GDV German Insurance Association

VERSION 2.0

Climate change scenarios in ORSA

Approaches to implementing regulatory requirements
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GDV

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Version 2.0

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Second, updated and expanded edition

Preface to the second edition

The ever-advancing climate change is also having an increasing impact on the regulatory requirements for insurance companies. In 2022, companies were required to include climate change scenarios in their ORSA reports for the first time. To support its member companies, the German Insurance Association (GDV) developed possible approaches for implementing this requirement at short notice, publishing them in February 2022 (Version 1.0).

The member survey for GDV's sustainability report showed that that this assistance was widely used and rated very positively. At the same time, the assistance also still had gaps in some areas. Further development therefore seemed to make sense. In September 2022, moreover, the NGFS released a new generation of its climate change scenarios, from which new insights emerge. GDV is now presenting an updated and expanded new version (Version 2.0) of the approaches to climate change scenarios in the ORSA.

During the further development, the presentation of the scenarios and models of the NGFS was completely restructured and is now also significantly more detailed. With respect to methodology, considerations for assessing the materiality of climate change risks were added. In terms of the impact on capital investments, the new scenarios generated by NGFS have resulted in extensive changes. Moreover, the aspect of model actuality, the basic features of the entire transition and possible portfolio-specific considerations are now addressed, among other things. In addition, issues of model uncertainty play a much larger role than before. Regarding the impact on personal insurance, items were also restructured and additions were made, especially on air pollution. Examples of specific quantification approaches for flood and hail hazards were added to the property/casualty insurance impacts. In addition, heavy rainfall considerations were added.

We hope that this Version 2.0* once again contains new impulses for thought and insights that can be a useful aid for many companies.

Berlin, March 2023

* This present document is an English translation as of June 2023 of the German paper "Klimawandelszenarien im ORSA".

Contents

Introduction

With their sustainability positioning, German insurers are committing to the Sustainable Development Goals of the United Nations and the goals of the Paris Climate Agreement.[1] They support the goal of comprehensive decarbonisation of the European economy and are prepared to make their contribution to this end.

Accelerating climate change imposes risks and burdens on society that are more severe the fewer and the later countermeasures are taken. A transition as quickly as possible to a more sustainable way of living and doing business seems inevitable. For the economy, however, not only climate change itself but also this transition is associated with considerable disruptions and uncertainty.

For the German insurance industry, addressing climate change is part of doing business sustainably. As risk takers and investors, insurance companies are faced with the task of proactively identifying and assessing risks associated with climate change and transition in a forward-looking manner. Scenario analyses in which possible developments are studied as examples can serve this purpose. This is now also a requirement imposed on companies by the supervisory authorities. Findings from this should be taken into account in business planning and strategy and presented in the ORSA reports.[2]

For many companies, this new task represents a challenge. The German Insurance Association (GDV) has therefore worked with a project group, in which member companies from various lines of business and the Association of Private Health Insurers (PKV) are represented, to develop approaches for implementing the supervisory requirements for climate change scenarios in the ORSA. After the first version was published in 2022, a second, significantly revised and expanded version (Version 2.0) is now being presented by way of this document.

The document is intended to provide impulses for thought and identify ways in which companies could address the issue of climate change risk in the ORSA and approach the regulators' requirements. However, the concrete implementation in companies must be based on their own risk profiles and possibilities and is exclusively in the responsibility of the companies. All assertions in this document are non-binding and the approaches described are to be understood as exemplary. GDV assumes no liability for errors or variant interpretations.

Germany's Federal Financial Supervisory Authority BaFin already expected an assessment of material climate change risks using corresponding scenarios in the ORSA reports to be submitted in 2022. Due to the very tight deadline, GDV decided to provide initial approaches that could help with practical implementation as quickly as possible. This was done by way of the release of Version 1.0 in February 2022. As planned, work continued thereafter and the document was expanded to include aspects that could not be implemented in Version 1.0 in the short time available. Nevertheless, the present revised version (Version 2.0) does not claim to be an exhaustive presentation of the subject. Under no circumstances it is intended to define uniform market standards or to prescribe binding approaches for implementing supervisory requirements.

Finally, reference should be made to EIOPA's Guidance[3] on climate change scenarios in the ORSA, published on 2 August 2022. This non-binding guidance is also intended to provide insurance companies with a practical starting point for implementing climate change analyses in the ORSA, without excluding other approaches.

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1 Cf. GDV (2023).
2 The ORSA is the insurance companies' own risk and solvency assessment.

3 Cf. EIOPA (2022a).

OVERVIEW

Chapter 1 describes the regulatory requirements arising primarily from EIOPA's Opinion[4] on climate change scenarios in the ORSA of 19 April 2021. In addition, details on regulatory expectations from discussions with BaFin (including in the BaFin workshop in March 2021) are explained and the BaFin notes[5] on Solvency II reporting dated 26 September 2022 are presented.

Chapter 2 presents and explains the NGFS scenarios and models used as basis for the analyses in this document. Among other things, scenario selection, the question of the reference scenario, and the topic of model uncertainty are addressed. Additional sources, including further options for scenario selection, are listed in a separate collection* of materials, but this has not been updated any further since early 2022. More recent sources are therefore not included in this collection.

Chapter 3 presents different approaches on how the assessment of climate scenarios could be done methodically. Consideration is given to projections, multi-periodicity, business development and temporal horizons. Specific methodological aspects relating to capital investment, personal and property/casualty insurance are then briefly elucidated. In addition, this chapter provides guidance on how companies can identify potentially material climate change risks to their operations.

Chapter 4 discusses the impact of the transition on capital investment. After a few words on qualitative analysis, first some of the premises of quantitative analysis (including the issue of actuality) are addressed before the transition and its expected impact on capital investments are outlined. Possible approaches are presented for sector- and portfolio-specific considerations as well as for deriving spreads. Finally, projected developments for important investment-related variables such as equities, interest rates, spreads and property as well as selected macroeconomic variables such as economic output and inflation are presented. In this context, model uncertainty is also addressed in detail.

Chapter 5 analyses the potential impact of climate change on personal insurance, i.e., on the underwriting of life and health insurers. Various factors influencing life and health, such as temperature and air pollution, are considered quantitatively in parts and otherwise qualitatively. In addition, the potential impact of the transition on lapse and cost risk is addressed.

Chapter 6 presents the influence of climate change on the underwriting risks of property/casualty insurance. The impact of physical risks on the individual risks of windstorms, floods, hail, drought and wildfires is elucidated. Methodological approaches are presented that could make it possible to draw conclusions about annualities. For the risks of flooding and hail, an example is given of how possible quantification might look concretely. Finally, impulses for thought on how to deal with reinsurance contracts in the context of climate change is provided and the significance of transition risks for property/casualty insurers is discussed.

Chapter 7 briefly touches on other risks that could arise in the context of climate change. These include operational risks, reputational risks and liquidity risks.

Chapter 8 is intended to provide impulses for thought for a critical examination of the results from the climate change scenarios. To this end, a number of possible questions are formulated. In general, the chapter serves to assess results from climate change scenarios of all kinds, which necessarily have an exemplary character and are associated with a large degree of uncertainty. Here, too, capital investments, personal insurance and property/casualty insurance are discussed separately.

