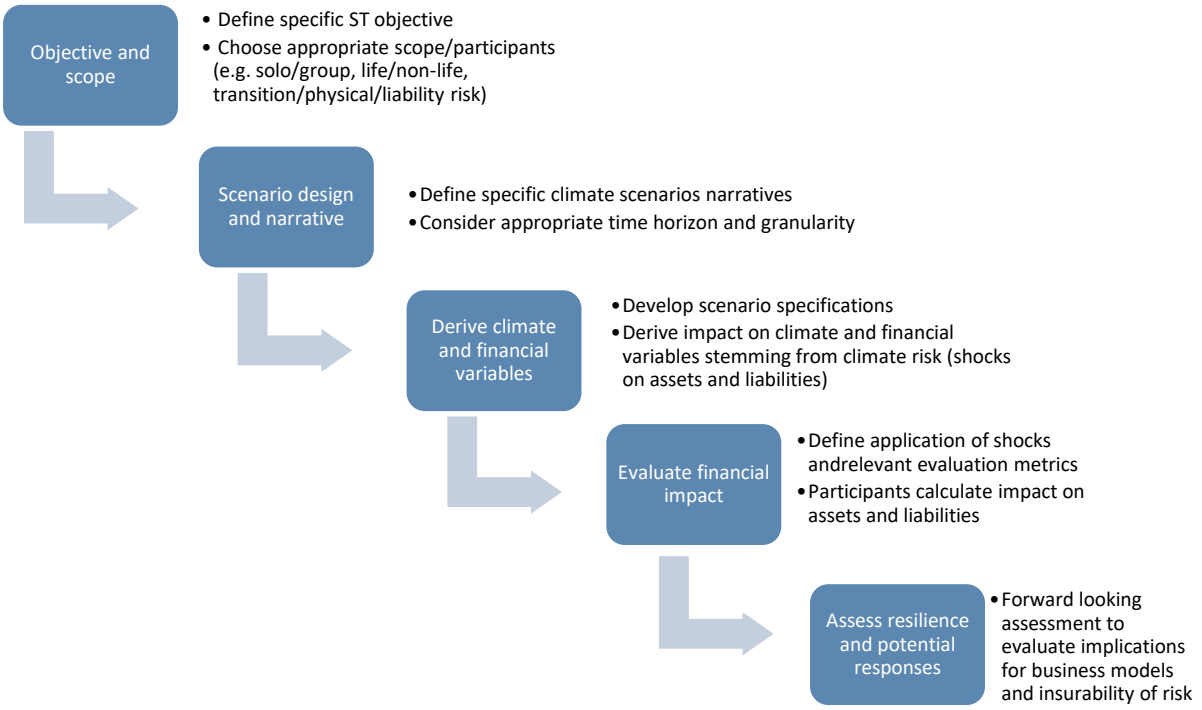
		Credit risk	Assets	Deteriorating creditworthiness of borrowers/bonds/counterparties as entities that fail to properly address transition risk may suffer losses Specific example: bond price/yield shock	Yes
		Underwriting risk	Liabilities	Decrease of underwriting business due to increase of insurance prices in response to higher than expected insurance claims (non-life) or changes in policyholders' expectations and behavior related to sustainability factors (e.g. green reputation) (life)	No
	Legal liability risk	Underwriting risk	Liabilities	Higher than expected claims on professional indemnity cover, as parties are held accountable for losses related to environmental damages caused by their activities	No
		Legal/reputational risk	Assets / Liabilities	Insurers could be held responsible for climate change and/or not doing enough to mitigate/adapt	No

13. On top of these direct transmission channels on insurers' business and balance sheet (BS), there may also be important second-round effects and feedback loops (indirect effects), as climate change may lead to a wider worsening of macroeconomic conditions further affecting insurance business, while there might also be indirect exposures stemming from other financial institutions. Depending on the modelling approach, these second round effects could also be taken into account for calibrating a ST scenario.

1.2 Elements of a Climate Change Stress Test exercise

14. The overall process of a climate change ST exercise is similar to a traditional ST, though its aim and design may differ. The figure below provides a stylized overview of the different elements of a climate ST exercise that are covered in this paper. In particular, different scenarios and modelling approaches for assessing the impact on both assets and liabilities of insurers stemming from *physical* and *transition* risk will be considered, for both non-life and life business (including health).

FIGURE 1-1 STYLIZED OVERVIEW OF CLIMATE CHANGE STRESS TEST ELEMENTS



15. The below chapters are structured as follows: the possible objective(s) of a climate ST exercise are discussed in section 2. The principles of climate change scenario design and specification are discussed in section 3. The modelling approaches for deriving specific shocks to assets and liabilities are discussed in section 4.1 (for transition risk) and in section 4.2 (for physical risk). The metrics for evaluating the financial impact are presented in section 5, while the possible approaches to a forward looking assessment, including responses and adaptation strategies to infer implications for business models, are discussed in section 6. In each section, different options are explored with a discussion of the pros and cons, with the aim of collecting concrete stakeholder feedback on the different methodologies presented.

2 Objective of Climate Change stress test

16. ST exercises can be designed to pursue micro- or macroprudential purposes.[12] The design of a climate change-related exercise, despite its specificities, follows the same logic and should have its objectives clearly defined at inception, which will inform the design and scope of any climate change ST.

17. In particular, given the forward-looking and long-term nature of climate change risks, a climate change ST exercise is expected to be more explorative compared to traditional financial stress testing. Furthermore, it is important to consider the type of risks that will be assessed, as a climate ST can incorporate all types of climate change risks (transition, physical) separately, in conjunction or focus on one particular source of risk. Finally, a climate ST can also provide information about potential issues regarding affordability and availability of insurance products in the future (more macroprudential objective to assess

[12] For a thorough discussion on the objective of a ST exercise refer to Chapter 2 of the 1st EIOPA publication on the Methodological Principles of Insurance Stress Testing available at https://www.eiopa.europa.eu/content/methodological-principles-insurance-stress-testing_en

potential spillovers and implications for protection gap / forward looking aspects). Against this, a climate ST can be designed to cover microprudential or macroprudential objectives. As for any type of ST exercise it is key that the objectives are defined upfront and the other elements designed accordingly[13]. Table 2-1 below provides an overview of the main micro- and macroprudential objectives of a climate change ST.

TABLE 2-1 OVERVIEW OF POSSIBLE OBJECTIVES FOR A CLIMATE ST

Microprudential objectives	Macroprudential objectives
• Assess vulnerabilities and resilience of individual (re)insurers to climate change risks and assess size of potential financial exposures/losses to adverse climate scenarios • Enhance understanding of potentially long-term climate change risks and implications for business models • Enhance risk management capabilities to assess and mitigate climate change risks	• Assess vulnerabilities and resilience of overall (re)insurance sector and potential systemic climate change risks • Assess potential spill-overs to other financial sectors and the real economy of climate change risks • Assess potential implications for future insurability of risks and potential protection gap for the real economy related to climate change risks/perils

18. EIOPA acknowledges that at this stage any climate change ST should be considered more as an explorative exercise and part of an important learning process to better understand the potential implications of climate change risks for the insurance sector rather than a conclusive quantitative assessment of the impact of an adverse climate based scenario on the capital position of the European insurance industry. As such, a step-by-step approach is considered, starting with a more microprudential exercise to assess individual vulnerabilities given the current BS exposures. The latter may be enriched with a separate forward-looking assessment (mostly via a qualitative questionnaire) to assess the implications of climate change risks in insurers' business models and potential spillover effects stemming from reactive management actions/responses. At a later stage, more comprehensive macroprudential exercises can be considered, but even after experience is gained, climate change stress testing are expected to look at multiple scenarios to assess potential outcomes for firms due to the inherent uncertainty of forward-looking assessment.

3 Scenario design

19. Selecting and designing suitable climate change scenarios in line with the ST objective(s) is an important element of a climate ST exercise and requires addressing a set of key questions related to risk coverage, time horizon and granularity of scenario specifications.

20. To begin with, physical and transition risks are interlinked and affect financial firms in distinct ways. The initial approaches taken by supervisors to better understand the impact of climate change tend to treat the two risks separately. The same approach is taken by the academia where much of the existing production focuses on one element or the other in insulation. Although approaching the two risks separately might help from a theoretical and operational perspective, by simplifying the analysis and enhancing transparency, it neglects to understand the interplay between the two risks. The complex dynamic between physical and transition risks can generate both mitigating and mutually reinforcing effects which

[13] For a description of the key constituent of a ST exercise refer to Chapter 2 of EIOPA (2020) Methodological principles of insurance stress testing. Available at: *https://www.eiopa.europa.eu/sites/default/files/publications/methodological-principles-insurance-stress-testing.pdf*

need to be analyzed in a ST scenario in order to create more multi-dimensional approaches for forward-looking stress testing.[14] Any climate scenario should in principle therefore involve a trade-off across both risks given their interrelated nature, e.g. continued emissions in the absence of strong climate policy will lead to rising temperatures that increase physical risks, whereas limiting these impacts requires substantial emissions reductions that may increase transition risks.

21. This section aims to further set out methodological principles to develop climate change risk related stress scenarios, looking at general principles, scenario specification, granularity and time horizon considerations.

3.1 General principles and scenario narratives

22. ST scenarios are intended to assess vulnerabilities to severe, but plausible adverse scenarios. In light of the complexity, uncertainty and long-term nature of climate change related risks, it is useful to define a set of general principles to follow in designing climate stress scenarios and narratives for the insurance sector:

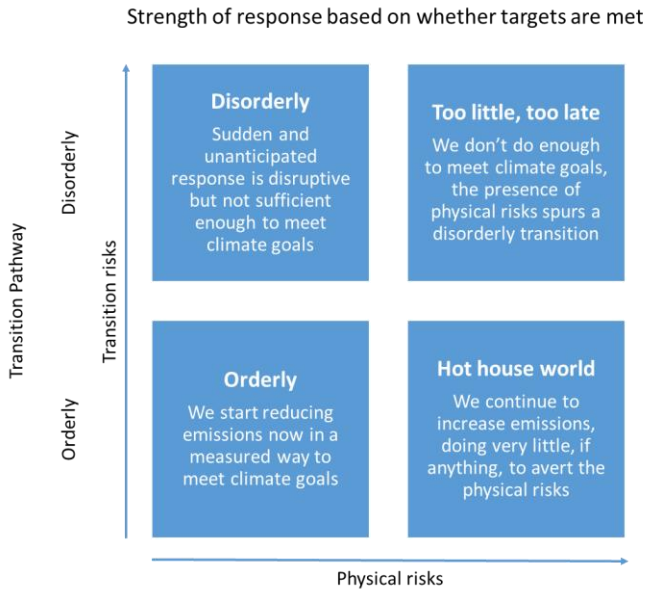
- **Principle 1:** given their distinct but interlinked nature, both transition risk and physical risk should ideally be assessed in conjunction in a climate change stress test;
- **Principle 2:** given the wide range of possible future climate paths, it is important to consider a range of climate change scenarios and transition pathways that capture different combinations of physical and transition risk. Applying multiple scenarios also allows to take into account different key dimensions, such as the role of climate policy;
- **Principle 3:** ST scenarios should focus both on a central path climate projection and on adverse tail events, to assess whether the financial system and insurers are resilient in case of disruptive climate and transition scenarios;
- **Principle 4:** scenarios should entail information (ideally quantitative) about climate pathways (key changes in climate factors) and associated financial impacts at a sufficiently granular level. The scenarios should also allow for the identification of key variables/assumptions that affect scenario pathways;
- **Principle 5:** scenarios should cover appropriate time horizons to assess the long-term impact of climate change related risks, given the more long-term nature of climate scenarios, while allowing flexibility to derive short-term stress periods from long-term scenarios.

23. When designing the different scenarios, it can be particularly useful to focus on adverse outcomes along two dimensions as proposed by the NGFS (see Figure 3-1):

- The total level of mitigation of climate change risks or, in other words, how much action is taken to achieve Paris agreement goals and reduce greenhouse gas emissions (leading to a particular climate outcome);
- Whether the transition occurs in an orderly or disorderly way, i.e. are the actions sudden and unanticipated.

[14] See Annex 3 of The Green Swan (BIS and Banque de France 2020) for more details on the interactions between physical and transition risk.

FIGURE 3-1 STYLIZED CLIMATE SCENARIOS WITH TRANSITION AND PHYSICAL RISKS



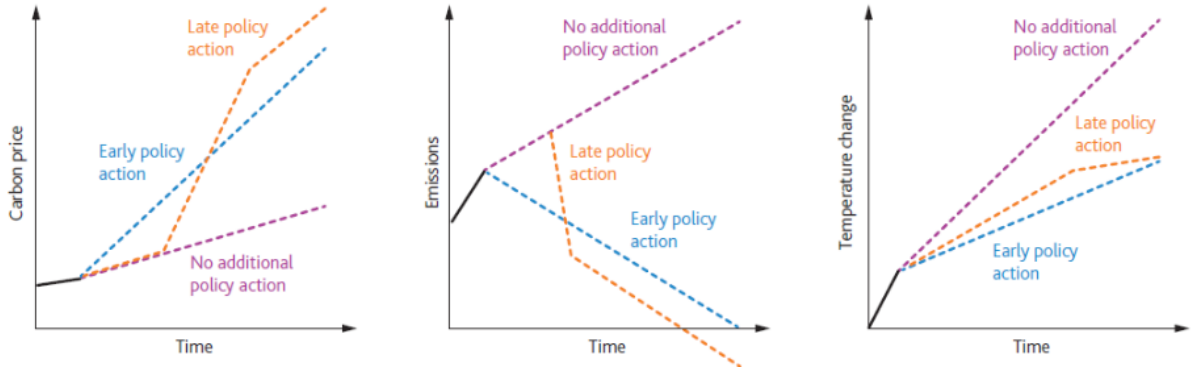
Source: NGFS Comprehensive report "A call for action: Climate change as a source of financial risk.

24. As such, the following scenario narratives seem particularly relevant for climate change related risks:

- **Early policy action, orderly transition** scenario where the transition to a carbon-neutral economy starts early and the increase in global temperature stays below 2°C, in line with the Paris Agreement. Physical and transition risks are minimized in this scenario;
- **Late policy action, disorderly transition** scenario where the global climate goal is met but the transition is delayed and must be more severe to compensate for the late start. In this scenario, physical risks arise more quickly early on and transition risks are particularly pronounced compared to the early policy action scenario;
- **Too little, too late** scenario**,** where the manifestation of physical risks spurs disorderly transition, but not enough to meet Paris agreement goals. Physical and transition risks are both high and severe;
- **Business as usual, no additional policy action** scenario ('Hot house world') where no policy action which has already been announced is delivered. Therefore, the transition is insufficient for the world to meet the Paris agreement climate goal and physical risks will be particularly pronounced.

25. Figure 3-2 provides an illustration of what the different scenario narratives/pathways could look like in terms of emissions, temperature and carbon prices. It should be noted that these scenario pathways would not explicitly incorporate social and political feedback effects, such as migration or political upheaval, in its specification or calibration, given the high degree of uncertainty related to these feedback effects.

FIGURE 3-2 STYLIZED PATHWAYS FOR POSSIBLE CLIMATE SCENARIO NARRATIVES



Source: Bank of England (2019): The 2021 biennial exploratory scenario on the financial risks from climate change

3.2 Scenario specification and granularity of technical specifications

26. Following the selection of scenario narratives, another important consideration relates to scenario granularity, as climate scenarios can be specified at different aggregation levels.

27. At the highest level, **the scenario narrative** discussed above would only describe the key assumptions about the climate transition, the timing of the shocks and climate outcomes.

28. As a next step, the scenario narratives can be translated into **specific climate outputs**, with pathways for specific climate factors related to physical and transition risk: global and regional temperature pathways, severity and frequency of perils, emissions, carbon price, energy prices and energy mix. Potential inputs for this can be the IPCC RCPs[15][16], IEA reference scenarios, General Circulation Models (GCMs) and expert judgment.

29. The climate scenario and factors can be further translated into **broad economic outputs** such as Gross Domestic Product (GDP), inflation and interest rate pathways. Potential tools for estimating these impacts are Integrated Assessment Models (IAMs), structural models, the LIMITs database or other macroeconomic models such as NiGEM or DSGE models.

30. Going one step further, **impacts can be disaggregated across economic sectors and countries** using appropriate industry classifiers, based on sensitivity to climate-related risks of specific economic sectors (for instance carbon/GHG intensities). Impacts could be classified using either NACE (4 digits where needed), GICS or GLEIF code classifiers or other classifiers, such as the Climate Policy Relevant Sectors (CPRS) developed by Battiston et al. (2017).[17]

31. Even more granular scenario specifications could derive **individual firm implications** (based on climate sensitivity of underlying activities of individual firms). This would require a highly granular mapping of the portfolio at individual asset level (ISIN) to calculate the impact of the specified shocks. A potential tool for this is the PACTA model[18] or similar approaches.