4 Cf. (EIOPA (2021a).
5 Cf. BaFin (2022).

NGFS LICENSE

Data from the NGFS Scenario Explorer were used for the illustrations of the development of economic variables in this document and the associated file *Daten_NGFS_Bundesbank.xlsx**. The NGFS is the Network for Greening the Financial System (hereinafter also referred to as the "Rights Holder"), a global association of central banks and supervisory authorities. All data are subject to copyright protection of the Rights Holder, who claims simple database rights under EU sui generis data bank protection laws.

However, the Rights Holder provides the NGFS Scenario Explorer to users free of charge. This is done under the exclusion of any warranty as well as under the inclusion of the license agreement viewable at https://data.ene.iiasa.ac.at/ ngfs/#/license, which as a public license is an adaptation of the Creative Commons Attribution 4.0 International Public License. With the use of the NGFS Scenario Explorer, the underlying data are subjected to processing through the application of scenarios. The figures contained in Chapters 2 and 4 and the corresponding data in the above file are the result of this processing. The Rights Holder maintains the copyright to these figures and data.

* only available for members of the German Insurance Association

1. Regulatory requirements

BACKGROUND

In 2018, the EU Commission kicked off the topic of climate change scenarios in the ORSA with its Action plan on financing sustainable growth and the resulting Request to EIOPA for an opinion on sustainability within Solvency II .

The EIOPA Opinion[6] on sustainability within Solvency II, dated 30 September 2019, states with respect to ORSA, inter alia:

- "Scenarios analysis will allow undertakings to consider the impact of sustainability risks beyond the one-year time horizon or where timing is unpredictable. Such analysis should be embedded in the undertakings' risk management, governance and ORSA. This should enable undertakings to identify and assess the climate change-related risks they would be exposed to in a forward-looking manner and inform business planning and strategy."

- "Climate change is likely to increase the frequency/severity of natural catastrophes. Such expected fluctuations need to be captured in the risk management strategies in a forward-looking manner in the ORSA. Past data on its own is unlikely to be a good predictor of future risks."

EIOPA writes there that further work is needed to define a consistent set of quantitative parameters that could be used in climate change scenarios and that firms can then adopt into their ORSA, risk management and governance practices as appropriate.

In April 2021, EIOPA issued another opinion specifically dedicated to climate change scenarios in the ORSA (EIOPA, 2021a), providing details of its expectations on what companies should consider when applying these scenarios. An explicit start for the application is not mentioned, but it is stated that EIOPA will start monitoring the application two years after publication, i.e. with the ORSA reports in 2023.

6 Cf. EIOPA (2019).

Since August 2022, according to Delegated Regulation 2021/1256[7] amending the Delegated Regulation on Solvency II, insurance companies have to integrate sustainability risks into their risk management and ORSAs.

Integrating climate change scenarios into the supervisory process also at the level of the Solvency II Directive is mentioned as measure 3(d) in the EU Commission's Renewed Sustainable Finance Strategy[8] of July 2021. This is reflected accordingly in the EU Commission's proposals for the Solvency II review of September 2021. If implemented accordingly, the existing requirement from the EIOPA opinion to quantify climate change scenarios would be anchored at the directive level. The start of the application of the directive amendments has not yet been determined, but is not expected before 2025.

The main contents of the EIOPA opinion on climate change risk scenarios in the ORSA (EIOPA, 2021a) are presented below.

OPINION GOALS

The Opinion sets out EIOPA's expectations for competent national authorities on how to monitor the integration of climate change scenarios by insurers in their ORSAs using a proportionate, risk-based approach:

- Supervisory convergence is to be improved in Europe.
- The forward-looking management of climate change risks is to be promoted in the short as well as the long-term perspective.
- Companies' climate scenarios need to be (further) developed when new methods are available and the companies have gained experience.
- The scenarios used are to be standardised to a certain degree. This is to balance the need for consistency in the market and the individuality of ORSAs.

7 Cf. European Commission (2021a).
8 Cf. European Commission (2021b).

CLIMATE CHANGE RISKS IN THE SHORT- AND LONG-TERM PERSPECTIVE

The risks are to be considered in the short-term perspective. Not only physical risks (e.g. due to frequency, severity, and distribution of extreme weather events), but also transition risks (e.g. due to introduction of a CO_2 tax or technological innovations) are to be considered.

In the long-term perspective, scenarios should be used to inform strategic planning and business strategy. Strategic opportunities as well as challenges are possible focuses (such as business models, risk profiles, insurability, affordability, solvency situations, etc.).

DEFINITION OF CLIMATE CHANGE RISKS

Climate change risks/sustainability risks are not a separate risk category, but materialise via the following already known risk types.

Transition risks are risks arising from the transition to a low-carbon, climate-resilient economy. They include:

- Political risks, e.g. as a result of energy efficiency requirements, CO_2 pricing mechanisms and policies to promote sustainable land use.
- Legal risks, e.g. the risk of litigation if negative climate impacts are not avoided or minimised, or if adaptation to climate change is not undertaken.[9]
- Technological risks, e.g. when a less climate-damaging technology replaces a more climate-damaging technology.
- Market sentiment risks, e.g. if consumer and business customer decisions shift toward less climate-damaging products and services.
- Reputational risks, such as the difficulty of attracting and retaining customers, employees, business partners and investors if a company has a reputation for damaging the climate.

Physical risks are risks arising from the physical impacts of climate change. They include:

- acute physical risks arising from certain events, in particular weather-related events such as windstorms, floods, fires or heat waves, which can damage production facilities and interrupt value chains.
- chronic physical risks resulting from long-term changes in climate, such as temperature changes, sea level rise, reduced water availability, loss of biodiversity, and changes in land and soil productivity.

In Appendix A to Annex II of Delegated Regulation 2021/2139,[10] which contains screening criteria on the environmental objectives of climate change mitigation and adaptation, physical risks are classified as shown in Table 1 (though the classification is not exhaustive).

MATERIALITY ASSESSMENT

The materiality of climate change risks should be identified through a combination of qualitative and quantitative analyses. In this regard, EIOPA writes (cf. Marginal Nos. 3.8–3.14 in EIOPA (2021a)):

- Qualitative analysis can provide insight into supervisory risks such as market risk, counterparty risk, underwriting risk, operational risk, reputational risk, strategic risk, etc.
- Quantitative analyses can be used to assess the exposure of investment and insurance portfolios to transition risks and physical risks as integral components of known risk types.
- Analyses are to consider future climate change impacts.
- Reinsurance protection for physical risks does not render them immaterial, according to EIOPA.
- If risks are determined to be not material, an explanation for the reasons must be provided.

Guidance on how materiality assessments can be done is given in Section 3.5.

9 Cf. NGFS (2021). Such liability or litigation risks are sometimes also understood as a separate type of risk. In particular, due to the possibility of risk transfer through liability insurance policies (such as general liability, professional liability or D&O insurance), these risks are of particular importance for insurance companies. In addition, these risks can also arise from direct claims against insurers (e.g. due to insufficient disclosure).

10 Cf. European Commission (2021c).

Classification of climate related hazards by the EU Commission

Table 1 · Appendix A to Annex II to Delegated Regulation (EU) 2021/2139

	TEMPERATURE-RELATED	WIND-RELATED	WATER-RELATED	SOLID MASS-RELATED
Chronic	Changing temperature (air, freshwater, marine water)	Changing wind patterns	Changing precipitation patterns and types (rain, hail, snow/ice)	Coastal erosion
	Heat stress		Precipitation or hydrological variability	Soil degradation
	Temperature variability		Ocean acidification	Soil erosion
	Permafrost thawing		Saline intrusion	Solifluction
			Sea level rise	
			Water stress	
Acute	Heat wave	Cyclone, hurricane, typhoon	Drought	Avalanche
	Cold wave/frost	Storm (including blizzards, dust and sandstorms)	Heavy precipitation (rain, hail, snow/ice)	Landslide
	Wildfire	Tornado	Flood (coastal, fluvial, pluvial, ground water)	Subsidence
			Glacial lake outburst	

Source: European Commission (2021c)

SCOPE OF CLIMATE CHANGE RISKS

Material risks should, where appropriate, be assessed using a sufficiently broad range of short and long-term scenarios (cf. Marginal Nos. 3.15–3.21 in EIOPA (2021a):

- Only a wide range of scenario outcomes with associated risks and uncertainties provides the management body with sufficiently deep insight to make decisions and take measures.
- Uncertainty increases with long modeling time horizons (driven by external factors such as demographics, economic development, policy on CO_2 emissions, technical change, market sentiment, etc.), resulting in a wide range of conceivable future states.
- At least two long-term scenarios should be calculated:
  - A climate change risk scenario where the global temperature increase remains below 2°C, preferably no more than 1.5°C, in line with EU (and German) commitments;[11]
  - a climate change risk scenario where the global temperature increase exceeds 2°C.
- The goal is to assess the robustness of the business strategy under different conditions.

BALANCE SHEET PROJECTIONS

In general, EIOPA clarifies in the Opinion (Marginal No. 3.23) its expectation that a high degree of accuracy must be provided in the presentation of balance sheets, solvency capital requirements and the overall solvency needs for a short-term time horizon. On the other hand, the longer the time horizon, the less accurate the projection of the balance sheet may be (Marginal No. 3.22).

For a (very) short-term observation period, companies can generally use the current balance sheet as a basis for their analysis and do not need to make a projection of the balance sheet. For other time horizons, including long-term ones, EIOPA allows the use of the current balance sheet as a simplification and presents this as a way to avoid multi-period projections (Marginal No. 1.23–5.15).

As another conceivable variant, EIOPA describes a partial projection of a balance sheet in order not to have to project the full balance sheet while still preserving the long-term nature of the climate change scenarios. For example, this could be used to project the evolution of claims for different perils or geographic areas, or to look at the asset side of the balance sheet in isolation

11 The colloquial formulation of a temperature increase of *x* degrees Celsius means an increase of *x* Kelvin.

in order to assess the impact of transition risks on the investment portfolio over time (Marginal No. 5.16).

EIOPA writes that though the projection of complete balance sheets would have some advantages such as ensuring internal consistency and compatibility of measures, nevertheless, the goal cannot be to project all individual balance sheet items in detail into the future, but to focus primarily on the components that are important for the analysis. As examples, EIOPA mentions the inclusion of new business in the projection of liabilities and the anticipation of an increase in the SCR for underwriting risks (Marginal No. 1.23–5.18).

TIME HORIZON

EIOPA clearly states in its Opinion (Marginal No. 3.3) that the time horizon for assessing long-term climate change risks using the scenario analyses could be longer than the usual time horizon in the ORSA. EIOPA defines the time horizon for considering climate change in the ORSA as follows:

- **Current climate change:** “up to today” records of the impact of climate change
- **Short-term climate change:** Outlook for the next 5 to 10 years
- **Medium term climate change:** Outlook for the next 30 years
- **Long-term climate change:** Outlook for the next 80 years (until the end of the century)

BaFin's current notes[12] on Solvency II reporting, published on 26 September 2022, sets out, among other things, BaFin's expectations for the application of climate change scenarios, including the time horizon of the scenarios:

“In the ORSA report, climate change risks must be explicitly addressed, at least if they are material to the company. In this case, the short and long-term (5–10 and 15–30 years, respectively) outlook for the company is to be addressed.“

It should be noted that the time horizon stated by BaFin is shorter than that required by EIOPA in its Opinion.

Specifically, this means that companies in Germany are currently allowed to make a different choice for the long-term time horizon than stated in the EIOPA opinion (EIOPA, 2021a). This could also result in a certain shift in the other temporal perspectives, consistent with this.

The examples in EIOPA's guidance (EIOPA, 2022a) also tend to be oriented toward the short- or medium-term time horizon.

What a possible handling of the different time horizons might look like in practical application is presented in Chapter 3.

(FURTHER) DEVELOPMENT OF CLIMATE CHANGE ANALYSES

EIOPA and BaFin expect (further) development of the scenarios in terms of scope, depth and methods:

- Initially, the focus can be on key drivers and what-if analyses to simplify long-term scenarios.
- Companies should (further) develop expertise and capacities.
- Today's scenarios do not (yet) contain all relevant information on transition-related and physical risks.
- When long-term, multi-period scenarios are calculated, new challenges arise.
- Systematic improvements of the analyses are the goal.

A key concern for supervisors is that insurance companies continue to develop climate change risk analysis or, if they have not already done so, begin addressing climate change risks immediately. Even if, for example, the data and methods are not yet available to the companies in the granularity and quality actually required, the supervisory authorities expressly desire for companies to start on the existing basis. This might also require new ways of doing things, e.g. using simpler assumptions and methods than would otherwise be the case or, in the area of capital investment, relying on publicly known results/tools from large asset managers, index providers, etc. BaFin rejects the idea of waiting until the desired database is available or so far advanced that companies can assess these risks as accurately as, for example, their underwriting risks. Companies should in contrast already use existing data/assumptions (from external sources, etc.) to assess these risks as best as possible and appropriate for them.

12 Cf. BaFin (2022).

The supervisory authorities emphasise the importance and necessity of (quantitative) analyses, especially in the area of long-term scenarios, though for companies without experience in the area, qualitative analyses would initially suffice. The qualitative analyses can be used as an approximation to become familiar with the topic and prepare the ground for quantitative approaches. As expertise is gained, the supervisory authorities expect systematic improvements in the analyses.

The evolutionary approach refers to the data and models used for the analyses, as well as to the range of assumptions for the scenarios. An expansion or deepening of various aspects should be considered in the further development of the scenarios (further sustainability risks, politics, macro and micro aspects in the economy, business orientation/model, etc.). Moreover, in a first stage of the evolutionary process, the more serious temperature increase scenario (global temperature increase of more than 2°C), for example, could be dealt with in greater depth. A second increase scenario (e.g. with limited increase of 1.5°C) could be examined by way of a deviation analysis compared to the first scenario.

LOW-RISK PROFILE UNDERTAKINGS

As mentioned above, as part of the Solvency II review, the EU Commission is proposing that a new article on climate change scenario analysis be added to the Solvency II Directive, requiring insurers to identify any material exposure to climate change risks in the future and, where appropriate, to use at least two long-term climate scenarios to assess the impact on their business. Insurers classified as low-risk profile undertakings (LRPUs) would be exempt from scenario analysis, but not from the materiality analysis, according to the proposal. A definition of the companies to be considered LRPUs in the future is also included in the EU Commission's proposals. However, the extent to which the new provisions of the Solvency II Directive will ultimately correspond to the proposals of the EU Commission is not yet clear.