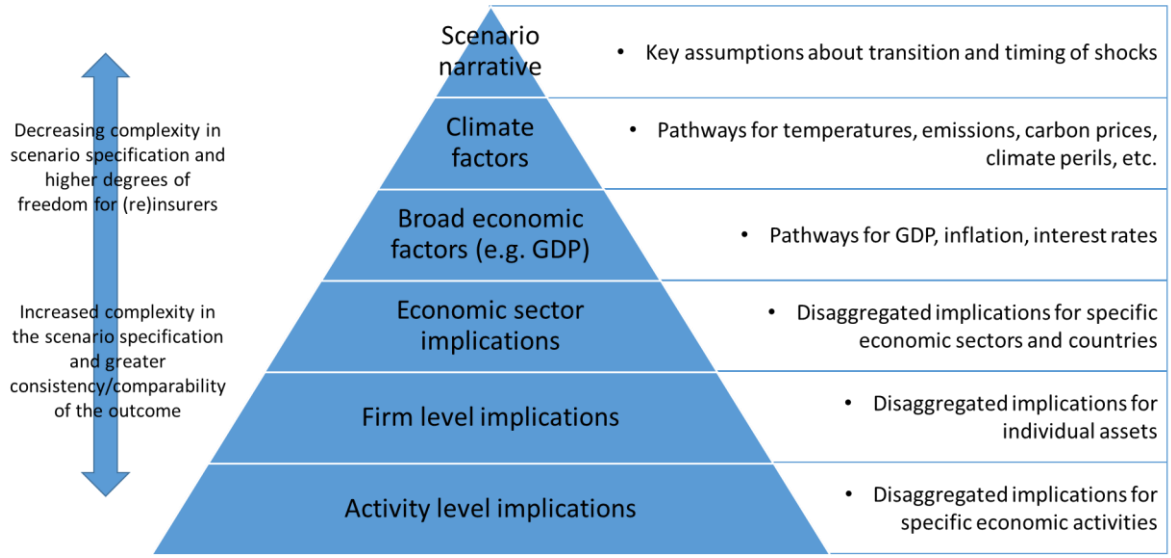
32. Finally, the most granular level of specification would derive **economic activity-level implications**. This would require participants of a ST exercise to identify and map the

[15] A new set of climate scenarios has been developed with respect to the sixth IPCC report (IPCC AR6), the Shared Socioeconomic Pathways" (SSPs). Compared to the previously used RCPs, the new SSP scenarios have been improved in a variety of ways. Link: The SSP Scenarios — English (dkrz.de)
[16] Detlef P. van Vuuren et al. (2011) The Representative Concentration Pathways: An overview. Climatic Change, 109(5).
[17] Battiston, S., Mandel, A., Monasterolo, I., Schuetze, F., Visentin, G. (2017) A climate stress-test of the financial system. Nature Climate Change 7, 283–288.
[18] https://2degrees-investing.org/resource/pacta/

economic activities of their individual counterparties/individual asset level to calculate the impact.

33. In general, the higher the level of aggregation/specification, the more degrees of freedom there are for participating firms to calculate and assess the (financial) impact of the climate scenario for their portfolio/business, but the results would be less comparable and more difficult to validate. Conversely, the more granular the scenario specification, the greater the complexity of the technical specifications and the exercise, but this would lead to greater consistency and comparability of the ST outcomes and could allow for more validation of the results. Figure 3-3 summarizes the different aggregation levels of scenario specification.

FIGURE 3-3 GRANULARITY OF SCENARIO SPECIFICATION



Source: EIOPA adapted from Bank of England.

34. The different levels of scenario granularity come with different advantages and disadvantages, which are summarized in the table below. These mainly relate to the trade-off between complexity, comparability and incentives for building risk management capacity.

TABLE 3-1 ADVANTAGES AND DISADVANTAGES OF DIFFERENT SCENARIO GRANULARITY FOR BOTTOM-UP STRESS TESTING

Aggregation level	Advantages	Disadvantages
Scenario narrative	• Simplicity: requires less detail in the specifications and can be clearly linked to climate research • Allows flexibility for firms to use different models • Forces firms to enhance modelling/risk management capacity to assess impact of high-level climate scenarios	• Greater flexibility reduces modelling consistency and comparability across firms • More difficult for participants to calculate impact on financial metrics • Results can be difficult to validate
Climate factors	• Only climate variables would have to be specified, which can be clearly linked to climate research • Allows flexibility for firms to use different models, but achieves more consistency concerning the impact on key climate factors • Forces firms to enhance modelling/risk management capacity in order to translate climate factors into financial impacts	• Greater flexibility reduces modelling consistency and comparability across firms • More difficult for participants to calculate the impact on financial metrics • Results can be difficult to validate

Broad economic factors	• Ensures consistency not only on climate factors, but also on the macroeconomic impact and key economic variables • Macroeconomic models can be used to estimate broad economic impacts	• Firms would still have to model implications from broad economic factors to their specific portfolio (reducing consistency/ comparability) • Uncertainty regarding model calibration • Broad economic factors do not distinguish between economic sectors, which could be impacted quite differently
Sectoral	• Provides clarity on the implications for different economic sectors and takes into account different impacts across economic sectors • Classifications are readily available (for instance NACE 2, GICS or GLEIF) • Results can be compared against similar studies	• No commonly accepted methodology yet to estimate sectoral impacts of climate scenarios (challenging to bridge climate models to economic sector impact) • Sectoral impacts do not take into account firm's heterogeneity within sectors • Requires mapping of the portfolio to economic sectors
Firm	• Takes into account firm-heterogeneity and specifies firm-specific impacts based on underlying activities based on activity • Ensures comparability /consistency as impacts are provided at individual asset level • Promotes risk awareness at counterparty level	• Very complex specification and requires extensive mapping of the portfolio to individual assets calculate impact • Relevant climate data at individual firm level data is often incomplete and only provides a partial view on consolidated firm activities • Less incentives for capacity/risk management building for firms to assess exposures of individual assets/counterparties, as impacts would be provided to them at a very granular level
Activity	• Specifies impacts at the most granular level • Incentives firms to assess climate exposures of assets based on the underlying activity	• Requires highly granular information on underlying economic activities of firms and how these activities would be impacted by climate change • Data on underlying activities is often not available and only provides a partial view on consolidated firm activities

35. Based on these advantages and disadvantages, EIOPA considers the most appropriate aggregation level for a bottom-up ST at this stage to be, at least, a specification that includes impacts at an economic sector whose shocks shall be calibrated, where applicable, at country and regional level:

- Sectoral level for corporate bonds, equities and real estate exposures. For specific sectors a higher granularity may be explored if needed (for instance based on technology used in energy production, e.g. coal, gas, oil or renewables);
- Country level for government bonds exposures;
- Regional level for climate related factors, such as temperature and emission pathways and intra-country regional level for climate-related perils.

36. This approach aims to strike a balance between complexity and comparability. A more granular specification (for instance with scenario outputs and shocks at individual firm-level) would be seen as too complex and burdensome at this stage for a bottom-up ST exercise, but can be considered further on as part of top-down approaches and sensitivity analysis on climate risks.

3.3 Time horizon and treatment of balance sheets

37. One of the challenges of designing climate change stress scenarios, is to define an appropriate time horizon that captures the relevant climate risk dynamics over time, while balancing this with modelling feasibility to ensure meaningful, consistent and comparable outcomes. In previous EIOPA STs on insurers and pension funds, the shocks had been applied on an instantaneous basis to the BS at the reference date with strict specifications

in the application of reactive management actions[19]. However, the full extent of climate change-related risks are expected to fully manifest over a medium to long time horizon (see Table 3-2), beyond the one typically used for stress testing (1-3 years), which makes the approach and the assumptions applied less plausible. At the same time, EIOPA acknowledges the difficulty in establishing the shocks to be applied for long term scenarios, which will be more hypothesis-driven.

TABLE 3-2 OVERVIEW OF CLIMATE CHANGE RELATED RISKS AND EXPECTED TIMING OF EFFECTS

Type of risk		Timing of effects	Financial impact
Physical risk	Extreme climate events	Short to medium term	Unanticipated shocks to physical assets, economic distress, possible systemic disruption
	Gradual warming[20]	Medium to long term	Anticipated shocks to physical and financial assets Anticipated shocks to financial and non-financial (e.g. long-term impacts on profitability of climate sensitive sectors)
Transition risk		Short to medium term	Unanticipated shocks to financial assets and potential stranded assets

Source: Adapted from NGFS Technical Supplement to First Comprehensive Report (2019)

38. In light of these challenges, Table 3-3 provides an overview of possible different approaches to the time horizon along two dimensions:

- The frequency of the calculation (i.e. whether calculations are required at intermittent intervals within the modelling horizon);
- Static/Fixed reference BS without reactive management actions or dynamic BS with reactive management actions (instantaneous shocks to reference BS versus dynamic BS)[21].

TABLE 3-3 POSSIBLE APPROACHES FOR THE FIXED/DYNAMIC BALANCE SHEET

Frequency of the calculation	Fixed/ Dynamic balance sheet	Outcome	Pros	Cons
At end of modelling horizon only	Fixed, impact on reference date balance sheet	Climate scenario modelled over short, medium, or long term with instantaneous shocks to balance sheet at reference date, no reactive management actions allowed	• Relatively easy to implement • Enhanced comparability • Allows to assess the potential impact given current business/balance sheets	• Reactive management actions/responses not considered which could overstate the impact
	Dynamic, balance sheet allowed to change	Climate scenario modelled over short, medium, or long term with instantaneous shocks to balance sheet	• Reactive management actions/responses taken into account, more realistic,	• Reduces comparability, as reactive management actions can vary and may be hard to validate

[19] The EIOPA Discussion Paper on Methodological Principles for Insurance Stress Testing distinguishes between embedded management actions and reactive management actions (Box 2.1 in the respective paper). In the context of climate change, the focus is on reactive management actions: actions that would be taken by undertakings in direct response to a climate change scenario and that are not assumed to be applied in the baseline scenario.

[20] One drawback of using gradual warming is the potential non-linear impact on climate change extremes for example.

[21] To ensure the plausibility and the consistency of the enforced reactive management actions against the designed adverse scenarios limitations in the applicable reactive management actions might be prescribed.

		at with reactive management actions allowed	notably for long-term impacts • Allows to assess impact of reactive management actions/responses	• Impact of reactive management actions difficult to assess depending on time horizon
At intermittent intervals (for instance 1 year or 5 year intervals)	Fixed, impact on reference date balance sheet	Climate scenario modelled over short, medium, or long term with instantaneous shocks to balance sheet at reference date for specific intervals, no reactive management actions allowed	• Medium complexity • Allows assessing impacts on current balance sheet over time	• Reactive management actions/responses not considered which could overstate the impact • Adds additional scenario specification and computational burden compared to only end-of period impact
	Dynamic, balance sheet allowed to change	Climate scenario modelled over short, medium, or long term with shocks to balance sheet at reference date for specific intervals, with reactive management actions allowed at each interval (e.g. shock T=10 compared to balance sheet at T=5)	• Reactive management actions and responses taken into at each interval, more realistic • Allows to assess reactive management actions and responses	• Highly complex both in terms of scenario specification and computational burden, full blown multi-period ST • Reduced comparability as results will be very hard to validate

39. At this stage, EIOPA is considering as a first step to assess individual vulnerabilities to climate change risks a ST approach based on:

- a medium-to-long term horizon (e.g. 15 to 30 years);
- shocks modelled as instantaneous to the reference date BS;
- a twofold exercise based on fix and a dynamic / constrained balance sheet;
- collection of qualitative information on the evolution of climate change impact on the business models of insurers;
- to be assessed at the end of the modelling horizon. Intermediate positions (e.g. in the middle of the time horizon) might be considered based on cost-benefit analysis.

40. This approach balances the long-term climate dynamics with operational feasibility and comparability and allows for the assessment of the potential impact of climate change-related risks given current BSs/business models (i.e. sizing the potential exposures in different climate scenarios). The approach also allows for collection of information on reactive management actions and on the qualitative evolution of climate change impact on business models. While for climate change-related risks a multi-period approach with the implementation of specific reactive management actions in each period of the simulation may be more appropriate, this would add considerable complexity to the design of a stress exercise, for which no common tools and methods for a bottom-up approach are available yet. The use of a framework based on dynamic BS approach with the use of (reactive) management actions and of a multi-period approach will be further explored in the future.[22]

41. The proposed approach could be also combined with a separate forward-looking assessment of the reactive management actions/responses to climate change-related risks to identify the risk mitigation responses that are considered by insurers in response to climate change. This approach would help to better understand the resilience of insurers to climate change and the implications of these responses on insurers' business models, for

[22] The 2020-2021 Banque de France / ACPR Climate Exercise that had a in the 30-years' time horizon and dynamic balance sheet represent a potential evolution of the current proposal.

instance with regards to asset allocation, underwriting risk coverage, Gross Written Premium (GWP) and/or protection gap and allow to assess potential spillovers effects to other financial sectors and the real economy (see also section 6).

3.4 Way forward

42. To summarize, and in light of the considerations above, EIOPA considers the following approach for a first climate change ST, recognizing that it is an important learning process:

- **Multiple climate scenarios** to be evaluated focusing on different climate outcomes/scenario narratives, given the uncertainty of future climate outcomes and to allow a range of different combinations of physical and transition risks. While this would add operational and computational burden to the ST exercise (as participants would have to calculate the impact of multiple, distinct climate scenarios), using multiple scenarios allows to take into account different key dimensions of climate change risks and better assess vulnerabilities and resilience to adverse climate scenarios.
- **Scenario and technical specifications** with specific climate variables at regional (intra-country) level for perils and financial impacts at a sectoral level (for corporate bonds, equities and real estate)[23] and country level (for government bonds), to ensure a balance between complexity and comparability. Methodologies for deriving, specifying and calibrating these variables will be discussed in more detail in sections 4.1 (for transition risk) and 4.2 (for physical risks). A more granular scenario specification, for instance at individual asset/firm level, would be seen as too complex and burdensome at this stage for a bottom-up ST exercise, but will be considered further as part of EIOPA's work on top-down methodologies and sensitivity analysis on climate risks.
- **A medium-to-long-term time horizon**, with end-of-modelling horizon scenario impact evaluated as an **instantaneous shock to the reference BS under a fixed and constrained framework.** This allows assessing the potential long-term financial impact of climate change related risks given current business models and BSs. As such it can give an important indication of the size of potential exposures, and hence the required transformation given current business models, should a specific climate scenario materialize, given the more long-term nature of climate scenarios.
- A **separate forward-looking assessment** designed to capture the reactive management actions/responses to climate change-related risks to identify the risk mitigation responses that are considered by insurers in response to climate change and better understand the implications of these responses on insurers' business models, their resilience and the potential spill-over effects (see section 6). This may be enhanced with questions designed to solicit information on the level of integration of climate change-related risks in areas such as governance, strategy, risk management and metrics and targets of insurers.

4 Modelling approaches

43. This section discusses different possible modelling approaches to derive and calibrate the physical and financial impact on insurers' asset and liabilities in a climate change scenario. Section 4.1 discusses modelling approaches for transition risk, whereas section 4.2 discusses approaches for physical risk. Section 4.2.3 subsequently discusses general principles regarding the specification and application of the shocks.

[23] For specific sectors a higher granularity may be explored if needed (for instance based on technology used in energy production, e.g. coal, gas, oil or renewables)

4.1 Transition risk

44. The shocks to the assets and related calibrations to capture the transition risks derives from the transmission channel as presented in Table 4-1.

TABLE 4-1 OVERVIEW OF THE MAIN TRANSMISSION CHANNELS ON THE ASSET-SIDE

Type of risk	Transmission Channel	Balance Sheet impact	Example	Asset classes affected
Transition risk	Market risk	Assets	Impairment of financial asset values due to low-carbon transition, for instance stranded assets, 'brown' real estate and/or decrease in value of carbon/GHG intensive sectors. Specific example: equity price shock	Equity Property Infrastructure
	Credit risk	Assets	Deteriorating creditworthiness of borrowers/bonds/counterparties as entities that fail to properly address transition risk may suffer losses Specific example: bond price/yield shock	Government bonds Corporate bonds Mortgages/Loans

45. The relevant asset classes considered are based on the main asset categories in Solvency II[24], i.e. government bonds (Complementary Identification Code - CIC 1), corporate bonds (CIC 2), equity (CIC 3), property/real estate (mortgages/loans) (CIC 8-9) and infrastructure investments (CIC 0). The focus would be to calibrate the severity of the negative shocks according to the climate sensitivity of the assets, in line with the adverse scenario approach of STs. Although the transition to a low-carbon economy can potentially also lead to positive shocks for certain assets, for instance in the case of "green" assets or technologies, this can only be considered in a stress testing framework if they can be duly justified.[25] The methodologies discussed below potentially allow for the integration of positive shocks, but the inclusion of these would have to be carefully considered in light of the ST objective with a focus on adverse scenarios.

46. Each of the sub-section below is devoted to a modelling approach and focuses on the asset classes that are treated in the method, including the discussion on methodologies and data sources to calibrate the shocks (more details about the modelling approaches can be found in the Annexes, section 7.2). The criteria for the calibration refer to the level of the shock (asset level, industry/sector level or geographical level), the future economic trajectories and forward-looking climate policy shock scenarios. In particular, the derivation of impacts from climate policy shocks are considered. Climate policy shocks negatively affect high carbon firms and sector's profitability. One example for climate policy shocks is the introduction of a carbon tax. Table 4-2 provides an overview of the main asset classes and list the methodologies that could be used to derive the financial impact of transition risk (including the level of granularity the methodology would allow the shock to be specified).

47. The list of methodologies is by no means exhaustive[26] and EIOPA intends to liaise with the academic community, practitioners and model vendors for the exact calibration of the shocks. Furthermore, given the data limitations and reliance on assumptions of the methods presented, the results give only an approximation of the possible future development of assets in the light of climate change scenarios. Depending on the

[24] As laid out in the Commission Implementing Regulation (EU) 2015/2450, Official Journal of the European Union, L 347, 31 December 2015 (p. 1208).
[25] For instance, CARIMA, the stress testing module of the PACTA tool and others emphasize that risks are two-sided and therefore, positive shocks should be considered in stress-testing.
[26] The overview focuses on open-source and publicly available methodologies. EIOPA is aware that commercial model vendors have also developed specific climate change risk models, but these are excluded from the list.

assumptions and limitations of the methods, it is crucial to bear in mind that the results might change over time with varying assumptions or parameters and should therefore not be seen as a forecast.

TABLE 4-2 OVERVIEW OF THE MAIN ASSET CLASSES AND METHODOLOGIES THAT COULD BE USED TO DERIVE THE FINANCIAL IMPACT OF TRANSITION RISK[27]

Assets	Methodology	Granularity
Government bonds	CLIMAFIN (Battiston and Monasterolo,2019)	Country-level
	NiGEM / Gaussian VAR (BdF)	Country-level
Corporate bonds	CARIMA (Gorgen et al.)	Asset level, sector level or country level
	CLIMAFIN (Battiston et al.)	Asset or Sector level
	NiGEM (DNB and BdF)	Sector level
	PACTA (2dii)	Asset or technology level
Equity	CARIMA (Gorgen et al.)	Asset level, sector level or country level
	CLIMAFIN Battiston et al. (2019)	Asset or Sector level
	NiGEM (DNB and BdF)	Sector level
	PACTA Model (2dii)	Asset or technology level
Property/real estate (mortgages)	CARIMA (Gorgen et al.) PACTA (2dii)	Firm-level Individual Property level
Infrastructure investments	See corporate bonds or equity (depending on the type of infrastructure exposure)	

48. Finally, due to the high degree of uncertainty, assumptions and the limitations of climate modelling and the uncertainty of future (political, economic, or societal) developments, any of the methodologies discussed below will ultimately have to be complemented with expert judgment based on review of available literature/estimates on climate impacts to validate the shocks in terms of severity and plausibility.