BaFin writes on this aspect in its current notes on Solvency II reporting that companies with a low-risk profile, if they are exposed to material climate change risks, must at least state the extent to which they are exposed to such risks. They should also indicate what climate change-related medium-term impacts they expect to have on their future claims development, capital requirements and capital investments, and how they would respond to these.

2. Scenarios and models

Scientific knowledge on the course of man-made climate change is extremely extensive and growing. Similarly, with respect to analyses that incorporate socioeconomic consequences of climate change and mitigation measures, the literature continues to grow and models continue to evolve.

Accordingly, in its "Opinion on the supervision of the use of climate change risk scenarios in ORSA",[13] EIOPA also makes no stipulations on the use or consideration of specific climate change scenarios. For insurance companies, there are a variety of ways to approach the topic in practical terms.

GDV's project group looked at a variety of different sources in advance.[14] Both academic publications and studies from international supervisory practice (including the Bank of England, De Nederlandsche Bank) were taken into account.

For this paper, the work of the Network for Greening the Financial System (NGFS)[15] was chosen as a starting point. Speaking in favour of this decision is the fact that the NGFS has developed concrete, apparently well suited climate change scenarios and makes the corresponding data freely available with the NGFS Scenario Explorer and the Climate Impact Explorer.[16] The fact that the NGFS encompasses supervisory authorities relevant to the insurance industry, such as BaFin and EIOPA, also ensures that the scenarios – developed for purposes similar to the ORSA – should meet supervisory requirements.

However, this decision of the GDV project group is not a determination in the sense that this is the only possible or reasonable selection. A determination of this kind is not intended and generally not possible. With a view to the individual risk profile, every insurance company can instead base its own analyses on other valid sources or use them as a supplement.

2.1 Climate change scenarios of the NGFS

The **Network for Greening the Financial System (NGFS)**, established in 2017, brings together central banks and regulators around the world to help achieve the goals of the Paris Climate Agreement. This is to be done by strengthening the role of the financial system in managing risk and mobilising capital for green and low-carbon investments in the context of sustainable development. To this end, the NGFS defines and promotes best practices to be implemented both within and outside the NGFS membership and conducts analyses on Green Finance. Currently, the NGFS has 121 members from all continents and 19 international organisations as observers.[17] In Germany, Deutsche Bundesbank and BaFin are members of the NGFS; at the European level, ECB, EBA, EIOPA, and ESMA are members.[18]

2.1.1 Basic information about the scenarios

To provide a common frame of reference for examining the impacts of climate change and climate policy, the NGFS provides a set of **six climate scenarios.**[19] The scenarios include projections not only of temperatures, emissions, and policies, but also of the energy sector, land use, and macroeconomic and financial variables. Under the respective scenario assumptions, coherent projections are generated for this purpose with the help of an Integrated Assessment Model (IAM).

13 Cf. EIOPA (2021a).
14 See separate collection of materials (as of February 2022, not continued, and only available for members of the German Insurance Association).
15 Cf. NGFS (2022b).
16 For an explanation of the relationship between NGFS scenarios and Climate Impact Explorer data, see NGFS (2022a).
17 The secretariat of the NGFS is located at the Banque de France in Paris.
18 The strong commitment of the German and European supervisory authorities to the work of the NGFS is reflected, among other things, in the fact that Sabine Mauderer, a member of the Bundesbank's Executive Board, currently holds the position of Vice Chair of the NGFS and will assume the NGFS Chair in 2024. The Scenario Design and Analysis workstream of the NGFS, which is relevant to climate change scenarios, is led by the ECB's Director General Macroprudential Policy and Financial Stability, Cornelia Holthausen.
19 For basic information about scenario analysis of climate change impacts on the financial system and financial institutions, see NGFS (2020).

Thereby, three different IAMs are available, so that for each climate scenario there are three different variants to choose from.[20]

In September 2022, the NGFS already published the **third vintage of the scenario set** after 2020 and 2021 together with the most important results from the NGFS's point of view.[21] The International Monetary Fund's (IMF) October 2021 view of the global economy now serves as an updated starting point for the scenarios.[22] This means that while the Covid 19 pandemic and related supply chain problems are taken into account, the consequences of Russia's war in Ukraine are not (this applies in particular to recent developments in the energy sector and inflation, which started in 2021 but intensified massively in 2022).[23]

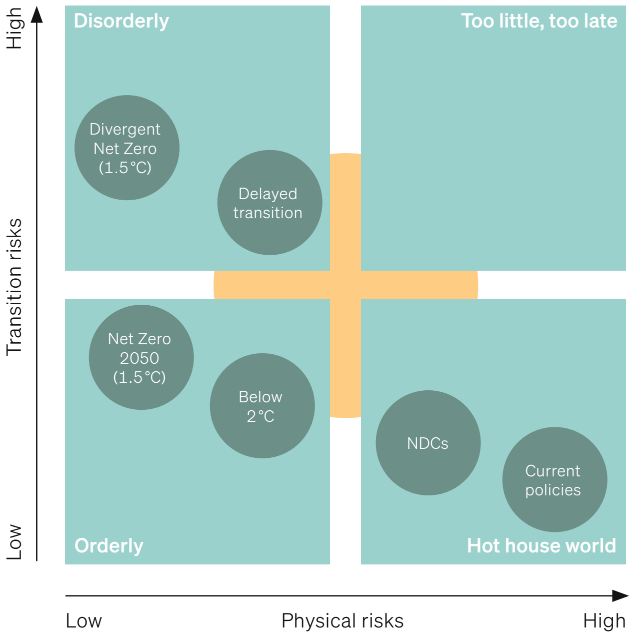
Compared to the previous vintage, not only some data and assumptions have been updated, but also the modeling has been further developed. All comments in this document refer to the current third vintage of NGFS scenarios.[24]

In principle, various future socioeconomic developments are conceivable. The NGFS scenarios are all based on the same basic assumptions about key socioeconomic factors, such as harmonised population trends, general economic trends, and food and energy demand.[25] These socioeconomic assumptions are taken from the Intergovernmental Panel on Climate Change (IPCC) common socioeconomic pathway SSP2[26] which is common in this context.

In each of the climate scenarios, the development of the CO_2 price is determined. For simplicity, this CO_2 price serves as a measure of the intensity of the overall climate policy measures.[27] In reality, however, governments use many different fiscal and regulatory instruments, which are associated with different costs and benefits.[28]

NGFS scenarios

Figure 1 · Classification of the six NGFS scenarios based on the physical and transition risks associated with them



Source: NGFS (2022a), p. 4

The individual scenarios represent different conceivable developments associated with very different levels of physical and transition risks (see Figure 1). At the same time, the scenarios are also defined in different ways.[29]

20 See Section 2.4.
21 The NGFS (2022b) slide set provides a high-level overview of current scenarios, their evolution, and key findings on transition and physical risks. NGFS (2022a) serves as detailed technical documentation of the scenarios, models, and data, along with additional source references.
22 Cf. NGFS (2022a), p. 5 and IMF (2021).
23 Specifically on this issue, see NGFS (2022c), p. 4.
24 Version 1.0 and 1.1 of this paper have been based on the second vintage of NGFS scenarios published in 2021.
25 Cf. NGFS (2022a), p. 4
26 Cf. e.g. Kriegler et al. (2012) or O'Neill et al. (2017).
27 Cf. NGFS (2022b), p. 27 and NGFS (2022a), p. 77.
28 In the NGFS scenarios, there is a dependence of the results on the assumed use of government revenues from the CO_2 price. If these revenues are used for investments, this will boost future economic output. If the revenues are instead returned to economic agents (e.g. through repaid government debt, reduced taxes or increased transfers) and are at least partly channeled into consumption rather than investment, the future economic output may be significantly lower in comparison to the first case. In each of the scenarios described in more detail below, the revenue from the CO_2 price is assumed to be returned to households. From the point of view of social justice and political feasibility, (partial) compensation of households also seems a plausible assumption from a German perspective.
29 Cf. NGFS (2022a), pp. 16–19.