4.1.1 CLIMAFIN

Government bonds

49. Government bonds are not immune to climate change risks. A climate policy shock might affect the coupon rate and the expected value of a sovereign bond, through the channel of its intermediate impact on the sovereign net fiscal assets and its default probability (Battiston and Monasterolo, 2019).[28] However, due to the interconnectedness of the capital markets, the competitiveness of the real economy and financial stability, the impact of climate change on government bonds is more complex than, e.g., for equities or corporate bonds.

50. The approach by Battiston and Monasterolo (2019) is based on the CLIMAFIN model developed by Battiston, Mandel and Monasterolo (2019)[29] and focuses on the analysis of a disorderly policy transition on sovereign bonds, through the channel of firms' profitability to sectors' Gross Value Added (GVA). This approach prices forward-looking climate transition risks in the value of individual sovereign bonds, by including the characteristics of climate risks (i.e. uncertainty, non-linearity and endogeneity of risk) in financial valuation,

[27] One challenge in a climate stress test is to create one consistent scenario, using different methodologies for each asset class. In this context, some simplifications and assumptions would be required to obtain one scenario covering all asset classes. Furthermore, as new methodologies are being developed, this table should not be regarded as exhaustive.

[28] Battiston, S. & Monasterolo, I. (2019). A Climate Risk Assessment of Sovereign Bonds' Portfolio Working paper, available at SSRN: https://ssrn.com/abstract=3376218

[29] Battiston S., Mandel A., Monasterolo I. (2019): CLIMAFIN handbook: pricing forward-looking climate risks under uncertainty". Working Paper, Climate Finance Alpha.

using policy-relevant 2°C-aligned climate mitigation scenarios from the LIMITS project database (Kriegler et al. 2013).[30] The model first analyses the impact of the shock on firms and sectors' profitability and subsequently calculates the change in market share and GVA for sectors and firms in fossil fuels and renewable energy sectors, using two Integrated Assessment Models (IAM) (GCAM and WITCH). This serves as a basis to calculate the impact on fiscal revenues of sovereigns and finally on sovereign fiscal assets and default probability, which affects the value of sovereign bonds.[31]

51. The study uses different data sources. The Nomenclature of Economic Activities (NACE) Rev2 classification of economic sectors allows to associate the exposure of a specific financial instrument to a specific sector of economic activity which allows, by remapping the subsectors in five climate-relevant sectors, to distinguish carbon-intensive and low-carbon sectors. Lastly, using data on energy and electricity production and proxies by fossil fuel, nuclear and renewable energy technology, by British Petroleum (BP), Statistical Review of World Energy 2018 and by the IEAs World Energy outlook (2018), Battiston and Monasterolo (2019) estimate the gross value added of each technology and its share on total electricity production by country. More detailed information on their findings can be found and its application to insurers' sovereign bonds can be found in Annexes, section 7.2.1.[32]

Corporate bonds and equity holdings

52. The method which is used for government bonds, i.e. the CLIMAFIN approach developed by Battiston et al. (2019), can also be extended for the analysis of transition risk on corporate bonds and equity holdings.

53. The approach embeds climate scenarios in adjusted financial pricing models and allows forward-looking transition risk shocks obtained from climate economic models (e.g. IPCC). As such, it allows embedding forward-looking risk scenarios in the valuation of counterparty risk, in the probability of default of bonds and largest losses on investors' portfolios (Battiston et al., 2019).

54. The CLIMAFIN approach would allow asset shocks to be specified for climate-sensitive sectors (for corporate bonds and equities) and climate-sensitive countries (government bonds), but could also be used to derive more granular shocks at individual issuer level.

55. However, one drawback is that IAMs have limitations relating to the model structure and behavior which, in turn, may affect the policy relevance of the outcomes and hence may not be suitable for scenario analyses (see IMF, 2019).

[30] Kriegler E, Tavoni M, Aboumahboub T, Luderer G, Calvin K, De Maere G, Krey V, Riahi K, et al. (2013) What does the 2 C target imply for a global climate agreement in 2020? The LIMITS study on Durban Platform scenarios. Climate Change Economics 4(4), 1340008.

[31] According to Battiston et al. (2019), the climate spread metric introduces climate as a source of risk in 10-years' bond yields. Shocks are potential gains (positive) or losses (negative) on individual sovereign bonds associated to countries disordered transition to a 2°C-aligned economy by 2030.

[32] The application to insurers' sovereign bonds is also described by Battiston, S., Jakubik, P., Monasterolo, I., Riahi, K. & van Ruijven, B. (2019). Climate risk assessment of sovereign bonds portfolio of European insurers, EIOPA Financial Stability Report December 2019, available at: https://www.eiopa.europa.eu/content/eiopa-financial-stability-report-december-2019

4.1.2 CARIMA

56. Görgen et al. (2019)[33] build on previous work Fama and French (1993)[34] and Elton et al. (1995)[35] to capture the sensitivity of carbon risks on assets such as corporate bonds among other asset classes. Their work, named "Carbon Risk Management" (CARIMA) aims at measuring, quantifying, and managing carbon risks and financed emissions.

57. The authors develop a factor model approach to capture the sensitivity of carbon risks on corporate bonds among other asset classes, by introducing a Carbon Risk Factor BMG ("Brown-Minus-Green"), which can be used to derive a 'Carbon Beta'. This Carbon Beta measures the effect of unexpected changes in the transition process of the economy towards a green economy.

58. The CARIMA approach is a fundamental approach to analyze the drivers of returns of assets and the range of the application of the Carbon Beta is wide as it can be determined for several asset classes such as stocks, corporate bonds, loans, portfolios and funds.[36] Moreover, the Carbon Beta can be aggregated to country or sector level and thus allows country and sector analyses. For the purpose of stress testing, the Carbon Beta can be used for generating scenarios. However, one of the most important limitations of this and similar methods is that the "real" market portfolio is unknown.

Corporate bonds

59. For the purpose of measuring the effect of Carbon Risk on corporate bonds, the authors estimate a factor model including the Carbon Risk Factor BMG. In the context of corporate bonds, a high positive value of Carbon Beta means that the value of the asset will fall compared to the entire market, given a transition process. If, analogously, the Carbon Beta takes a high negative value, it implies the opposite, i.e. the value of the asset will increase compared to an average asset, given a transition process. Carbon Betas close to zero imply that the asset moves to an average extent by the transition process.

Equities

60. For equities, transition risk impacts share prices through revenues and capital charges with varying effects across sectors. By affecting the market value of a company, the CARIMA approach allows to derive shocks to individual assets and climate sensitive sectors.

Property/real estate (mortgages) and loans

61. In the case of loans and mortgages real estate projects, Carbon Risk emerges from credit risk, in particular default risk. Transition risk on real estate can be linked to higher energy efficiency standards or lower household wealth due to increased energy costs and expected price development of properties will, in turn, lead to changes in the valuation of mortgages associated to the property. By calculating the Carbon beta of loans related to real estate projects, one is able to build a proxy for transition risk on property and real estate projects.

[33] Görgen, M., Jacob, A., Nerlinger, M., Riordan, R., Rohleder, M., Wilkens, M. (2019) Carbon Risk. Working Paper.
[34] Fama, E. F., French, K. R. (1993) Common risk factors in the returns on stocks and bonds. Journal of Financial Economics, 33 (1), 3–56.
[35] Elton, E.J., Gruber, M.J., Blake, C.R. (1995) Fundamental Economic Variables, Expected Returns, and Bond Fund Performance. Journal of Finance, 50(4), 1229-56.
[36] The freely available Excel-tool provides an intuitive starting point for investment professionals to quantifying Carbon Risk and its effect on investments.

62. In general, the CARIMA method measures the impact of Carbon Risks on financial assets using historical return time series. For loans, however, such historical return time series or historical time series of (present) values are not available. Hence, the Carbon Beta can only be measured indirectly by using the Carbon Beta of corporate bonds and stocks. There are several possibilities to indirectly determine the Carbon Beta for loans.

63. First, if a firm issues corporate bonds and the Carbon Beta can be calculated, the Carbon Beta of that firm's loans can be also be determined. This may be relevant for non-listed firms, where no times series of stock returns are available. Second, if a firm issues stocks and the Carbon Beta can be calculated, the Carbon Beta of that firm's loans can be also be determined. This may be relevant for listed firms that do not issue corporate bonds. Third, if a firm issues corporate bonds and stocks, the Carbon Beta of that firm's loans can be estimated by the Carbon Beta of comparable firms. This may be relevant for listed firms that are financed by stocks and corporate bonds. Finally, if a firm issues neither corporate bonds nor stocks, the Carbon Beta of that firm's loans can be estimated by the Carbon Beta of comparable firms. This may be relevant for non-listed firms that are financed with capital market instruments.

Infrastructure investments

64. Infrastructure investments usually have bond or equity exposure. Building on the Carbon Betas of equity and corporate bonds, one can consider whether infrastructures investments have a different risk profile. Otherwise, it is possible to consider infrastructure investments as part of the bond and equity shocks depending on the underlying industry.

65. One major issue is that in order to calculate Carbon betas, the CARIMA models rely on historic returns. Especially in the case of alternative investments such as real estate, underlying returns are often unavailable or only provide recent data. One solution is to consider proxies for missing historic returns.

4.1.3 NiGEM model

66. De Nederlandsche Bank (DNB) and Banque de France designed their energy transition risk ST using the multi-country macroeconomic model NiGEM. DNB considers risks related to a delayed policy response (with a sudden and sharp increase in the carbon price) to climate-risk and asymmetric technology shocks.[37] Banque de France studies the impact of different transition pathways (in terms of timing, level of carbon taxation, and distribution channels) to reach the Paris agreement goals. In both approaches, the macro-financial impacts of the climate scenarios are derived within the NiGEM model (i.e. the climate shocks – carbon price in particular - are inputs into the model which generates broader economic and financial shocks).

67. As not all industries are equally vulnerable to scenario conditions, DNB computes Transition Vulnerability Factors (TVFs) to account for the heterogeneous reactions of different industrial sectors, depending on their carbon footprint. The TVFs take into account not only an industry's own emissions, but also the emissions of the supplying firms throughout the entire production chain. Differently from the binary measures often used (green vs. brown industry), the TVFs capture a more granular distribution of sensitivities across 56 sectors. In order to capture interactions effects related to the production chain and sector-specific emissions intensities, Banque de France connects NiGEM with a sectorial model and obtains

[37] Vermeulen, R., Schets, E., Lohuis, M., Kölbl, B., Jansen, D., Heeringa, W., 2018. An energy transition risk stress test for the financial system of the Netherlands. DNB Occasional Studies No 16-7. Available at: https://www.dnb.nl/en/binaries/OS_Transition%20risk%20stress%20test%20versie_web_tcm47-379397.pdf.

impacts of an increase in carbon price on sectoral value added and turnover. Furthermore, to disentangle the effect between winners and losers, the Banque de France connects the sectorial model to a firm-level credit risk rating model, in order to address the intra-sectoral (firm-level) heterogeneities.

68. DNB translates the NiGEM forecast of stock price indices and government bond yields into industry specific equity and bond returns. To derive equity returns by industry, the equity losses incurred in a given scenario and based on excess market returns are transposed at the sectoral level through the TVFs. Bond prices are instead derived according to changes in the risk free interest rate (when it increases, bond prices decrease) and in industry-specific credit risk spreads (when they increase, bond prices decrease). Banque de France and L'Autorité de contrôle prudentiel et de résolution (ACPR) aim at determining the sensitivities of industry specific stock returns to climate risk by means of the following two approaches: a) the NiGEM-based projections of stock price indices are translated into associated industry level stock returns by means of a previously estimated CAPM-like relationship; b) the NiGEM-and-Sectorial-Model-based projections of industry specific value added (or sales revenues) and associated dividend flows are linked to the industry level stock return using a Dividend Discount Model with discount factors given by credit-risk-adjusted EIOPA Risk Free Rates (RFR) with proper maturity. As far as industry specific bond returns are concerned, they are determined by adding to the NiGEM-based sovereign yield projections an industry specific credit spread component.

69. As such, the financial shocks are provided both as broad economic factors (such as GDP, inflation and interest rates movements) and sector specific shocks (based on carbon intensity). The benefit of this approach is that it takes into account different vulnerabilities across industries and the impacts can be readily calculated using a combination of macroeconomic models and input-output tables on carbon footprints. The limitations of specifying shocks at a sectoral level using the NiGEM model are that it does not allow for firm-level heterogeneity within industries for the financial shocks and that the climate shocks have to fit the specifications of the macroeconomic model (to be used as inputs). Banque de France tries to address this issue subsequently with a firm-level credit rating model, using the sectorial model outputs. A second challenge concerns the ability to generate a term structure of risk-free rates (instead for short-term and long-term maturity only) with nominal term premia across the maturity spectrum. A third challenge relates to the combination of an interest rate shock (consistent with the climate scenario and modelled on the climate policy shock) and a sector specific credit spread shock for bonds.

4.1.4 PACTA model

70. The PACTA model assesses the alignment of firms' investments portfolios with respect to a 2°C scenario. The goal of this approach is to analyze the current exposure of the portfolio to economic activities affected by the transition to a low-carbon economy, to illustrate the alignment with a 2°C transition within a period of five years and to assess the expected future exposure to high- and low-carbon economic activities.

71. The PACTA model[38] calculates the expected benchmark exposure for each technology in the specific asset class. Current and planned production (fossil fuel and automotive sector) and current installed capacity as well as new capacity additions (power sector) are sourced from business intelligence databases. Using this forward-looking production and capacity data at the physical asset level, the model maps this data to their immediate owners and parent company to generate an aggregate "current production profile" for each technology.

[38] 2° Investing Initiative (2019). 2° SCENARIO ANALYSIS Report - Background Information, available at https://www.transitionmonitor.com/wp-

72. Linking these production plans to the financial assets (equity and fixed income) issued by the company, it is possible to derive the current exposure in the respective asset class and geography and adding a trend scenario line, e.g. International Energy Agency - IEA's 2°C compatible sustainable development scenario, to each technology. The models time horizon is five years, which reflects the time horizon of capital expenditure planning for which meaningful data is available, across all sectors. The chosen scenarios reflect potential technologies pathways to meet climate goals and are subject to uncertainty. The providers of the climate technology pathways are the IEA, Greenpeace, Bloomberg, among others.

73. For stress testing purposes, the PACTA approach can be used to derive individual asset shocks ("stressed values") based on the adjustment in physical production that would be needed to align with a 2 degree scenario (for instance based on a 'late and sudden' type of adjustment). The sensitivity could be measured depending on a) when policy action is taken and b) how strong the policy measures are (i.e. how fast does the economy move to decarbonize).

74. This detailed assessment would require physical production to be linked to a set of defined scenarios. For assets where this information is available, shocks can be based on the required change in production necessary to meet the targets in a 2 degree scenario. An advantage of this approach is that it takes into account firm-level heterogeneity and shocks are based on actual physical production. However, a drawback of this approach for bottom-up stress-testing is that it would require highly granular individual asset level specifications for the shocks (only available for those assets that can be linked to physical production, which are mostly listed equity and corporate bonds) and participants would have to map their portfolio to the individual shocks.

Corporate bonds

75. For corporate bonds, the re-pricing could be based on a calculation of the expected change of net income due to the required adjustment to align physical production with the 2 degree target in a specific scenario.

Listed equity

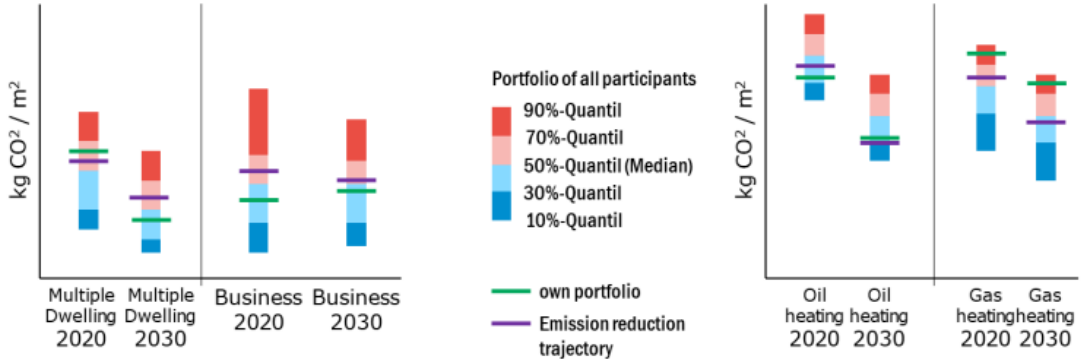
76. For equity, the shocks rely on the calculation of the expected change of net income and in turn the expected NPV of future dividends and market price of equity.

Real estate

77. In the application of the PACTA model to Swiss pension funds, 2 degree initiative has developed a method to analyze the CO_2 emissions of a building or a real estate/mortgage portfolio, to compare it to peers and to assess the alignment with climate objectives for the real estate sector.[39] Given the location of the property, information on the heating system, energy consumption area or refurbishment details, the model calculates the CO_2 emissions for each property. A visual sample is given in Figure 4-1.

[39] 2° Investing Initiative (2017). OUT OF THE FOG: Quantifying the alignment of Swiss pension funds and insurances with the Paris Agreement and 2° Investing Initiative (2019). CLIMATE ALIGNMENT ASSESSMENT 2020 BRIEFING FOR INVESTORS.

FIGURE 4-1 CO2 EMISSIONS FOR SELECTED SWISS REAL ESTATE PORTFOLIO



Source: 2° Investing Initiative (2019). CLIMATE ALIGNMENT ASSESSMENT 2020 BRIEFING FOR INVESTORS

Limitation

78. An important limitation is that due to the fact that the mapping of physical assets to financial securities is based on the ISIN of the underlying security, coverage may be limited. Although previous reports on PACTA's scenario analysis, e.g. California insurance companies (see Annexes, section 7.2.3 for more information), report a coverage of only 28% for fixed income and equity investments, the authors argue that within the portfolio, i.e. investments that are covered, account for 90% of energy-related CO_2-emissions in a typical portfolio. Moreover, the coverage in a European sample employed by EIOPA[40] was substantially higher when considering the most relevant asset classes and adjusting for participations.

79. Moreover, forward-looking data is subject to uncertainty as it is based on current public plans from companies. With respect to the time horizon of five years, the companies' plans will certainly change.

Way forward

80. The number of modelling approaches that can be considered in a stress-testing framework for climate change risks in insurance companies is vast. This section has illustrated the heterogeneity in assumptions, data sources and methodological approaches. For the calibration of future climate ST scenario it is therefore important to carefully consider:

- **Multiple modelling approaches** to compare and validate the shocks to be included in the scenario specifications;
- **Granularity of the model output** and whether they fit with the objective of the ST exercise and allow the shocks to be specified in such a way they can be implemented by stress test participants;
- **Data challenges** and issues related to the consistency of data sources, in obtaining time series which are long enough, the lack of forward-looking data, comparability of data, which may all result in low data coverage;
- **Complexity of models**, which lead to difficulties in implementing such models in bottom-up stress testing. Moreover, models such as Integrated Assessment Models show that they may

[40] Refer to: https://www.eiopa.europa.eu/document-library/publication/sensitivity-analysis-of-climate-change-related-transition-risks_enhttps://www.eiopa.europa.eu/document-library/publication/sensitivity-analysis-of-climate-change-related-transition-risks_en

not be suitable for stress testing frameworks. Finally, stress testing assumptions should consider expert judgement in defining material stresses;

- Due to variety of assumptions and respective data requirements in modelling approaches, it is challenging to find a model which captures risks for the derivation of stress in one unified model. This leads to "**patchwork models**" which are difficult to interpret.

81. Going forward, EIOPA intends to liaise with the academic community, practitioners and model vendors for the exact calibration of the shocks.

4.2 Physical risks

82. This section looks at the methodologies and approaches to derive the impact on assets and liabilities of insurers stemming from physical risk. Section 4.2.1 will consider the impact on the liability side and section 4.2.2 will consider the impact on the asset side.

TABLE 4-3 TRANSMISSION CHANNELS ON THE BALANCE SHEET STEMMING FROM PHYSICAL RISKS

Type of risk	Transmission channel	Balance sheet impact	Example
Physical risk	Underwriting risk	Liabilities	Higher than expected insurance claims on damaged insured assets (non-life) or higher than expected mortality rates (life)
	Market risk	Assets	Impairing of asset values due to financial losses affecting profitability of firms, due to for instance business interruptions, or damage to real estate. Specific example: equity price shocks
	Credit risk	Assets	Deteriorating creditworthiness of borrowers/bonds/counterparties/reinsurers due to financial losses stemming from climate change Specific example: bond price/yield shock

4.2.1 Impact on insurance liabilities

83. Physical risks from climate change are expected to mainly impact the liabilities of insurance companies through higher claims, manifesting themselves in

- changes to the frequency, severity and correlation of specific weather-related events such as heatwaves, floods, wildfires and storms, and
- in the longer term, broader shifts in climate such as changes in precipitation and extreme weather variability, sea level change and rising average temperatures.

4.2.1.1 Non-life shocks

84. As presented in the Prudential Regulation Authority of the Bank of England (PRA)'s framework for assessing financial impacts of physical climate change (PRA May 2019)[41], there is a wide range of possible impacts from climate change on general insurance firms' liabilities. Consequently, there is no single climate change scenario that can assess this impact effectively across all firms and across all business decisions. Nevertheless, it is generally agreed that the frequency, severity and correlation of natural catastrophic event are expected to increase with climate change. This paper considers windstorm (including hail), floods (coastal, inland, or flash flood), heatwaves, wildfires and droughts as the more material perils amplified by climate change.

85. Given the relatively short-term nature of non-life (re)insurance liabilities, the impact of climate change on catastrophe perils may be difficult to distinguish from natural variability. As such, over a short horizon the impact of climate change may be dwarfed by other factors

[41] A framework for assessing financial impacts of physical climate change, BoE, May 2019.

such as interest rate movements, natural climate variability or changes in exposure. Shocks over a longer time horizon can pick up trends and can serve to illustrate any costs of inaction, in particular as medium term to long term shocks are therefore expected for physical risks in non-life (PRA May 2019).

86. To define the shocks, EIOPA proposes two approaches:

- Prescribing specific Nat-Cat events linked to climate change evidence ('event-based scenario' similar to the approach in the EIOPA 2018 ST exercise for Nat-Cat);[42]
- Prescribing changes to frequency, severity and correlation of specific (regional) perils linked to climate change evidence (but not prescribing the specific events).

87. Table 4-4 provides an overview of the pros and cons of the different approaches.

TABLE 4-4 ADVANTAGES AND DISADVANTAGES OF EVENT-BASED SCENARIO VS. CHANGES TO SEVERITY, FREQUENCY AND CORRELATION PARAMETERS FOR PERILS

Approach	Advantages	Disadvantages
Event-based scenario	• The approach will allow for the evaluation of the impact of a specific set of catastrophic events on the European insurance sector linked to climate change (e.g. specific windstorm or flood event) providing additional insights into the resilience of the sector to such physical risks	• Challenging to link specific events explicitly to climate change. Also different ST participants would license different models, thus finding exactly the same event in a catalogue could be not straight forward. • The approach could be expensive and challenging for undertakings/groups that do not have an internal model for computing catastrophic losses and might rely on external consultants / data provides. This is particularly true for medium-sized/small non-life solo undertakings • The approach doesn't allow for a similar severity of shocks for all participants (depending on the specific Nat-Cat events in the scenario) • The comparability of results could be hampered by the fact that current modelling tools allow for customisation by participant groups that may lower the estimations of the final losses
Changes to severity, frequency and correlation parameters for perils	• The approach will allow for the evaluation of the impact of changing severity, frequency and correlation of specific (regional) perils linked to climate change, providing additional insights into the resilience of the insurance sector to such physical risks • The approach would allow more similar severity of the shocks for all participants, as they are not tied to specific events, but broader perils	• Challenging to link increasing severity and frequency of specific perils to climate change and even more for the correlation • It may be difficult to translate shocks to parameters into specific financial losses (requires granular data on the type of coverages provided and how they would be impacted by different perils). • The comparability of results could be hampered as participating groups may use different modelling tools to estimate financial impact

88. EIOPA proposes to **prescribe changes to severity, frequency and correlation of parameter for specific (regional) perils** (in particular heavy precipitation, floods, heatwaves, wildfires, subsidence, windstorm hail and droughts). This could help ensure for more comparable severity across participants as impacts are not tied to specific events prescribed, but broader Nat-Cat perils linked to climate change.

[42] See also the EIOPA Discussion Paper on Methodological Principles in insurance stress testing (section 5.2.2.2)

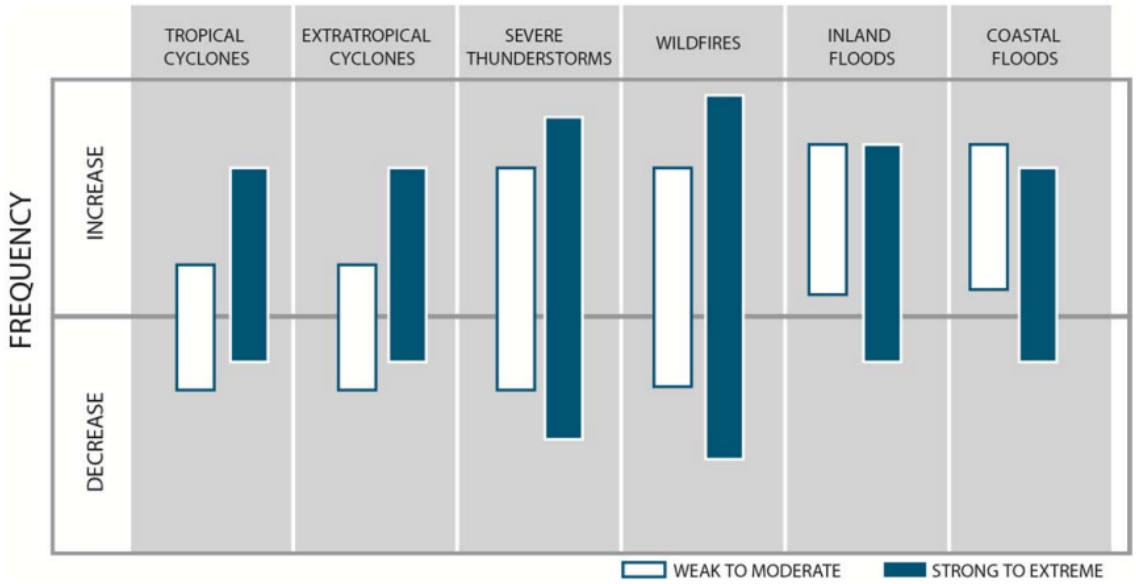
89. For the calibration of the shocks, EIOPA will, if needed seek support from external sources such as data providers, including reinsurers and climate scientists, as it needs to be closely linked to scientific evidence on the expected impact of climate change on different perils. For instance, one can refer to various climate scenarios, such as the IPCC's Representative Concentration Pathways (RCPs), and for a range of assumptions used to translate hazard impacts into potential loss impacts. As part of its work the IPCC creates optimistic and pessimistic emission scenarios which are used in future projections.

90. The definition of shocks for a specific peril and/or region of interest, could include determining:

- key drivers influencing the severity of a given peril;
- impact of climate change on those drivers;
- historic trends and/or potential future trends impacting these drivers;
- a measure of uncertainty in the current climate and the strength of climate change signal that will be distinct from inherent natural variability in today's climate;
- change in likelihood of events (or event drivers) of a given severity;
- change in geographic areas impacted by a given peril; and
- the relation of the information above to greenhouse gas emission projection(s), recognizing that research outcomes are based on a range of IPCC model outputs.

91. To develop those shocks one could use as example, the climate change impacts from AIR (2017) as summarized in Figure 4-2, showing a likelihood of increases or decreases in frequency of weak-to-moderate intensity events (with a 2- to 10-year return period) and strong to extreme events (50 to 1-in-250 year return period) for different weather-related phenomena by the end of the 21st century. Length of bar indicates degree of uncertainty. Note that the relative positions of the bars represent globally-averaged estimates; significant regional differences may exist and would need to be considered separately.

FIGURE 4-2 LIKELIHOOD OF INCREASES OR DECREASES IN FREQUENCY OF WEAK-TO-MODERATE INTENSITY EVENTS



Source: AIR (2017)

4.2.1.2 Life and health shocks

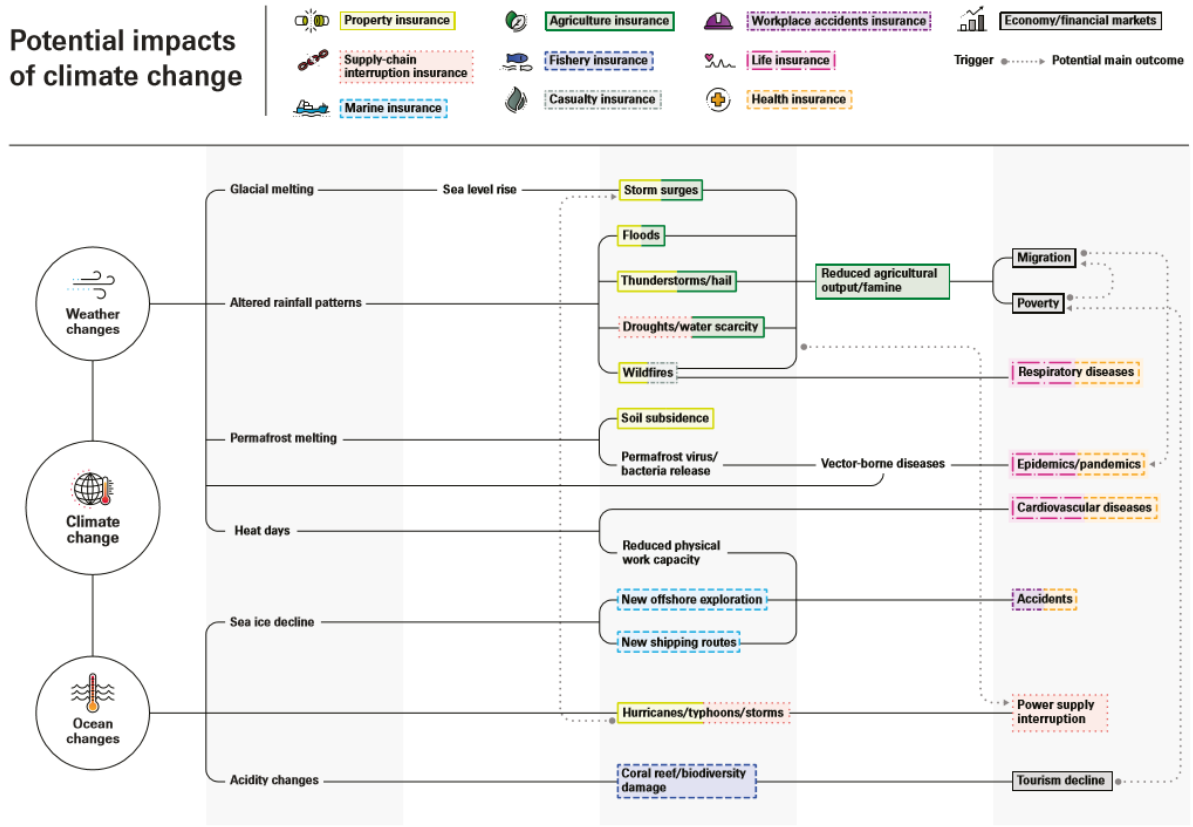
Direct impacts

92. Preliminary evidence suggests that the most pronounced risks affecting human health stem from heatwaves, floods, droughts wildfires and vector-borne diseases. As temperatures

warm and wildfires become more frequent, air quality may also deteriorate, potentially accelerating costs related to the health, and life insurance lines of business. It is the cascading risks related to climate change, such as the increased threat of pandemics because of warming temperatures and air pollution due to more frequent wildfires that will have significant effects on human life and health.

93. Swiss Re has elaborated the transition graphic identifying the potential impact of climate change on human life and health as reported in Figure 4-3.

FIGURE 4-3 POTENTIAL IMPACT FROM CLIMATE CHANGE ON LIFE AND HEALTH



Source: Swiss Re SONAR 2019 New emerging risk insight

94. One of the main factors expected to impact mortality is extreme heatwaves, particularly in populous areas which previously haven't been heavily affected. An example of one such event is the 2003 heatwave in Europe, which is estimated to have caused 70,000 deaths. As temperatures rise, the frequency and severity of such events will likely increase.

95. IPCC report on Impacts of 1.5°C of Global Warming on Natural and Human Systems shows that increasing temperatures and high humidity due to climate change is another area of concern. This combination enables vector-borne diseases to conquer new ground, such as the Zika epidemics. Climate change will extend the transmission season and geographical range for many infectious diseases.

96. UN studies on human health and adaptation to understand climate impacts on health shows for example Lyme disease, avian influenza, meningitis, dengue fever and tropical bacterial and viral infections are projected to increase with global warming, including potential shifts in their geographic range.

97. The California wildfires of 2018 and the Australian ones of December 2019 shows that severe drought conditions can lead to increased wildfires, which in turn lead to air pollution.

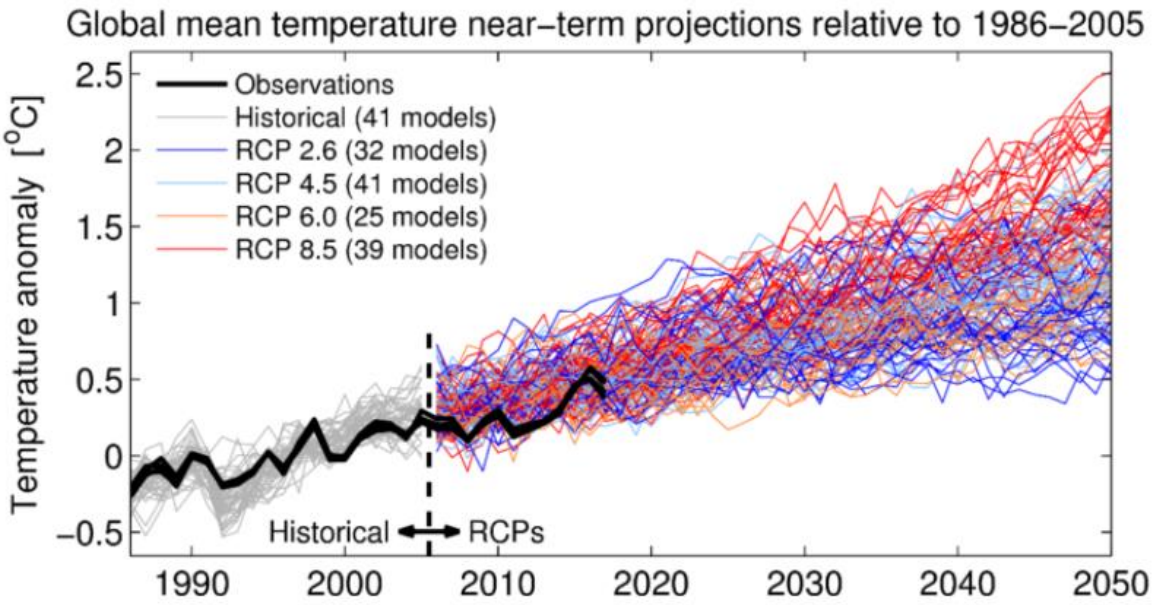
98. The lack of conclusive and widely recognized evidences on the impact of climate change on biometric risks does not allow to exclude them a priori. EIOPA will therefore monitor the evolution of the researches in that field and, when designing and calibrating life and health shocks, will consult both climate scientists and health experts to calibrate potential life & health sector climate change shocks.