2.1.2 Scenario definitions

Two of the six scenarios are based on the assumption of specific policies from which the trajectories of greenhouse gas emissions and temperatures are derived. Because climate change mitigation measures are insufficient in these two scenarios, they result in a "**hot house world**" associated with the greatest physical risks:

- **Current Policies**: Mere continuation of the climate protection measures already in force without increasing the ambition level (**no additional or more stringent measures**), resulting in a median global temperature increase of 3.1–3.2°C by 2100 (depending on the IAM)[30] with temperatures continuing to rise unchecked thereafter.[31]

- **Nationally determined Contributions (NDCs)**: Achievement of already pledged national targets[32] for emission reductions by 2025 and 2030, thereafter further reductions with a comparable level of ambition (assumptions are subject to high uncertainty), resulting in a median global temperature increase of 2.3–2.6°C by 2100 with further rising temperatures thereafter.

The remaining scenarios are instead based on certain assumptions about temperature, from which appropriate trajectories of emissions and finally the necessary –much more ambitious – extent of policy measures (summarised in the CO_2 price) are derived.

In two of these scenarios, the most cost-effective way to comply with the specified temperature increase within the framework of the model assumptions is assumed.[33] These two scenarios are referred to as "**orderly**" scenarios:

- **Below 2 °C**: Limiting the global temperature increase by 2100 to 2°C (without interim overshoot) with a probability of 67%, resulting in a median increase by 2100 of 1.5–1.7°C with a previously reached peak 0.1–0.2°C higher.

- **Net Zero 2050 (1,5 °C)**: Limit global temperature rise to 1.5°C by 2100 (with slight interim overshoot) with a 50% probability (consistent with Paris Climate Agreement commitments), resulting in a median rise of 1.3–1.5°C by 2100 with a previously reached peak 0.2°C higher.

Almost the same limits on temperature rise are achieved in two other scenarios by a much more costly path, which assumes that measures are taken late or fail to optimally incorporate individual sectors of the economy and technologies.[34] Overall, therefore, the policy measures must be all the more serious if the assumed temperature targets are to be achieved in the end nonetheless. Accordingly, the transition risks are greatest in these two scenarios which are referred to as "**disorderly**."

- **Delayed Transition**: Limitation of the global temperature increase to 2°C by 2100 (deviating from the below 2°C scenario, however, with interim overshoot,) with a probability of 67 %, resulting in a median increase of 1.4–1.6°C by 2100 with a previously reached peak 0.1–0.3°C higher.

  Special feature: No additional measures until 2030 (development as in Current Policies)**, from 2030 previously unanticipated tightened climate protection policy.**

- **Divergent Net Zero (1,5 °C)**: Limiting global temperature rise to 1.5°C by 2100 (with slight interim overshoot) with a 50% probability (consistent with Paris Climate Agreement commitments), resulting in a median rise of 1.3–1.4°C by 2100 with a previously reached peak 0.1–0.3°C higher.

30 For Integrated Assessment Models (IAMs), see Section 2.4.

31 In the following, the colloquial formulation of a temperature increase of *x* degrees Celsius means an increase of *x* Kelvin compared to the level of the reference period 1850–1900.

32 In principle, the national contributions published by the UNFCCC Secretariat (United Nations Framework Convention on Climate Change) in Bonn by the end of March 2022 are taken into account. However, there are certain variations between the IAMs.

33 Among the assumptions in all scenarios is that decarbonisation efforts will vary internationally.

34 In both disorderly scenarios, only low availability of Carbon Dioxide Removal (CDR) processes from the atmosphere is initially assumed. These are, in particular, reforestation and carbon capture and storage (CCS) in the use of bioenergy. In contrast, the two orderly scenarios assume medium availability of CDR processes. Negative emissions from CDR processes allow remaining emissions (e.g. from agriculture or countries still behind in transition) to be offset, thereby achieving net zero targets. Subsequently, they enable a slow reduction of the CO_2 concentration in the atmosphere, which is a necessary – but due to feedback effects and tipping points possibly not sufficient – precondition for temperatures to decrease again. However, especially in the case of afforestation, it is questionable how great its contribution can be in terms of a rapidly and permanently effective sink in carbon emissions in reality. Accordingly, the third vintage NGFS scenarios generally assume smaller contributions to net emissions reductions from CDR. The Delayed Transition scenario, in particular, nevertheless shows notably negative net emissions from 2070 onward.

Special feature: Sharply different CO_2 prices in the transport and buildings sectors on the one hand and energy and industry on the other.

2.2 Scenario assessment and selection

The six NGFS scenarios are associated with very different climate and economic trends. Some are more suited to the study of physical risks, while others are more suited to the study of transition risks.

2.2.1 Consideration of physical risks

The trajectories of temperature rise in the various NGFS scenarios shown in Figure 2 vividly illustrate how the two scenarios based on current policies or announced policies (NDCs) lead to a hot house world with dramatic consequences for humans and nature. This makes them very different from the other four scenarios.

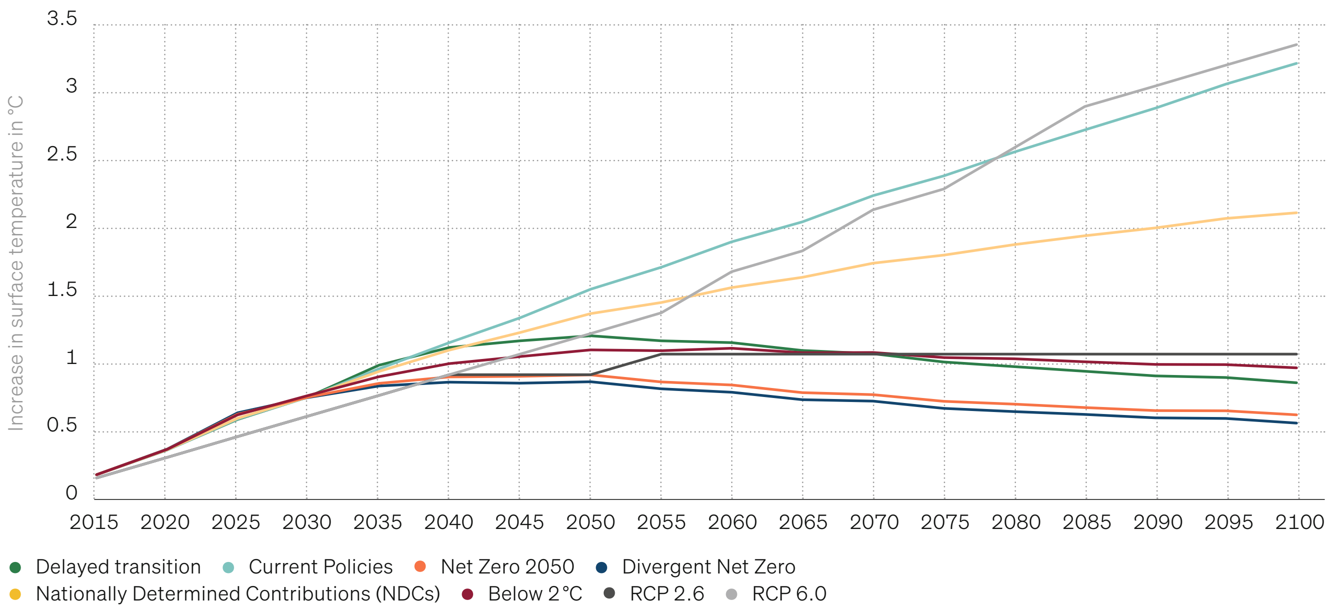
An examination of the physical risks posed by temperature rise based on the NGFS scenarios should therefore in any case include one of these two scenarios, preferably the Current Policies scenario.

Accordingly, this paper considers the Current Policies scenario.

To examine physical risks, mapping to IPCC representative concentration pathways (RCPs) is also possible. As Figure 2 shows, the various orderly and disorderly scenarios are still roughly within the range of the IPCC's low temperature scenario (RCP 2.6), in which the temperature increase ends in mid-century and remains clearly below 1.5°C in the long run. The Current Policies scenario, on the other hand, is close to the high temperature scenario (RCP 6.0) in which the temperature increase continues unabated, exceeding 3°C by the end of the century.

Air temperature

Figure 2 · Increase in mean surface temperature relative to the reference period 1850–1900 in the six NGFS scenarios (global increase) and the two IPCC scenarios RCP 2.6 and RCP 6.0 (increase in Germany)* by 2100 (NGFS scenarios: median values of a probability analysis with 600 variously calibrated model runs, unit: Kelvin, model: NiGEM NGFS v1.22, IAM: Mean value of the three Integrated Assessment Models, see Section 2.4)



* The data for the two RCP scenarios come from the analyses for the IPCC's Fifth Assessment Report (AR5), since in the current analyses for the sixth status report (AR6) RCP 6.0 is no longer one of the IPCC standard scenarios though RCP 6.0 is referred to in many scientific publications. The fact that global data are presented for the NGFS scenarios, but data for Germany are presented for the RCP scenarios, also results from issues of data availability. However, for the other RCP scenarios 2.6, 4.5, and 8.5, it can be seen that the differences between the results for AR5 and AR6 (for AR6 temperature data, see Fyfe et al. (2021) and IPCC (2021), respectively) and between the results for Germany and the world are relatively small and not crucial to the comparability with the NGFS scenarios.
The regulatory requirements for ORSA relate to global temperature development. For physical risks of German insurers, however, temperature development in Germany is likely to be the most important factor in many cases.

Source: Own illustration based on data from the NGFS Phase 3 Scenario Explorer

In contrast, there are hardly any transition risks in the Current Policies scenario, which means with regard to investments that it is generally not sufficient to consider this scenario alone for the ORSA.

2.2.2 Consideration of transition risks

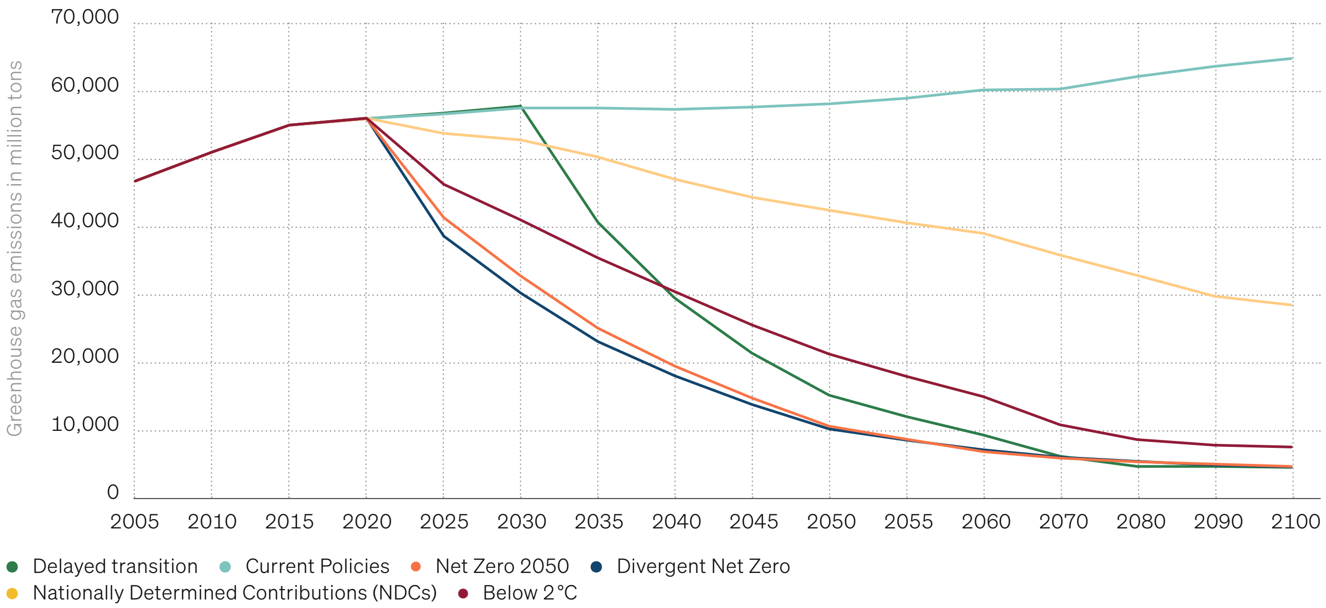
The trends in emissions of CO_2 and other greenhouse gases (expressed as CO_2 equivalents) underlying the temperature changes are shown in Figure 3. Achieving the 1.5°C or 2°C targets will require rapid and large declines in emissions – only a gradual decline, as in the NDCs scenario, would already lead to a hot house world. Among the four scenarios that avoid a hot house world, the 2°C orderly transition scenario has the least steep reduction path. Significantly steeper sections of the reduction paths result if either more stringent climate protection is postponed even further into the future (Delayed Transition) or if – which now seems very unlikely – the official 1.5°C target is actually still met (Net Zero 2050 and Divergent Net Zero).

Figure 4 shows that the CO_2 price must increase sharply over time, especially in the two 1.5°C scenarios and (after the initial delay) in the Delayed Transition scenario.[35] While the emission trajectories of the Net Zero 2050 and Divergent Net Zero scenarios differ only slightly, it is evident here that the respective emission reductions are associated with significantly different costs for the economy and society: In direct comparison, the price in the Net Zero 2050 scenario, which corresponds to an Orderly Transition, is significantly lower than in the Divergent Net Zero or Delayed Transition scenarios, both of which correspond to a Disorderly Transition with permanently higher prices. The steepest sections of the (average) CO_2 price development are also found in these two scenarios (Divergent Net Zero and Delayed Transition). Accordingly, this is also where the greatest economic impact of decarbonisation is expected.

35 The mean value of the three Integrated Assessment Models is shown, even though they differ significantly with respect to the CO_2 price (see Section 2.4). However, the assertions made here are covered by all model variants.