4.2.2 Impact on insurance assets

99. On the asset side, scenario analysis for physical risk is fundamentally different from transition risk in its assumptions. While a financially adverse transition shock is predicated on an abrupt or drastic reduction in carbon emissions, physical risk is assumed to increase with the frequency and severity of weather events, and consequently with the emission of carbon. Calibration of an asset shock that includes both transition risk and physical risk is therefore challenging, as the business-as-usual scenarios that most amplify physical risk are those in which the manifestation of transition risk is minimal.

100. Further, there are several challenges to quantifying the repercussions of physical risks on asset prices. Firstly, it is the uncertainty regarding the speed at which relatively long-term climate scenarios would ultimately be transmitted to asset prices. It is not clear how to make assumptions on how, if at all, market players discount[43] the future losses of an asset whose present profitability helps generate such losses by contributing to future systemic volatility. Moreover, physical risks over the next 10-20 years are largely independent from current policy decisions and emission pathways given the strong inertia of climate systems and the past 150 years of GHG emissions[44].

FIGURE 4-4 GLOBAL MEAN TEMPERATURE NEAR-TERM PROJECTIONS RELATIVE TO 1986-2005



Source: Climate Lab Book (2019) Comparing CMIP5 & observations. Available at: https://www.climate-lab-book.ac.uk/comparing-cmip5-observations/

[43] See http://eprints.whiterose.ac.uk/125845/1/Actual_resubmission_DiscountingDisentangled_AEJP_2017_R2.pdf for a survey on the so-called Social Discount Rate (SDR) is used by economists and policy experts (Drupp, Moritz A., et al, AER 2018). A positive discount rate reduces the present value given to projects which benefit future generations.

[44] See http://427mt.com/2019/06/17/scenario-analysis-for-physical-climate-risk-part-1-foundations/ for a review of scenario analysis for physical climate risk.

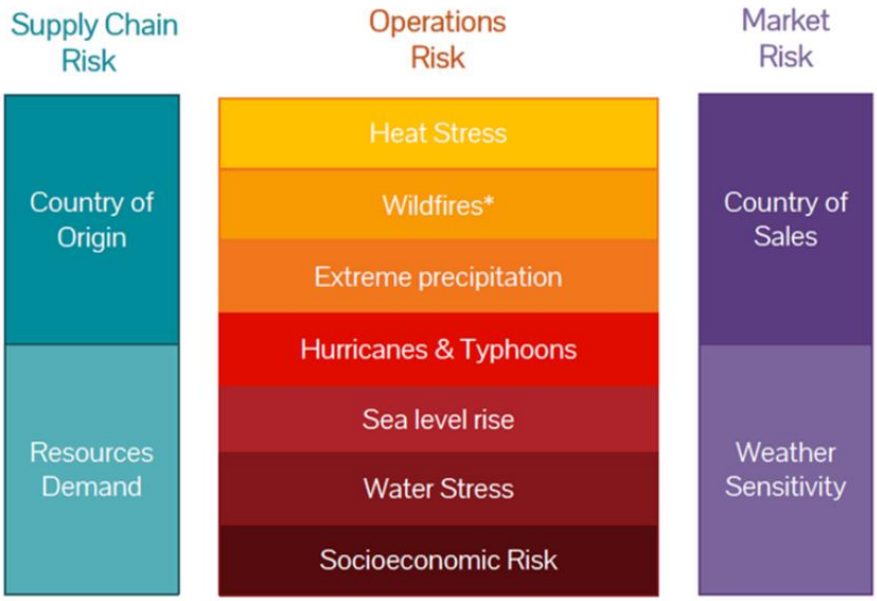
101. Secondly, it is the difficulty approximating a given company's exposure at the sectorial or even geographical level. Unlike transition risk, to which most players of certain sectors of activity are commonly exposed, more granular information is likely necessary to calibrate meaningful shocks linked to physical risk. While certain components of physical risk, such as heat stress, may be assumed to materialize at a regional level, exposure to other components, such as hurricanes or sea level rise, cannot easily be captured at broad geographical levels (e.g., the country level). Physical damage can occur with different severity at two production plants from the same sector and same approximate geographical area. Further, physical damage leave a firm's home market untouched while devastating firms essential in its supply chain.

102. Lastly, it is worth mentioning the difficulties in using an empirical approach for this type of exercise. First, academic research on the relationship between climate events and corporate bond and stock performance is still very limited. Further, while market players in the past may have reacted sluggishly to a publicly-traded company that has suffered an adverse weather event, reactions in the future may become more pronounced as investors begin to better apprehend underlying climate trends and their implications on future economic conditions.

103. In a June 2019 post, the publisher and provider of data, market intelligence and analysis related to physical climate and environmental risks Four Twenty Seven outlined a methodology[45] for a score that measures an equity or fixed-income security's exposure to physical climate risks. While the purpose of this scoring tool is to help investors identify and mitigate risk in their portfolios, Four Twenty Seven suggests that "differentiated impacts by sectors can lay the foundations for a stress test, as industry risk levels can be used to set initial assumptions on sector-wide impacts."

104. Risks are broken down into three categories: supply chain risk, operations risk and market risk as shown in Figure 4-5.

FIGURE 4-5 RISKS BROKEN DOWN INTO SUPPLY CHAIN RISK, OPERATIONS RISK AND MARKET RISK



Source: Four Twenty Seven (2019) Scenario Analysis for physical Climate Risk: Equity Markets. Available at: http://427mt.com/2019/06/18/scenario-analysis-for-physical-climate-risk-equity-markets/

[45] http://427mt.com/2019/06/18/scenario-analysis-for-physical-climate-risk-equity-markets/

105. Scores for Operations Risk are produced by screening each corporate site for its exposure and sensitivity to a set of climate hazards including extreme precipitation, sea level rise, hurricanes, heat stress, water stress and wildfires. At present, 2,000 companies have been scored in this category. Market Risk and Supply Chain scores are given based solely on financial data, and are available for 10,000 companies.

106. Despite its difficulties, it is conceivable to apply shocks more broadly at the industry level, by applying stresses based on the average exposures of companies in that industry. For example, manufacturing firms in the technology sector rely on complex supply chains in Southeast Asia that can be disrupted by extreme weather events, such as typhoons and extreme precipitation as depicted in Table 4-5.

TABLE 4-5 SECTOR EXPOSURES TO PHYSICAL RISK

		427 data-derived estimates of exposure to select climate hazards			
GICS Sector	**GICS Industry Group**	**Average score**	**Operations Risk Score**	**Market Risk Score**	**Supply Chain Risk Score**
Information Technology	Semiconductors & Semiconductor Equipment	56	43	70	62
Information Technology	Technology Hardware & Equipment	54	44	64	57
Utilities	Utilities	53	46	37	70
Health Care	Pharmaceuticals, Biotechnology & Life Sciences	52	42	63	57
Consumer Staples	Household & Personal Products	50	40	65	57
Materials	Materials	50	42	60	51
Industrials	Transportation	50	43	41	63
Consumer Staples	Food & Staples Retailing	48	41	57	52
Consumer Discretionary	Automobiles & Components	48	42	66	34
Industrials	Capital Goods	47	42	57	40
Consumer Discretionary	Consumer Durables & Apparel	46	40	54	46
Energy	Energy	45	39	48	51

Source: Four Twenty Seven (2019) Scenario Analysis for physical Climate Risk: Equity Markets. Available at: http://427mt.com/2019/06/18/scenario-analysis-for-physical-climate-risk-equity-markets/

107. More precise analysis at the security level would require data on the location of a company's main production plants, the location of its suppliers and the location of their main customer base where sales are conducted. Applying weights to the relative importance of these three considerations at the (e.g., at the industry level) would yield a total exposure to physical risk per security. Finally, to conduct an asset-side ST, assumptions need to be made which link asset price movements to each climate scenario considered (RCP 2.6, RCP 4.5, RCP 8.5, etc.), although as mentioned above, the choice of scenario is unlikely to drastically alter the path of climate outcomes in the near (10-20 year) term.

108. Impacts to sovereign bonds are considered to be negligible in advanced economies[46], ratings on certain emerging regions (such as Southeast Asia or the Caribbean) will require additional scrutiny, particularly if significant shares of their economies are concentrated in sectors which are exposed to physical damage.

109. While EIOPA acknowledges that physical risks can also have an impact on insurers' assets and investment, currently no robust methodology or data source seems available to estimate and calibrate this impact reliably. As such, the first EIOPA climate stress test is expected to focus on insurance liabilities when it comes to physical risks. Methodologies to also integrate shocks to assets stemming from physical risk will be explored further in the future.

[46] https://www.spratings.com/documents/20184/1634005/How+does+sandp+incorporate+ESG+Risks+into+its+ratings/6a0a08e2-d0b2-443b-bb1a-e54b354ac6a5

4.2.3 Way forward

110. To derive the impact of physical risks on assets and liabilities, for the future climate ST, EIOPA considers the following methodologies and approaches.

111. **On the liability side,** EIOPA proposes to prescribe changes to severity, frequency and correlation of parameters for specific (regional) perils (windstorm, heavy precipitation, floods, heatwaves, wildfires, subsidence, hail and droughts). This will help ensure for more comparable severity across participants as impacts are tied to broader Nat-Cat perils linked to climate change. For the calibration of the shocks, EIOPA will seek support from experts, if needed, from external sources such as data providers, including reinsurers and climate scientists, to ensure that it will be closely linked to specific evidence on the expected impact of climate change on different perils.

112. Availability of robust methodology or data source to estimate and calibrate the impact of physical risks on insurer's assets and investments is limited. Thus, the first EIOPA climate stress test is expected to focus on insurance liabilities when it comes to physical risks. Further methodologies will be explored to integrate shocks to assets stemming from physical risk.

4.3 Specification and Application of shocks

113. In light of the above discussion, EIOPA envisages the following variables to be specified in a climate ST scenario, noting that the exact specification would also build on the Network for Greening the Financial System's reference scenarios[47]. The financial variables would reflect the macroeconomic and financial impact of the combination of climate-related risks (the climate variables) in each scenario; they would not layer on an additional macroeconomic shock that is unrelated to climate change.

TABLE 4-6 OVERVIEW OF KEY VARIABLES TO BE SPECIFIED IN CLIMATE ST SCENARIO

Climate variables		Financial variables	
Physical risk	**Transition risk**	**Macroeconomic**	**Financial markets**
• Global and regional temperature pathways • Frequency, severity and correlation of specific and material climate-related perils for different regions (for non-life) • Mortality / morbidity parameters (for life)	• Emission pathways (aggregate and disaggregate across world regions and economic sectors) • Carbon price pathways • Commodity and energy prices, by energy source • Energy mix	• GDP (aggregate and disaggregated by economic sector and country) • Interest rates (RFR)[48] • Inflation • Residential and commercial real estate prices	• Government bond yields • Corporate bond yields, disaggregated by economic sector • Equity indices/shocks, disaggregated by economic sector

114. In any scenario covering both transition and physical risk, the shocks across both risks would have to combined to derive the total financial impact (i.e. the ultimate financial impact would be a combination of both risks).

115. In general, the same principles apply regarding the application of shocks as discussed in EIOPA's Discussion Paper on Methodological principle of insurance stress testing (and in particular Chapter 5 thereof). Where a positive marginal impact arises from the application

[47] See NGFS (2021), Technical documentation to the NGFS Scenario V2. Network for Greening the Financial System, Paris, France and NGFS Scenarios Portal

[48] Shocks to interest rates only stemming from climate change shocks if they can be justified by the model (i.e. additional macroeconomic shocks are not considered).

of the scenario shocks, these would in principle be allowed (no capping of impact). The topic will be nevertheless further considered in the context of each ST exercise.

116. In principle, shocks would be applied to the reference date BS as an instantaneous shock, with and without the use of reactive management actions.

Treatment of reinsurance

117. Insurers typically have risk mitigation techniques in place at the reference date related to Nat-Cat risk, in particular proportional and non-proportional reinsurance treaties.

118. For the purpose of climate change ST and to assess the resilience of the (re)insurance sector, the treatment of reinsurance is of particular importance. The following approaches can be considered in this regard:

- Impact calculated gross of reinsurance (i.e. reinsurance treaties are not taken into account for the calculation of the financial impact);
- Impact calculated both gross of reinsurance and net of reinsurance;
- Impact calculated net of reinsurance, but with shock to reinsurance recoverables;
- Impact calculated net of reinsurance.

119. Given the importance of reinsurance for physical risks, the preferred approach would be to ask the **impact both gross and net of reinsurance**. For the calculation of the net impact, in case reinsurance treaties in force at the reference date allow for reinstatement, reinstatements (including potential related costs) should be taken into account. However, any change in the treaties, including changes in the reinstatement regime against the prescribed shocks, should be treated as reactive management actions.

120. With regard to the reinsurance recoverables, the following could also be applied in addition: recoverables are accounted for as a credit to be received from reinsurers. In a more complex catastrophe scenario the recoverability of insurance losses through reinsurance treaties could also be shocked. To this end an additional shock considering the default of some reinsurers (e.g. the largest ones) or their ability to fully repay the claims could be considered. To do so, the largest counterparty could be selected and their recovery rate could be shocked according to the Credit Quality Step (CQS) of the reinsurer (using as a reference the probability of default prescribed in the SII standard formula).

121. With regard to national guarantee schemes (Nat-cat schemes) for Nat-cat events, which may exist in some jurisdictions, these may only be taken into account if they are already implemented in the best estimate at the reference date, are clearly enforceable and lead to 'automatic' – (based on pre-defined triggers rather than ex-post decision) risk transfer similar to reinsurance (i.e. they are not dependent on an action by a third-party/government to declare a national emergency). Where feasible, both the gross and net of amount can be requested. The aim is to ensure a comparability of the gross financial impact across countries in light of the heterogeneous Nat-cat schemes coverage across countries.

4.3.1 Way Forward

122. Shocks will be derived from the described model / approaches, however they will be specified in line with the guidance provided in the first methodological paper, namely:

- for the transition risk in terms of shocks to prices / yields to the specific asset classes
- for the physical risks, on the liability side in terms of change in the best estimate assumptions or discontinuance of parameters used in the estimation of the technical provision, on the assets side in term of change in value of asset classes pending on the development of a robust methodology.

123. The granularity of the specification of the shocks will be specifically defined in the context of each exercise and inspired to the possible extent to the first methodological paper on stress tests.

124. The calibration of the shocks will account for the long term nature of the risks at stake and will incorporate the interactions between transition and physical risks once sufficiently robust models will be available.

5 Metrics for evaluation

125. In order to assess the impact of a scenario, depending on the type of risks that are evaluated (physical, transition or both), a set of indicators based on key figures computed under baseline and stressed scenarios are considered. The aim of those indicators is to provide a comprehensive picture of the major drivers behind the impact of the prescribed scenarios on the Solvency II BS and on the profitability of the participants. These two groups of indicators are considered key metrics for climate change stress test. Moreover, a set of technical indicators are provided with the purpose of complementing the analysis (especially for the assessment of the impact of the physical risks). Given the uncertainties inherent in the modelling of financial impacts of long-term climate scenarios, evaluation metrics should focus on sectoral losses and portfolio composition on the asset side and on the liability side and other balance sheet indicators. Also, profitability indicators pertaining to technical losses should be part of the assessment. Typical Solvency II indicators covering capital and solvency position (Solvency Ratio, Own Funds) increase the complexity of the assessment and requires assumptions to cover the evolution of the exposures over long time horizon. Against this, EIOPA may consider to include also capital and solvency indicators based on cost/opportunity analysis and upon specific requests.

5.1 Balance sheet indicators

TABLE 5-1 BALANCE SHEET INDICATORS BY TYPE OF RISK

Indicator	Type of risks	Notes
Excess of Asset over Liabilities (change of)	Physical and transition	
Asset over Liabilities (change of)	Physical and transition	
Stressed value or price change for each of the identified assets (or class of assets) or change in portfolio market evaluation	Only transition	Only for assets mapped to climate relevant sectors, physical assets and their related technologies.
Relative change of total technical provisions	Only physical	Only non-life business could be considered unless the scenario include also the impact of a change in mortality/morbidity

5.2 Profitability indicators

126. The indicators are split between “main” and “ancillary” based on their significance and availability.

TABLE 5-2 PROFITABILITY INDICATORS BY TYPE OF RISK

Type	Indicator	Type of risks	Notes
Main	Loss Ratio	Only physical	Overall or split by relevant lines of business
Ancillary	Overall impact on the firm’s profit and loss	Physical and transition	
Ancillary	Impact on the firm’s technical result	Only physical (for non-life insurers); both (for life insurers)	Overall or split by relevant lines of business

5.3 Technical indicators

127. With reference to the potential loss metrics that can be used in assessing the physical risk deriving from the climate change, depending on the purpose of the analysis, the following distinction should be considered:

- **expected losses** – typically average annual losses (AAL) or median losses to show how average losses might change due to the impact of climate change;
- **tail losses** – showing how the losses that might be expected in an extreme year could move as a result of climate change.

128. Table 5-3 provides a list of potential technical indicators for complementing the assessment of the climate change impact. The indicators are split between "main" and "ancillary" based on their significance and availability.

TABLE 5-3 TECHNICAL INDICATORS BY TYPES OF RISKS

Type	Indicator	Type of risks	Notes
Main	Gross/ceded/net aggregated losses	Only physical	
Main	Exposures (Sum Assured)	Only phiyical	Overall (baseline figures). As ancillary information and only if available, split by event[49]/geographical area
Main	Total assets subject to transitional risks	Only transition	Baseline figures. Overall or split by sector or technology
Main	Probable maximum loss (PML)	Only physical	It shows the value of the largest loss that is considered likely to result from an event
Main	Annual Probability of occurrence	Only physical	It shows the probability that, over a period of one year, an event of a given magnitude occurs.
Only for IM users	1 in X years AEP (aggregate exceedance probability)	Only physical	It shows the maximum amount of losses caused by all the events over a period of one year, corresponding to the given probability level
Only for IM users	Annual Average Loss (AAL)	Only physical	It shows the average losses from property damage experienced by a portfolio per year[50].
Only for IM users	1 in X years Return period	Only physical	It shows the magnitude of an extreme event (for instance an event with a 1-in-100 year return period has a 1% chance of being exceeded by a higher magnitude event in any year)
Ancillary	Return period of gross losses	Only physical	

129. The above indicators give information on the overall impact of a certain scenario (calibrated considering the effect of the climate change). To measure only the impact of climate change (compared to the current situation), the indicators should be calculated including the expected impact and how this could develop in the future. In this last case, a modest annual change can have a substantial compounded impact in a longer time horizon.