Greenhouse gas emissions

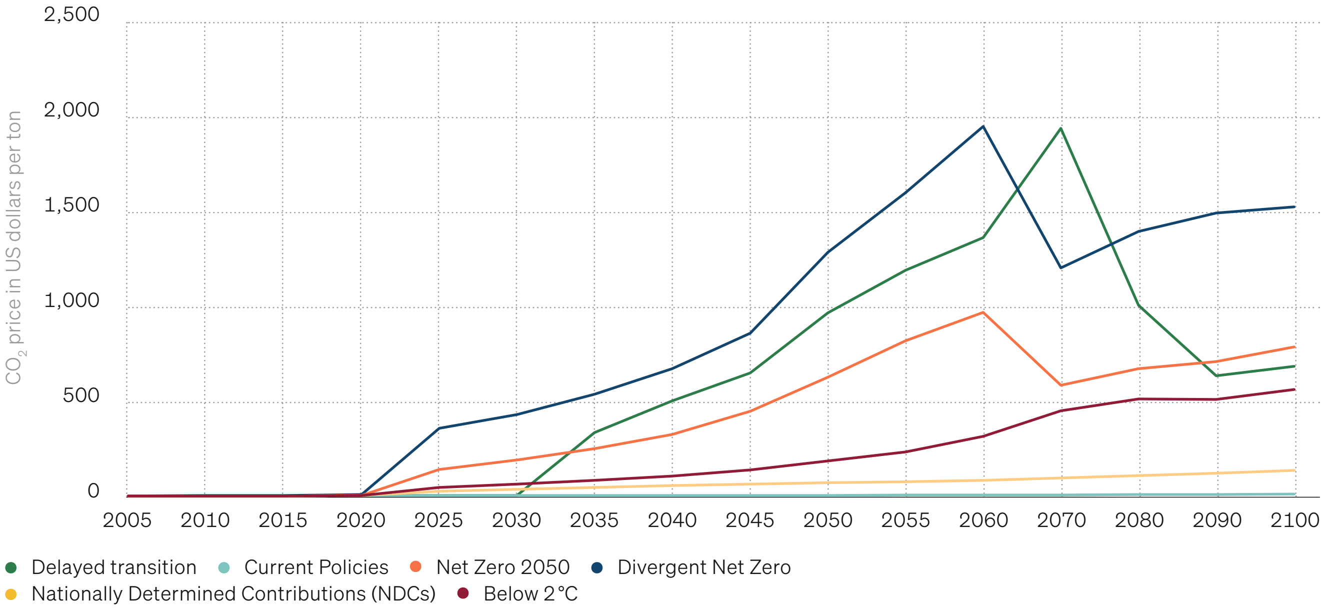
Figure 3 · Evolution of global emissions of Kyoto Protocol greenhouse gases (CO_2, CH_4, N_20 and fluorinated greenhouse gases) in the six NGFS scenarios through 2100 (until 2060 5-year steps, thereafter 10-year steps, unit: Millions of metric tons of CO_2 equivalents per year (determined using the respective global warming potential over 100 years, GWP100), model: NiGEM NGFS v1.22, IAM: Mean value of the three Integrated Assessment Models, cf Section 2.4)



Source: Own illustration based on data from the NGFS Phase 3 Scenario Explorer

CO_2 price

Figure 4 · Evolution of the CO_2 price in the six NGFS scenarios until 2100 (until 2060 5-year steps, thereafter 10-year steps, unit: US dollars in 2010 prices per ton of CO_2 equivalent (average price within scenario, if applicable), model: NiGEM NGFS v1.22, IAM: Mean of the three Integrated Assessment Models (IAMs) – for the IAMs and specifically the significant differences in CO_2 price between the IAMs, see Section 2.4)



Source: Own illustration based on data from the NGFS Phase 3 Scenario Explorer

Overall, the scenarios result in **higher transition risks** if[36]

- the **level of ambition** of climate protection is high (a significant limitation of the temperature increase implies a lower residual budget of emissions and consequently more drastic measures);
- Measures are taken **late** (less time available requires more drastic measures – no cost-benefit optimal transition regarding the time dimension);[37]
- Measures are **unsystematic** (sector-specific targets instead of a uniform emission price make emission reductions more expensive overall – no cost-benefit-optimal transition with respect to the sectoral dimension)[38] and
- **few CDR processes** are available (negative emissions, e. g. from afforestation and CCS[39] could offset other residual emissions that are difficult to avoid – no optimal cost-benefit transition with regard to the technological dimension).

An examination of the transition risks associated with climate change mitigation based on the NGFS scenarios should therefore include either the Delayed Transition or the Divergent Net Zero scenarios, each of which have some of these transition risk-increasing points and, as a result, the steepest increases in the price of CO_2.

Below, as in Version 1.0/1.1 of this paper, the Delayed Transition scenario is used as an example.

36 Cf. Section 2022b), p. 27.
37 This is true despite the future technological advances and cost reductions expected in the models.
38 This may also apply – in a global view of transition risks – to international differences in ambition levels and measures, but this cannot be assessed with the NGFS scenarios.
39 For carbon capture and storage (CCS), see footnote 34.

2.2.3 NGFS' assessment of risks

The NGFS itself states high-level findings on transition and physical risks:[40]

In the Net Zero 2050 scenario, transition risks have a moderately negative effect on global GDP. Negative effects of higher CO_2 prices and energy costs on demand are partially offset by the positive effects of using government CO_2 revenues for investment and tax cuts. In the disorderly scenarios, the negative effects on GDP are stronger, as the speed of transition combined with investment uncertainty negatively affects consumption and investment.

GDP declines due to physical risks vary with the different temperatures in each scenario. In the first half of the century, the effects are still similar, but after that they begin to differ strongly. In 2100, the negative effects in the Current Policies scenario are by far the highest (GDP up to 20 % lower than in the baseline case), as decarbonisation and temperature targets are missed.

In all scenarios and on all time scales, physical risks outweigh transition risks. Strict climate change mitigation policies in line with the Net Zero 2050 scenario pay off as early as 2050 and strongly reduce risks toward the end of the century. In any case, however, there is a need to invest in adaptation measures.

2.3 Reference scenario

The assessment of climate-related risks requires the definition of a benchmark or reference scenario, i.e. for all variables considered, a specification must be defined against which the impacts of climate change scenarios can be measured and assessed.

For the assessment of **physical** risks, the level of the recent past or a pre-industrial average is usually used as a reference (e.g. global temperatures, precipitation, sea level). Thus, no reference developments are fictitiously extrapolated; instead, historically observed values are simply used as a benchmark for the future values projected in the scenarios. With respect to physical risks, this approach makes sense because the natural variables under consideration usually only change on long-term time scales.[41] Without ongoing climate change, no significant changes would have been expected in the span of a human lifetime.

In terms of **economic** (and sociodemographic) variables, the situation is different in some cases. Even in a fictitious world without climate change, there would be developments in this area that would lead to significant changes over the course of decades. Therefore, the (non-trivial) question of a suitable benchmark arises here.

2.3.1 Approaches for an appropriate comparison

Simply using current values would have the disadvantage that negative effects caused by climate change or decarbonisation could easily be masked by positive effects of long-term trends that are independent of them. The fundamental growth trends in economic output (GDP), wages and capital stock are the main factors to be considered here. This also includes rising equity valuations in the long run. In contrast, other important variables, such as inflation, interest rates and spreads, tend to have a stationary character. Overall, however, this leads to the conclusion that an appropriate benchmark for measuring and assessing climate risks should in any case take long-term trends into account.