[49] Potential events linked to the climate change: Floods (coastal and inland); Wildfires; Droughts; Subsidence; Hurricanes; Tornados; Heat waves; Extreme precipitation events; Severe thunderstorms; Cyclones (tropical and extratropical.

[50] Average annual losses can be derived from an exceedance probability curve that shows the probability that a given threshold of losses will be exceeded in any one year

130. The results of the analysis should also capture uncertainty where possible (such as using different tools to assess the same physical climate change risk or presenting results as a range). Qualitative assessments can, in some cases, complement and support analysis given the uncertainty in current knowledge of climate change impacts for some material perils.

131. In addition to quantitative indicators, some qualitative information could be gathered with the aim of having a more comprehensive picture of the overall impact of the climate change. One aspect that could be investigated through a qualitative questionnaire is, for example, the sustainability of the business model and its evolution due to the climate changes (see also chapter 6 below).

5.3.1 Way forward

132. Depending on the type of risks that are evaluated (physical, transition or both), EIOPA proposes a set of indicators based on main and ancillary figures to be computed under baseline and stressed scenarios in order to capture the impact of the prescribed scenarios on the Solvency II Balance Sheet and on the profitability of the participants. The recalculation of the capital requirements under stress scenario is not part of the indicators described in this paper, however, in the future, it may be considered to be embodied in climate ST exercises.

133. In terms of **balance sheet indicators**, EIOPA proposes Excess of Assets over Liabilities and Asset over Liabilities. In addition, the stressed value or price change for each of the identified assets (or class of asset) or change in portfolio market evaluation and the relative change of total technical provisions could be asked, depending on the risk evaluated (transition/physical risk).

134. The **profitability indicators** proposed by EIOPA encompass Loss Ratio as main indicator, the overall impact on the firm's profit and loss and the impact on the firm's technical result as ancillary indicators depending on the risk evaluated (transition/physical risk) and the approach taken in the climate exercise.

135. Regarding the **technical indicators**, EIOPA proposes a set of main and ancillary indicators (see 5.3) with reference to potential loss metrics (expected losses and tail losses).

6 Second-round effects, spillover and forward looking assessment

136. The direct impacts of transition and physical risks to insurers and the actions taken by insurers against these shocks might generate externalities to other financial sector and the real economy. Responses to climate change could lead to limitations in the availability and affordability of insurance coverage, which could be one of the main indirect effects of climate change. Increasing physical risks to insured property and assets may constrain insurers' capacity to underwrite insurance if premiums rise beyond demand elasticity and customer willingness to pay[51]. This can create a situation of underinsurance due to difficulties to access insurance, where premiums rise so high that insurance will no longer

[51] Issues Paper on Climate Change Risks to the Insurance Sector approved by IAIS executive Committee and the Sustainable Insurance Forum on 25 July 2018. Link:https://www.insurancejournal.com/research/app/uploads/2018/08/IAIS_and_SIF_Issues_Paper_on_Climate_Change_Risks_to_the_Insurance_Sector_-1.pdf

be seen as an affordable or attractive option, particularly for lower income areas and also for individuals and businesses located in hazard-prone regions.

137. In the context of adverse climate change trends, insurers may react offering more restrictive terms and conditions, shortening their contract time boundaries, increasing their withdrawal capacity, capping payouts or, ultimately, refusing to underwrite risks in a given area. High self-retentions on the customer side and other reactive management actions may make people decide to renounce coverage, which will in turn cause potential business losses for insurers and widen the insurance protection gap. Indeed, insurers could lose underwriting business due to increase of insurance prices in response to higher than expected insurance claims (non-life) or changes in policyholders' expectations and behavior related to sustainability factors (e.g. green reputation) (life).

138. The issues of underinsurance and the eventual limitations in the supply of insurance for high risk areas or for given risks due to uncertainty in the underlying risks could widen the already existing protection gap if governments and the insurance industry do not play a preventive role with measures such as risk perception and assessment, risk reduction and mitigation and finally risk transfer (reinsurance).

139. Besides the indirect effects of physical risks on insurers, the transition into a lower carbon economy may influence the types of insurance products and services demanded from insurers. These new products and services shaped by new technologies, policy changes and evolving market sentiment may disrupt conventional industrial organization, business models and associated needs for insurance coverage. While such changes may create opportunities, they may also indirectly create risk for the insurance sector.

140. Across these risk factors, the industry, academia and supervisors generally agree that there is potential for climate change to present a substantial challenge to the business model of insurers[52]. In particular, while there are opportunities for the sector from writing new climate change-related business, it is also possible that climate change may reduce or eliminate the sector's appetite to provide insurance cover for specific sets of activities, assets or groups. The inherent uncertainty and forward-looking nature of these indirect risks make them more challenging to assess.

141. EIOPA finds merit in conducting a forward-looking assessment of the long-term reactive management actions and responses from insurers to climate change-related risks An exercise of this nature may help identify the risk mitigation responses that are considered by insurers and, at the same time, help better understand the implications of these indirect effects on insurers' business models (for instance with regards to risk coverage, GWP and/or protection gap) and their potential spillover effects. Given its specificity an ad-hoc definition of objective and data collection is needed.

142. The assessment of potential second-round effects through a forward-looking assessment of reactive management actions has both a microprudential and the macroeconomic objective; on the one hand it can provide insight on the response and resilience of individual insurers, and on the other hand it can also help assess potential spillover effects stemming from the collective responses of the insurance sector.

143. The aim of collecting information that can help identify potential indirect effects within a climate ST exercise is to enhance the explorative power of this tool with forward-looking information that may give further insight on: the potential evolution of insurers' business models, the widening of the already existing protection gap in insurance, the

[52] "The impact of climate change on the UK insurance sector". A Climate Change Adaptation Report by the Prudential Regulation Authority. September 2015

availability of insurance and reinsurance coverage, issues of affordability of insurance, future loss of current levels of business and wider risks of financial spillovers.

144. This kind of assessment will serve to gather both quantitative and qualitative information on how the insurance sector as a whole is preparing itself to tackle the indirect effects of climate change risks in their business models through reactive management actions. The forward-looking nature of a climate ST can contribute to raise awareness of these threats and incite the insurance sector to align their business models and risk management strategies with a more sustainable model that is prepared to cope with these challenges. Hence, an assessment of post-reactive management actions can shed some light on the insurer's preparedness to deal with climate change-related risks as well as on the potential second-round effects caused by these actions.

145. While a forward-looking exercise of this nature will attempt to draw out qualitatively and, to the extent possible, quantitatively some of the potential second-round effects on insurers business from direct impacts of a given climate change scenario(s), EIOPA recognizes the limitations of this exercise given the medium/long-term nature and the uncertainties surrounding climate change risks[53]. In this sense, although a forward-looking assessment of insurer's responses to climate change scenarios may not capture the full impact of potential indirect effects of climate change, it can serve as a first assessment of the adaptation of business models to different climate change scenarios as well as a starting point for future EIOPA assessments of second-round climate change effects.

146. In order to analyze how climate change scenarios will impact insurer's business models and what reactive management actions they intend to implement, the collection of a combination of qualitative and quantitative information is the preferred option.

147. With regards to the quantitative side, insurers could be asked to quantify the impact of the ST scenarios on selected metrics of their business such as the current and expected level of underinsurance and insurance coverage, the reinsurance dependency and availability, and information on premium "tipping points".

148. For example, insurers can be asked to report information regarding the expected impact on future premiums (GWP) for specific peril coverage from the scenarios of the ST and the "tipping point" at which insurers might/will no longer be able to provide coverage. Also, the difference between the impact on insurers from liability-shocks in terms of insured losses and the total economic losses of the prescribed shocks may be indicative of the protection gap that may arise in the future.

149. On the qualitative side of the exercise, insurers could be asked to provide forward-looking information on what management actions they anticipate taking in order to adapt to a given scenario(s) (e.g. changes to asset allocation, changes to reinsurance programs, change in the composition of the liability portfolios, and re-capitalization plans). This information can help assess the potential shift climate change is causing in the demand for insurance products, the geographic locations, perils and coverage for which an insurance company has increased its premium rates, limited its sales or limited or eliminated coverage because of catastrophic events, and the expected evolution of reinsurance coverage which can also help identify in which areas and for which risks the protection gap is widening.

150. In addition, the qualitative information should explore the level of integration of climate change-related risks in the governance, strategy, risk management, underwriting

[53] Mckinsey Global Institute, Climate risk and response: Physical hazards and socioeconomic impacts, January 2020 Report-Link: https://www.mckinsey.com/business-functions/sustainability/our-insights/climate-risk-and-response-physical-hazards-and-socioeconomic-impacts

and investment practices and overall business models of insurers. Exemplificative questions are provided in Annexes, section 7.3.

151. For analyzing the impact on regional/national protection gap issues, the scope of this information gathering exercise would require a sufficiently large sample of solo undertakings at country-level in order to cover local markets and identify regional or country specific protection gap issues. In this regard, it is especially important that the information is then aggregated at country level. In addition, a certain degree of comparability across different participating insurers, distinguishing between life and non-life insurers, is also relevant. Caveats in the analysis apply such as the existence of state guarantee schemes, risk-sharing platforms for Nat-cat events and other country-specific government pools.

152. In the context of a forward-looking assessment based on quali/quantitative information which includes reactive management actions, it is worth signaling the key role of the data validation process, not only in terms of consistency but also in term of plausibility against the depicted scenario(s). For example, direct insurers could indicate a possible response to an increase in the frequency of windstorms would be to purchase additional reinsurance; whereas reinsurers could say that their response would be to reduce exposure to this segment; these responses are clearly incompatible. One possible solution to this would be a two-stage process for the forward-looking risk assessment, where management actions would be reviewed by EIOPA/NCAs for consistency followed by a second round of submissions where certain management actions could be in some way restricted (e.g. not permitted or permitted) based on the understanding of how the market dynamics might evolve. Such an approach would obviously have implications for both the duration of the exercise and the level of resources required to support the stress test.

153. An overview of the advantages and disadvantages of a forward-looking information gathering exercise is provided in Table 6-1 below.

TABLE 6-1 ADVANTAGES AND DISADVANTAGES OF AN ANCILLARY FORWARD-LOOKING ASSESSMENT

Advantages	Disadvantages
• Can shed more light on potential issues regarding affordability and availability of insurance products • An exercise of this nature will help raise awareness about climate related risks within the industry • Can help enhance insurer's risk management capabilities • Can help better understand how insurers assess climate-related risks through preventive risk management and adaptation strategies to infer implications on business models	• Takes into account entity specific risk profiles which can pose challenges with regard to the comparability of the results • Existence of country specific guarantee schemes and government pooling can pose challenges with regards to comparability of the results • Can pose additional burden on the sample • Issues regarding the reliability of management actions • May not be relevant for smaller companies since climate integration (and other ESG elements) is an expensive strategy

7 Annexes

7.1 Overview of ST exercises by supervisors with main elements

Authority	Publication	Method	Type of risk	Time horizon	Scenarios	Balance sheet impact	Description
Bank of England (i)	Link	Stress test (bottom-up)	Physical and transition risk	30 years, with 5 year reporting intervals	BUA, Early Policy Action, Late Policy Action	Asset and liabilities, based on impact on individual counterparties	Participating institutions (large UK banks and insurers) are required to calculate the impact on their exposures for three detailed climate scenarios provided by the Bank of England.
Bank of England (ii)	Link	Stress test (bottom-up)	Physical and Transition risk	2100 (with evaluations at 2022 and 2050)			Insurers analysed impact of physical and transition risk on both their assets and liabilities in three policy scenarios.
Bank of France	Link	Stress test (bottom-up)	Physical and Transition risk	2020-2050 (reporting steps at 2025, 2030, 2035, 2040, & 2050)	Transition: Orderly (baseline), delayed, accelerated Physical: RCP 8.5 (+4 degrees by 2100)	55 sectors considered for asset-side transition shocks. CATNAT impacts (flood, marine submersion, droughts and cyclones) projected at the *department* level.	5 years of "static balance sheet" + 25 years of "dynamic balance sheet" allowing for the integration of strategic management actions.
De Nederlandsche Bank (i)	Link	Stress test (top-down)	Physical and Transition risk				Analysis of how the asset-side exposures of Dutch banks, insurers and pension funds are affected in scenarios of a disruptive energy transition.
De Nederlandsche Bank (ii)	Link	An exploration of climate-related risks for the Dutch financial sector	Physical and Transition risk				
California Insurance Commissioner	Link	2°C scenario analysis	Physical and Transition risk ansition risk				
EIOPA Sensitivity analysis 2020	Link	Sensitivity analysis (top-down)	Transition risk	2019-2030	Transition: A late and sudden policy shock; a supplementary scenario based on the IEA "Beyond 2 degrees" (B2DS) scenario	Price sensitivity of equity, corporate bonds and government bonds holdings	Impact on the assets side

Example of DNB physical risk stress test:
In 2017, DNB conducted a stress test that included stresses related to the physical climate risks of a sample of Dutch non-life insurers. The physical risk stress test focused on windstorm frequency and severity as well as hail risk severity. Insurers were asked to model the impacts of a large windstorm

event; three medium-sized windstorm events happening in a single year; and a large local extreme weather event occurring in the area where the insurer has the largest concentration risk.

Example of Climate change scenarios in the PRA insurance stress test[54]

The PRA has asked large life and non-life insurers to explore – on a best-efforts basis – their exposures to the physical risks of climate change as well as risks associated with the transition to a low-carbon economy. The PRA specified three climate change scenarios and requested insurers to consider the impact of each scenario on selected metrics of their business models and asset valuations:

- The first scenario involves a sudden transition, ensuing from rapid global action and policies, and materialising over the medium-term business planning horizon that results in achieving a temperature increase being kept below 2°C (relative to pre-industrial levels) but only following a disorderly transition. In this scenario, transition risk is maximised. This scenario is based on the disorderly transitions highlighted the IPCC Fifth Assessment Report (2014). Shock parameters are illustrative of potential impact in 2022.
- The second scenario involves a long-term orderly transition that is broadly in line with the Paris Agreement. This involves a maximum temperature increase being kept well below 2°C (relative to pre-industrial levels) with the economy transitioning in the next three decades to achieve carbon neutrality by 2050 and greenhouse-gas neutrality in the decades thereafter. The underlying assumptions for this Scenario are based on the scenarios assessed in the IPCC Special Report on Global Warming of 1.5°C (2018). Shock parameters are illustrative of potential impact in 2050.
- The third scenario with failed future improvements in climate policy, reaching a temperature increase in excess of 4°C (relative to pre-industrial levels) by 2100 assuming no transition and a continuation of current policy trends. Physical climate change is high under this scenario, with climate impacts for these emissions reflecting the riskier (high) end of current estimates. Shock parameters are illustrative of potential impact in 2100.

The point in time at which the shocks occur differs for each scenario, with the illustrative potential impacts occurring in 2022, 2050 and 2100.

TABLE 7-1 IMPACTS OF PHYSICAL RISKS ON GENERAL INSURERS' LIABILITIES

		Physical risks scenario		
Sector	Assumptions	A	B	C
US hurricane-exposed lines of business	% increase in frequency of major hurricanes	5%	20%	60%
	Uniform increase in wind speed of major hurricanes	3%	7%	15%
	% increase in surface run-off resulting from increased tropical cyclone-induced precipitation (cumecs)	5%	10%	40%
	Increase in cm in average storm tide sea-levels for US mainland coastline between Texas and North Carolina	10cm	40cm	80cm
UK weather-exposed lines of business – flood, freeze and subsidence	% increase in surface run-off resulting from increased precipitation (cumecs)	5%	10%	40%
	Uniform increase in cm in average storm tide sea-levels for UK mainland coastline	2cm	10cm	50cm
	Increase in frequency of subsidence-related property claims using as benchmark the worst year on record	3%	7%	15%
	Increase in frequency of freeze-related property claims using as benchmark the worst year on record	5%	20%	40%

Source: FSI 2019

[54] Source: FSI 2019 and PRA General Insurance Stress Test 2019.

EIOPA Sensitivity analysis 2020

The sensitivity analysis of climate-change related to transition risks carried out by EIOPA employs a "what-if" scenario analysis based on the investments in high and low-carbon industries that are considered highly climate-policy relevant. Holdings of government bond were also included to provide insights into possible values at risks (VaRs) under the scenarios and assumptions employed. The "what-if" scenarios draw input from several external sources and combine them in a consistent narrative calibrated on the current holdings of European insurers.

The exercise started with a mapping of individual securities (equity and corporate bonds) to physical production in key climate-relevant sectors. Investments were sourced from regulatory reporting under Solvency II. These investment holdings were subsequently mapped using information about group ownership structure and detailed production level data available to 2° Investing Initiative. For government bond holdings, Solvency II reporting data was used.

Based on the identified exposures, a "what-if" sensitivity analysis was carried out. This sensitivity analysis assessed possible impacts on investment holdings if economies were required to re-align and transition away from CO2-dependent production and consumption. Under the assumption that climate risk may not be fully reflected in asset prices so far and, and in line with previous studies on the topic, the sensitivity analysis considered a policy shock that would have an impact on market prices that can be interpreted as a change in price compared to current levels.

The asset price adjustments for equity and corporate bonds were considered to be a function of the change in production that would be required if the economy were to align with two scenarios prepared by the International Energy Agency's (IEA), namely the Sustainable Development Scenario (SDS, often referred to as a "2 degree scenario") and the "Beyond 2 degrees" (B2DS) scenario, which requires slightly stronger policy action. The second scenario can be interpreted as a scenario that is likely to have a higher probability of limiting global warming to 2 degrees (or below).

The required change in production is directly linked to a carbon budget and is consistent with the generally framed narrative we are using in this analysis. For each of the considered sectors (e.g. energy, mining etc…) and technologies (e.g. coal power, oil power, renewable power), a price adjustment factor was calculated based on the current relevant physical production levels and projections for future production levels computed and extrapolated using data available to 2DII. The practical implementation of this scenario required a model or a view on how the production and profit will change in each sector and a methodology to consider how this shift will affect market prices of the assets held in the insurance portfolio. This analysis relies on detailed scenario outputs from the IEAs set of integrated assessment models (IAMs) and was carried out in collaboration with the 2° Investing Initiative.

Given the data available, price adjustments were computed consistent with the IEA scenarios in the Power, Oil&Gas, Coal and Automotive sectors. In addition, price adjustments in the cement and aviation sectors were based on the shocks employed by the Prudential Regulation Authority at the Bank of England (2019). For Government bonds, the methodology and approach followed Battiston, S., Jakubik, P., Monasterolo, I., Riahi, K., van Ruijven, B. (2019) and was an implementation of the methodology described therein.

The exercise was carried out at on a top-down basis and it contains a number of important caveats that should be noted. First, it was not possible to map the full portfolio of European insurers, so the results represent a subset. Second, certain sectors that may also react to a typical "policy shock", most notably the agriculture and real estate sectors are not considered due to data limitations. Third, effects stemming from shocks to GDP or other macroeconomic variables were not included in the assessment. Fourth, the calibrations of the price adjustments rely on extrapolations and sometimes somewhat limited data, and consider changes that might stem from events that might happen by the end of this decade. These calibrations are naturally fraught with intense uncertainty.

2020-2021 Banque de France / ACPR Climate Exercise

The results of the ACPR / Banque de France pilot climate exercise were published in May 2021. Using climate scenarios pertaining to both transition and physical risks, this pilot exercise aimed to produce a long-term assessment of the exposure of French financial institutions to climate change risks. The 30-year time horizon and dynamic balance sheet phase together illustrated insurers' visions for coping with the different financial risks posed by various emissions pathways. Moreover, the exercise produced important methodological advancements and made an array of datasets publically available for use by other supervisors or financial institutions.

Three ecological transitions were considered in the exercise: an orderly transition (which served as a baseline), a delayed transition and an accelerated transition. The two latter should be considered as adverse variants, resulting in a significantly higher degree of macroeconomic perturbation despite ultimately reducing emissions by 2050 to levels consistent with the 2015 Paris Accords. A separate scenario was used to evaluate physical risk, which was not assumed to have any sectoral or asset-side dimension.

The public policy instrument underlying all three scenarios was a carbon tax schedule. The representative baseline scenario assumes an immediate introduction of an optimal carbon price, which increases by approximately $10/ton per year of CO2 until 2050. The delayed transition depicts the case of a late introduction of a carbon tax, jumping from $87/ton of CO2 in the baseline to $219 in 2035 and increasing steadily afterwards. The second adverse scenario depicts the case of a sudden (accelerated) transition which is made worse because of the immaturity of technological innovations. An increase in the carbon price is therefore accompanied with a negative productivity shock. In this last scenario, the carbon price is unexpectedly revised and assumed to reach $184/ton of CO2 in 2030, following the carbon trajectory set in the alternate NGFS reference scenarios for a disorderly transition.

For each scenario, a general equilibrium modelling framework provides various impacts of the climate policy shocks, including GDP, inflation and interest rates. 55 distinct sectors were modelled, and a mapping to NACE and other standard codes was provided to participants with respect to the financial impacts. While the suite of models used ensured an internal consistency of the structure of the economy, several models were used to translate transition scenarios obtained from climate models into macroeconomic, sectoral, financial and firm-level variables. These models include climate models such as the so-called Integrated Assessment Models (IAMs), a multi-country in-house "NiGEM" macroeconomic model, the Banque de France credit rating model and various financial modules to project various asset prices through time.

Shocks to equity prices were provided (by sector) using a dividend discount model. First, the NiGEM and sectoral models described above provide projections of turnover and value added between 2025 and 2050. Next, the assumption is made that distributed dividends equal 50% of return of capital, the latter being the 33% of value-added. Lastly, this dividend stream (associated to the respective sector and geographical area) is discounted using an empirical average of an index stock return plus a sector-specific risk-correction component to derive a shock to the market value of the asset.

Econometric approaches such as reduced-form vector auto-regressions (VAR) were used to project risk-free yield curves and sovereign spreads (by country) and corporate credit spreads (by country and sector). Historical time series were used to ultimately generate forecasts conditional to a future path (the scenario) of the macroeconomic covariates described above. For instance, the RFR term structures at date t, for any given climate scenario provided by NiGEM model, are obtained as conditional forecasts of the yield curve conditionally to the future path of macroeconomic variables (GDP, inflation, etc.) between 2020 and 2050.

The sectors most impacted by the transition scenarios include Crop and Animal Production, Mining & Quarrying, Petrol & Gas, Manufacturing, Electricity & Gas, and Construction. The impacts to these

sectors varied considerably across asset classes: as a deviation from the baseline, the most affected sectors suffered 3-4% losses in the adverse variants for corporate bonds, while the most affected equities suffered losses between 20-25%. Nonetheless, with ex-ante exposure to climate-relevant sectors amounting to only 17% of total assets (due largely to existing divestment commitments), overall impacts to French insurers' balance sheets was low to moderate.

When interpreting these results, it should be borne in mind that none of the scenarios analysed include an economic recession by 2050, contrary to the usual practice of stress tests. Instead, the adverse scenarios imply a lower trend in economic activity and productivity, in addition to sectoral reallocations. Based on the current balance sheet structures, it nevertheless appears that considerable efforts must be made to help significantly reduce greenhouse gas emissions by 2050 and to contain the rise in temperature by the end of the century.

7.2 Modelling approaches for transition risk

7.2.1 CLIMAFIN model application to sovereign bonds

The approach by Battiston and Monasterolo (2019) is based on the CLIMAFIN approach developed by Battiston, Mandel and Monasterolo (2019) and focuses on the analysis of a disorderly policy transition on sovereign bonds, through the channel of firms' profitability to sectors' Gross Value Added (GVA). The authors develop the first approach to price forward-looking climate transition risks in the value of individual sovereign bonds, by including the characteristics of climate risks (i.e. uncertainty, non-linearity and endogeneity of risk) in financial valuation. Using policy-relevant 2°C-aligned climate mitigation scenarios that correspond to a certain level of Greenhouse gases (GHG) emissions' concentration in the atmosphere (IPCC 2014), the authors calculate economic trajectories for fossil fuels and renewable energy sectors and sub-sectors associated to a disorderly transition (business-as-usual – BAU, i.e. no climate policy) to a mild or tight climate mitigation scenario using the LIMITS project database (Kriegler et al. 2013).

The authors analyse the impact of the shock on firms and sectors' profitability and calculate the change in market share and GVA for sectors and firms in fossil fuels and renewable energy sectors, using two Integrated Assessment Models (IAM) (GCAM and WITCH). This serves as a basis to calculate the impact on fiscal revenues of sovereigns and finally on sovereign fiscal assets and default probability. By introducing the "climate spread", the authors model the climate shock transmission to government's fiscal revenues, to the change in the value of the sovereign bond and its associated risk. Thus, climate policy shocks affect sovereign bonds on the country-level through the channel of probability of default, the value of sovereign bonds and the climate spread55.

The study uses different data sources. The NACE Rev2 classification of economic sectors allows to associate the exposure of a specific financial instrument to a specific sector of economic activity which allows, by remapping the subsectors in five climate-relevant sectors, to distinguish carbon-intensive and low-carbon sectors. Lastly, using data on energy and electricity production and proxies by fossil fuel, nuclear and renewable energy technology, by British Petroleum (BP)s Statistical Review of World Energy 2018 and by the IEAs World Energy outlook (2018), Battiston and Monasterolo (2019) estimate the gross value added of each technology and its share on total electricity production by country.

Battiston and Monasterolo (2019) apply the model to the sovereign bonds of the OECD countries included in the Austrian National Bank (OeNB)'s non-monetary policy portfolio. They find that the (mis)alignment of an economy could already be reflected in the sovereign bonds' spread (i.e. the climate spread) and change the fiscal and financial risk position of a country. Lastly, the authors

[55] According to Battiston et al. (2019), the climate spread metric introduces climate as a source of risk in 10-years' bond yields. Shocks are potential gains (positive) or losses (negative) on individual sovereign bonds associated to countries disordered transition to a 2°C-aligned economy by 2030.

calculate the Climate VaR and compute the largest gains/losses on the central bank's portfolio via financial network models (Battiston et al. 2017; Roncoroni et al. 2019).[56]
For illustrative reasons, Table 7-2 shows the impact of climate policy shocks on the value of sovereign bonds and sovereign bonds yields (climate spread) computed with GCAM and WITCH under the tighter climate policy scenario StrPol-450.

TABLE 7-2 CLIMATE SHOCKS ON SOVEREIGN BONDS (VALUES AND YIELDS)

Models' region	WITCH: bond shock (%)	WITCH: yield shock (%)	GCAM: bond shock (%)	GCAM: yield shock (%)
EUROPE	1,30	-0,16	0,13	-0,02
REST_WORLD	-17,36	2,45	n.a.	n.a.
EUROPE	0,84	-0,10	0,03	0,00
PAC_OECD	-5,21	0,67	-18,29	2,61
REST_WORLD	3,65	-0,44	n.a.	n.a.
LATIN_AM	-6,10	0,79	-4,22	0,54
LATIN_AM	-0,50	0,06	-0,34	0,04
EUROPE	1,24	-0,15	-0,11	0,01
EUROPE	-1,27	0,16	1,18	-0,15
EUROPE	-0,36	0,04	-0,42	0,05
EUROPE	3,75	-0,45	0,51	-0,06
EUROPE	1,58	-0,19	1,05	-0,13
EUROPE	2,64	-0,32	0,47	-0,06
EUROPE	1,34	-0,16	0,21	-0,03
EUROPE	-0,46	0,06	0,66	-0,08
EUROPE	0,50	-0,06	-0,07	0,01
EUROPE	0,78	-0,10	-0,08	0,01
EUROPE	1,94	-0,24	0,42	-0,05
EUROPE	-1,42	0,18	0,33	-0,04
PAC_OECD	-5,05	0,65	-5,48	0,71
REST_ASIA	-0,48	0,06	-0,50	0,06
EUROPE	2,60	-0,32	0,58	-0,07
EUROPE	1,85	-0,23	0,44	-0,05
EUROPE	2,45	-0,30	0,47	-0,06
LATIN_AM	-6,30	0,82	-2,71	0,34
EUROPE	-5,05	0,65	-0,91	0,11
REST_WORLD	-14,82	2,05	n.a.	n.a.
EUROPE	-12,85	1,75	-2,49	0,32
EUROPE	1,86	-0,23	0,27	-0,03
REST_WORLD	-1,54	0,19	n.a.	n.a.
EUROPE	2,30	-0,28	0,32	-0,04
EUROPE	-0,36	0,05	-0,77	0,10
REF_ECON	-2,63	0,33	-0,01	0,00
NORTH_AM	-4,04	0,52	-1,06	0,13

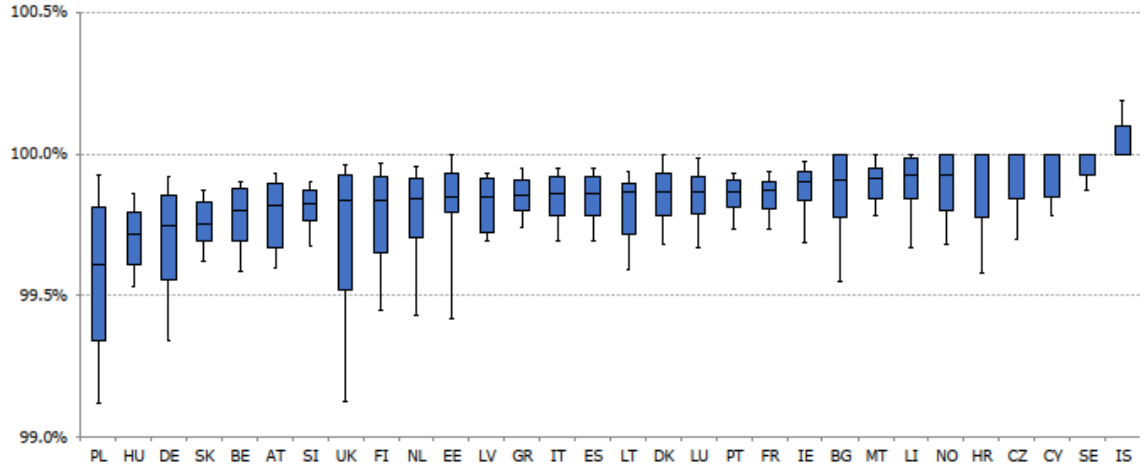
Source: Battiston and Monasterolo (2019)

A similar approach by Battiston et al. (2019)[57] analyses the impact of a climate policy shock on the sovereign holdings of European insurers, using Quarterly Solvency II Reporting and Centralized Security Database (CSDB) with solo data of insurers from 31 countries in EU/EEA that reported Solvency II data at the end of 2018 in an Integrated Assessment Model (IAM)[58],. They find that in a mild scenario[59] the portfolio impact of the climate policy shock, i.e. the ratio of the value of the portfolio after the shock over the initial value before the shock, ranges from 99.6% to 99.8%. Whereas in the adverse scenario[60], the impact of a climate policy shock equals and the median shock is about three times larger than in the mild scenario (Figure 7-1 and Figure 7-2).

FIGURE 7-1 IMPACT ON SOVEREIGN HOLDINGS (MILD SCENARIO)

[56] Battiston, S., Mandel, A., Monasterolo, I., Schtze, F., Visentin, G. (2017). A Climate Stress-test of the Financial System. Nature Climate Change, 7(4), 283288.
Roncoroni, A., Battiston, S., Escobar Farfan, L. O. L., Martinez-Jaramillo, S. (2019). Climate risk and financial stability in the network of banks and investment funds. Under review at Journal of Financial Stability.
[57] Battiston, S., Jakubik, P., Monasterolo, I., Riahi, K. & van Ruijven, B. (2019). Climate risk assessment of sovereign bonds portfolio of European insurers, forthcoming.
[58] CLIMAFIN framework as described in Battiston et al. (2019).
[59] Loss given default equal to 0.2 and elasticity of probability with respect to market share of 0.2.
[60] Loss given default equal to 0.4 and elasticity of probability with respect to market share of 0.5.

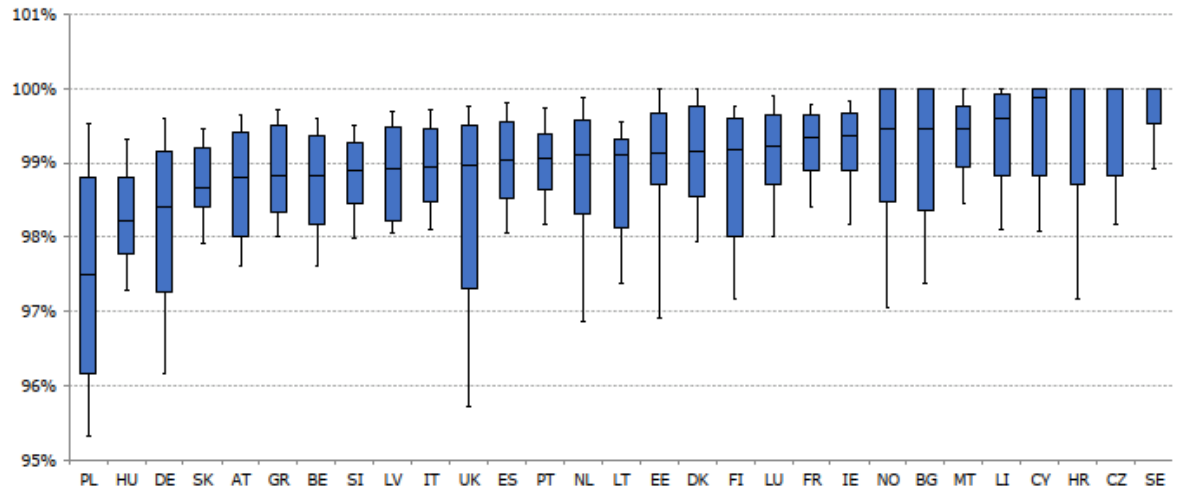
*Distribution of the impact on sovereign holdings of European insurers conditioned to the country of the holder, across climate policy shock scenarios under the **mild** scenario on market conditions.*



Source: Battiston et al. (2019)
Note: Y-axis corresponds to the percentage of the original value of government portfolios (e.g. 100% expresses 0% impact, 97% corresponds to a drop of 3%).

FIGURE 7-2 IMPACT ON SOVEREIGN HOLDINGS (ADVERSE SCENARIO)

*Distribution of the impact on sovereign holdings of European insurers conditioned to the country of the holder, across climate policy shock scenarios under the **adverse** scenario on market conditions.*



Source: Battiston et al. (2019)
Note: Y-axis corresponds to the percentage of the original value of government portfolios (e.g. 100% expresses 0% impact, 97% corresponds to a drop of 3%).

7.2.2 CARIMA model application

With the help of a comprehensive dataset[61], Görgen et al. (2019) design a scoring concept with 55 Carbon Risk Proxy Variables to assess whether firm values (or stock prices) are positively or negatively influenced by unexpected changes in the transition process towards a Green Economy, i.e. transition risk. Dividing these variables in group indicators "Value Chain", "Adaptability", and "Public Perception" to capture the three impact channels of carbon risk, the authors calculate a Brown-Green-Score (BGS) which measures the direction and magnitude of the changes in firm value due to transition risk.

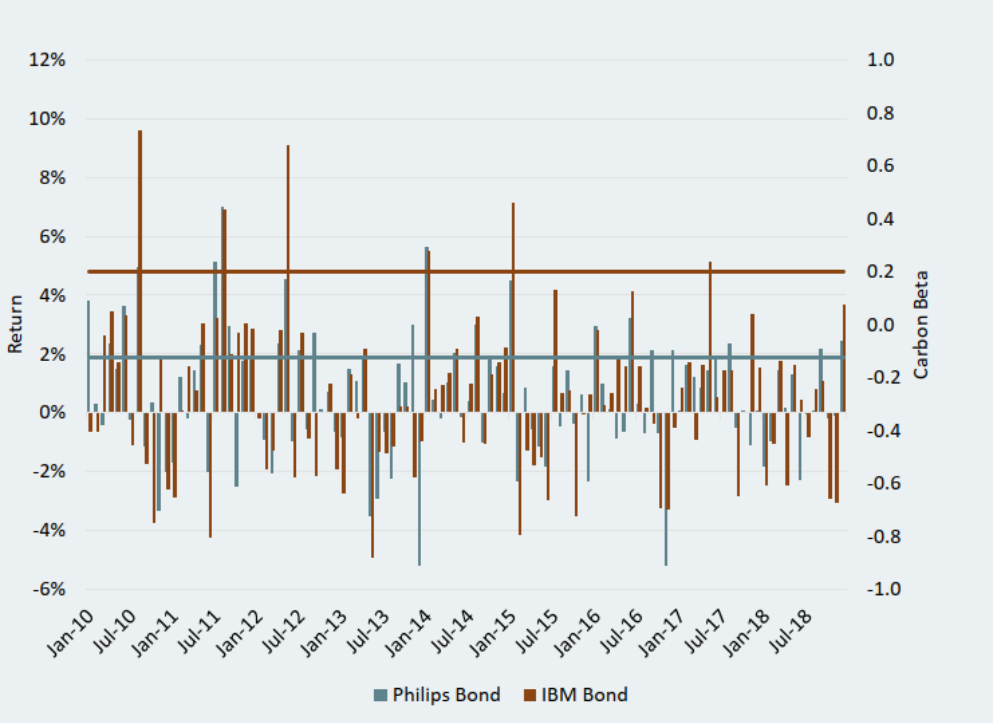
Using the Brown-Green-Score to identify brown and green firms, the authors assign to mimicking stock portfolios "brown" firms and "green" firms. Calculating a time series of historical portfolio returns for both stock portfolios and taking the difference between the two times series gives the Carbon Risk

[61] The master dataset combines Thomson Reuters ESG, MSCI ESG-Stats and IVA-Ratings, Sustainalytics ESG Ratings and CDP and capital market data from Thomson Reuters DataStream, and comprises data on ESG and other capital market variables for about 40,000 firms.

Factor BMG ("Brown-Minus-Green"). This time series of historical returns reflects investments in "brown" stocks while simultaneously selling "green" stocks.

By including the Carbon Risk Factor BMG in a factor model approach, one is able to analyse the impact of carbon risk on a financial asset. The regression analysis of the factor model allows the calculation of a Carbon Beta which measures the effect of Carbon Risk on financial assets. This Carbon Beta measures the effect of unexpected changes in the transition process of the economy towards a green economy, i.e. how will the return on an asset (bonds, stocks, funds or portfolios) change if the Carbon Beta changes, ceteris paribus, by one unit in relation to the market. An example of Carbon Betas for two corporate bonds are shown below in Figure 7-3.

FIGURE 7-3 CARBON BETAS FOR TWO CORPORATE BONDS



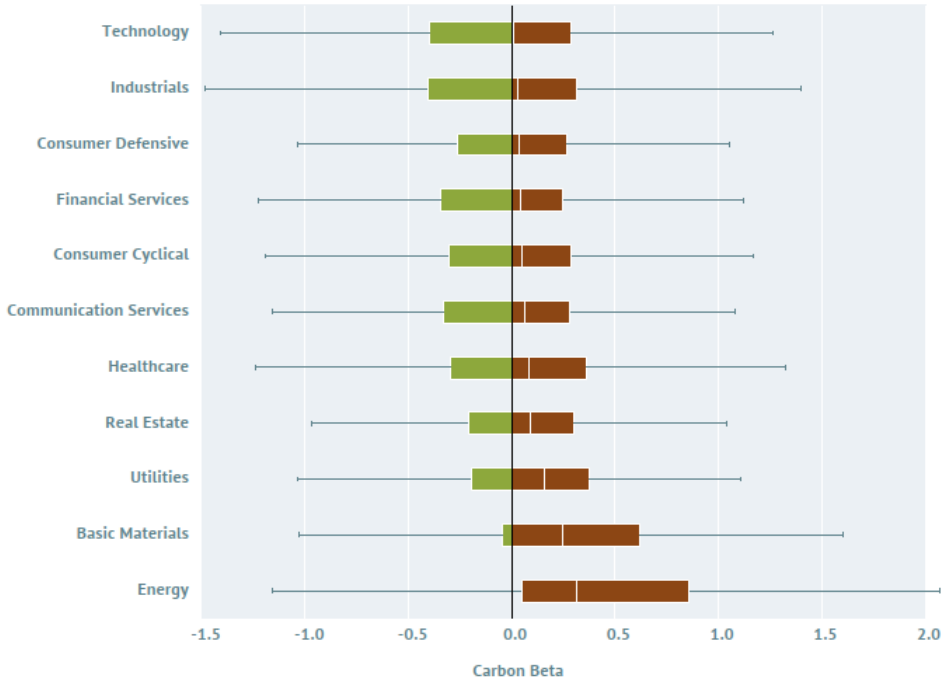
Source: CARIMA Excel-Tool (2019)

Similarly,

Figure 7-4 shows an example of carbon betas across sectors (depicted as a Box-and-Whisker plot of equally weighted aggregate Carbon Betas across sectors). [62]

[62] The Carbon Beta of a sector can be determined on an equal- or value-weighted basis.

FIGURE 7-4 EQUALLY WEIGHTED AGGREGATE CARBON BETAS ACROSS SECTORS



Source: CARIMA Excel-Tool (2019)

Finally, Table 7-3 shows an illustration for how a carbon beta can be estimated for a loan, using information on the corporate bonds and equity from the issuer or comparable firms.

TABLE 7-3 ESTIMATING THE CARBON BETA

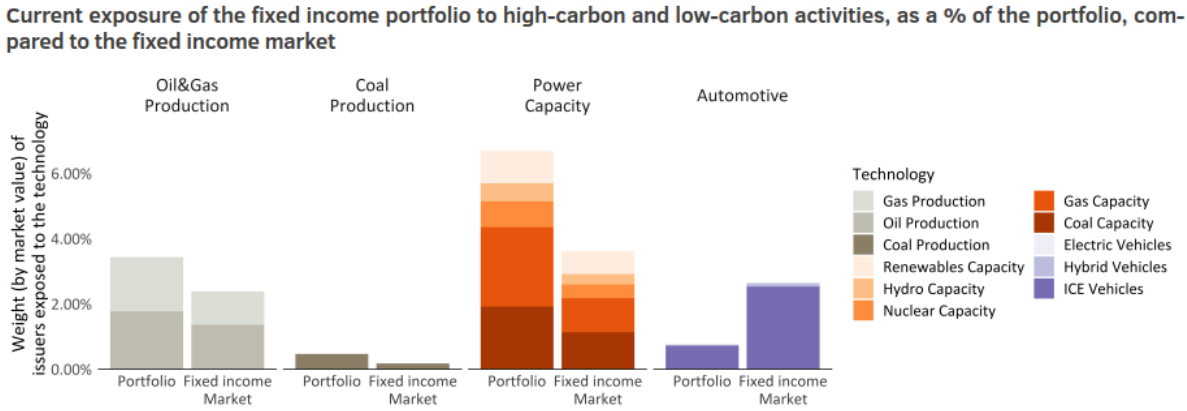
	Carbon Beta of the stock of the same firm is known	Carbon Beta of the stock of the same firm is unknown
Carbon Beta of a corporate bond of the firm is known	**C** Using the Carbon Beta of comparable firms to determine the Carbon Beta of a loan	**A** Using the Carbon Beta of a corporate bond to determine the Carbon Beta of a loan
Carbon Beta of a corporate bond of the firm is unknown	**B** Using the Carbon Beta of the stock to determine the Carbon Beta of the loan	**D** Using the Carbon Beta of comparable firms to determine the Carbon Beta of the loan

Source: CARIMA Manual (2019)

7.2.3 PACTA model application

The PACTA model allows to show the current technology exposure for asset classes, such as corporate bonds, with respect to a transition to a low carbon economy in comparison to a market portfolio. This market portfolio is based on the exposure of the global universe of assets in the relevant asset class to the sectors. Figure 7-5 shows the exposure for corporate bonds of California insurance companies.

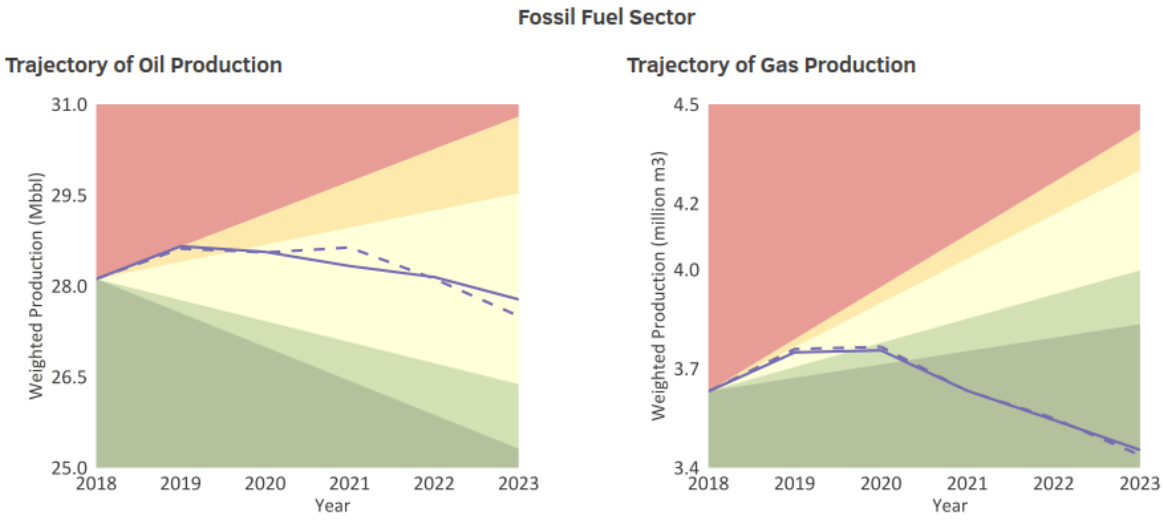
FIGURE 7-5 CURRENT EXPOSURE OF THE FIXED INCOME PORTFOLIO TO HIGH- AND LOW-CARBON ACTIVITIES



Source: 2° Investing Initiative (2019). 2° SCENARIO ANALYSIS Report - Insurance Companies Operating in California.

Given the current exposure of corporate bonds with respect to a transition to low carbon economy, Figure 7-6 shows the alignment of investment and production plans of companies in the portfolio with different climate scenarios and the Paris Agreement. Here shown for the fossil fuel sector.

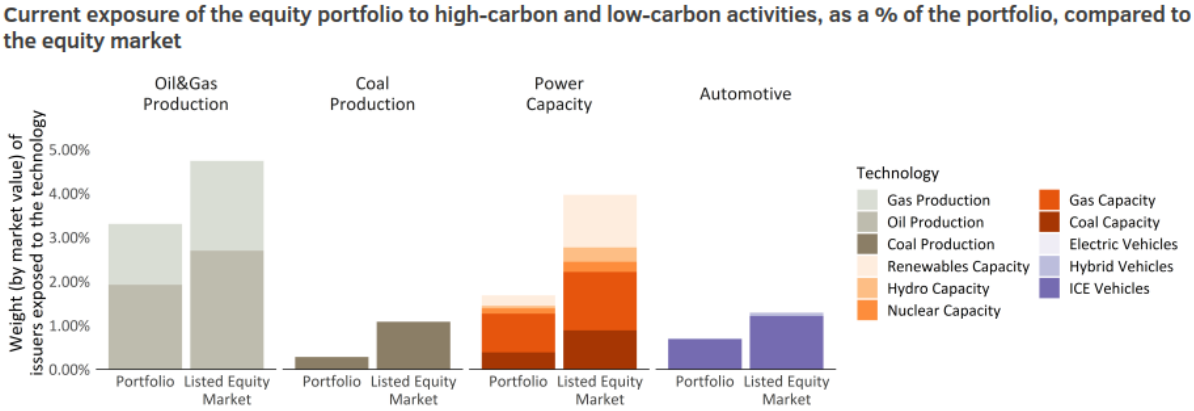
FIGURE 7-6 ALIGNMENT OF INVESTMENT AND PRODUCTION PLANS DIFFERENT CLIMATE SCENARIOS AND THE PARIS AGREEMENT



Source: 2° Investing Initiative (2019). 2° SCENARIO ANALYSIS Report - Insurance Companies Operating in California.

The current technology exposure for listed equity can be derived analogously to that for corporate bonds. Figure 7-7 below shoes the exposure for listed equity of California insurance companies.

FIGURE 7-7 CURRENT EXPOSURE OF THE EQUITY PORTFOLIO TO HIGH- AND LOW-CARBON ACTIVITIES



Source: 2° Investing Initiative (2019). 2° SCENARIO ANALYSIS Report - Insurance Companies Operating in California.

7.3 Second round effects – qualitative questionnaire

Without aim of completeness the annex provides some potential questions (aligned with the supplemental guidance for insurers of the Task Force on Climate-related Financial Disclosures (TCFD) recommendations on climate-related financial disclosures) which aim to see the level of integration of climate change considerations in four important areas of an insurance undertaking (i.e. governance, strategy, risk management, metrics and targets).

- Governance:

- Does your board and/or board committees oversee climate-related risks and opportunities? If so, what are the processes and frequency by which the board and/or board committees (e.g audit, risk or other committees) is informed about climate related issues?
- Does your board and/or board committees consider climate-related issues in any of the following aspects:
    a. when reviewing and guiding strategy, major plans of action, risk management policies, annual budgets, and business plans,
    b. when setting the organization's performance objectives, monitoring implementation and performance,
    c. when overseeing major capital expenditures, acquisitions, and divestitures?
- Has the board set goals and targets for addressing climate-related issues? Does the board monitor and oversee progress against goals and targets, and how?
- Has your organization assigned climate-related responsibilities to management-level positions or committees? If so, do these responsibilities include assessing, managing and reporting climate-related issues to the board or a committee of the board? How does management (through specific positions and/or management committees) monitor climate-related issues in your organization?

- Strategy:
    - Has your company identified climate-related risks and opportunities over the short, medium and long term? If so, please describe:
        a. what you consider as short-, medium- and long-term time horizon;
        b. the climate-related issues you have identified for each time horizon and whether any of these issues could have a material financial impact on your organization; and,
        c. the process or processes you have used to determine which risks and opportunities could have a material impact on your organization.
    - Has your organization identified climate-related issues that affect its business, strategy and financial planning? Specifically, do the identified climate-related issues impact your business and strategy in any of the following areas: products and services, supply chain and/or value chain, adaptation and mitigation activities, investment in research and development, and operations? If so, please elaborate.
    - In relation to the previous question, do the identified climate-related issues impact your financial planning in any of the following areas: operating costs and revenues, capital expenditures and capital allocation, acquisitions or divestments and access to capital? If so, please elaborate.
    - In addition, please describe the identified potential impacts of climate change risks and opportunities (supported with quantitative information where available) on your core business, products and services including:
        a. information at the business division, sector, or geography levels;
        b. how the potential impacts influence client, cedant, or broker selection; and
        c. whether specific climate-related products or competencies are under development, such as insurance of green infrastructure, specialty climate-related risk advisory services, and climate-related client engagement.

- Does your company use climate-related scenarios to inform the organization's strategy and financial planning? If so, please describe the scenarios used.
- Does your company factor climate-related risks and opportunities into relevant investment strategies? If so, is this done from the perspective of a total investment strategy or individual investment strategies for various asset classes?
- Has your company assessed the resilience of its strategy, taking into consideration a transition to a lower-carbon economy consistent with a 2°C or lower scenario and, where relevant to the organization, scenarios consistent with increased physical climate-related risk? If so please describe if the organization's strategy is affected, how it may change, and the climate-related scenarios and the time horizon(s) considered.
- In addition, if your company performs climate-related scenario analysis please provide the following information:
    a. description of the climate-related scenarios used, including the critical input parameters, assumptions and considerations, and analytical choices. In addition to a 2°C scenario, insurance companies with substantial exposure to weather-related perils should consider using a greater than 2°C scenario to account for physical effects of climate change and
    b. time frames used for the climate-related scenarios, including short-, medium-, and long-term milestones.

- Risk management:
    - Has your organization implemented processes for identifying and assessing climate-related risks? How does your organization determine the relative significance of climate-related risks in relation to other risks?
    - Please describe your company's processes for identifying and assessing climate-related risks on re-/insurance portfolios by geography, business division, or product segments, including the following risks:
        a. physical risks from changing frequencies and intensities of weather-related perils,
        b. transition risks resulting from a reduction in insurable interest due to a decline in value, changing energy costs, or implementation of carbon regulation, and
        c. liability risks that could intensify due to a possible increase in litigation.
    - Does your company use key tools or instruments, such as risk models, to manage climate-related risks in relation to product development and pricing? If so, please describe the key tools and instruments used as well as the range of climate-related events considered and how the risks generated by the rising propensity and severity of such events are managed.
    - Does your company consider the positioning of its portfolio with respect to the transition to a lower-carbon energy supply, production and use? Does your company actively manage its portfolio positioning in relation to this transition?

- Questions related to targets and metrics:
    - Does your organization use metrics to assess and manage relevant climate-related risks and opportunities in line with its strategy and risk management process? If so please describe which metrics are used. If relevant, please provide aggregated risk exposure to weather-related catastrophes of your property business (i.e., annual aggregated expected losses from weather-related catastrophes) by relevant jurisdiction.

- Does your organization use targets to manage climate-related risks and opportunities and performance against targets (e.g. GHG emissions)? If so, please describe which targets are used.

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