However, this does not tell us what should actually be used as a reference scenario. A sensible choice also depends on which question is to be answered by the analysis in the first place. In order to assess the costs and benefits of taking or not taking climate protection measures at the political level, it is useful to compare the different climate change scenarios. This shows which scenarios are better or worse than others, and by how much, and should be aimed for or avoided accordingly.

However, this is not the issue insurance companies are facing in the context of their ORSAs. For them, the question is more about what climate-related risks they might face in a given scenario. This primarily involves additional risks that are not yet reflected in the current valuations of investments and insurance contracts, although these already take many (other) risks into account. Thus, the problem of the reference scenario can essentially be traced back to the question of which possible climate-related future developments have already priced in today and which have not.

40 Cf. NGFS (2022b), p. 21.
41 Temporary or cyclical fluctuations are not considered here, the focus is on longer-term trends.

If, for example, one were to assume that both one's own underwriting valuation and the valuation of investments in the market were based on the assumption that there would be no additional climate protection measures whatsoever, though there would be strong growth in climate-related physical risks in the future, with corresponding economic damage and losses, and that these would already be fully priced into the valuations in particular, then the **Current Policies scenario** would lend itself as a reference scenario.

If, on the other hand, one tends to assume that, by and large, neither the physical risks looming in the next few decades nor the transition risks of earlier or later decarbonisation have been priced in so far, then the **Baseline scenario** of the NGFS lends itself as a reference scenario. This is a **counterfactual** scenario in which there is no (further) climate change. Specifically, this means that no action will be taken to combat climate change beyond what is currently in place, but there will still be no further climate change nonetheless. Accordingly, there are no transition or physical risks in this scenario. Thus, natural variables will remain at their current level, while economic variables will continue to grow undisturbed.

With regard to the economic variables, the Current Policies (and until 2030 also Delayed Transition) scenario on the one hand and the Baseline scenario on the other hardly differ at the outset. Only over time do the economic consequences of the physical risks become larger, and the Current Policies and Baseline scenarios diverge significantly, meaning that a different choice of reference scenario also leads to notable differences in the additional risks arising in the climate change scenarios considered.

In the following presentations, especially in Chapter 4 on the impact on capital investments, the Baseline scenario is used as the reference scenario throughout. However, it should be emphasised once again at this point that this scenario only serves as a fictitious benchmark. The future of the world will presumably move within the space of possible developments spanned by the six NGFS climate scenarios, with significant transitional and physical risks. The counterfactual Baseline scenario is definitely not one of these possible developments.

When **presenting** the results from the models, it is important to note, especially for the economic variables, that either their development in the respective scenario itself or the deviation from their development in the reference scenario can be considered. In publications of the NGFS, the second variant is usually chosen. In the illustrations in this document, however, the actual scenario results are shown and additionally compared to the reference scenario.

2.4 Integrated Assessment Models

There are three different versions of each NGFS scenario. Behind this are different **Integrated Assessment Models (IAMs)**, each designed to model the complex global dynamics between energy, macroeconomics, agriculture, land use, water and climate.[42] Although the three models have many features in common, each has its own characteristics that can affect the results.[43]

2.4.1 Model features

The two models **MESSAGEix-GLOBIOM** and **REMIND-MAgPIE** each consist of several submodels that interact with each other.[44] At least the submodels for energy and macroeconomics are each general equilibrium models that are solved with an intertemporal optimisation algorithm. This means that the representative agents in the model have perfect foresight and take all future developments into account in their decisions.[45] This allows the models to fully anticipate changes that will progress over the century (e.g. rising costs of non-renewable resources, falling costs of solar and wind technologies, rising CO_2 prices) and also to account for endogenous change in consumption, GDP and energy demand in response to climate policies.

In contrast, **GCAM** is a somewhat simpler model whose origins date back more than 40 years.[46] It is a partial equilibrium model and makes exogenous assumptions on the development of GDP and energy demand. The

42 Cf. NGFS (2022a), pp. 6–16 and pp. 19–37.
43 There are clearly divergent results in particular with regard to the development of some important economic variables. See Section 2.4.2 and Section 4.6.2.
44 The (sub) models MESSAGEix and GLOBIOM have been developed at the International Institute for Applied Systems Analysis (IIASA) in Laxenburg near Vienna, the (sub) models REMIND and MagPIE at the Potsdam Institute for Climate Impact Research (PIK) near Berlin.
45 This does not apply to the first years of the Delayed Transition scenario.
46 The GCAM model has been developed at the Joint Global Change Research Institute (JGCRI) of the University of Maryland and the Pacific Northwest National Laboratory in the USA.

representative agents do not form the expectations underlying their decisions in a forward-looking manner, but solely on the basis of past and present experience.

The model structure is as follows:

- **GCAM** (Version 5.3) is a dynamic recursive model that represents the combined development of energy, water, agriculture, land use, economic and climate systems. Assumptions on future GDP development are part of the model input. Decisions are either cost-driven (as in the energy system) or profit-driven (as in the land system).

- **MESSAGEix-GLOBIOM** (version 1.1-M-R12) consists of five submodels: the energy model MESSAGE, the land use model GLOBIOM, the air pollution and greenhouse gas model GAINS, the aggregate macroeconomic model MACRO, and the simple climate model MAGICC. The submodels are solved by intertemporal welfare maximisation.

- **REMIND-MAgPIE** (Version 3.0–4.4) consists of four submodels. REMIND is a general equilibrium model for energy and the economy that combines a macroeconomic growth model with a bottom-up engineering model of the energy system. MagPie models land use, which in turn is based on the dynamic global vegetation model LPJmL. The MAGICC climate model is also used here. The REMIND submodel on energy and the economy is solved by intertemporal welfare maximisation, and the MagPie submodel on land use is solved by recursive cost minimisation.

To **mitigate climate change**, the models include several options:

- Emissions abatement options in the area of energy generation and conversion designated as **(energy) supply** in the model include solar and wind power, nuclear power, carbon capture and storage (CCS), fuel cells and hydrogen (14–15 modeled options, depending on the IAM).

- On the **(energy) demand side**, i.e. especially in the industrial, building and transport sectors, improvements in energy efficiency, electrification and CCS can contribute to emission reductions (17–20 modeled options).

- There are also emission reduction opportunities in the **agriculture/forestry/land use (AFOLU)** sector such as reduced deforestation, forest management, and methane reduction in rice fields (7–8 modeled options).

- Finally, all models include two **CDR technologies** in the form of bioenergy with carbon capture and storage (BECCS) and (re)forestation.

Using these options, the models calculate a cost-effective transition path within the given conditions (scientific, technological, economic, political…). However, **economic damage and losses** caused by climate change are only partially taken into account:

- **Chronic physical risks** are represented by a temperature-dependent productivity loss, which leads to output losses compared to the (counterfactual) reference case.[47] Damage caused by chronic risks such as sea-level rise and indirect effects caused by possible social developments such as conflicts and migration are not taken into account.

- **Acute physical risks** are considered for the first time in the current third vintage NGFS model in a variant[48] of the REMIND-MAgPIE model through an output loss.[49] In addition, the NiGEM model (see Section 2.5), which is downstream of the IAMs as a further modeling stage, also considers output losses due to acute physical risks such as hurricanes or river flooding for the first time.[50]

47 While corresponding damage functions have traditionally been based on bottom-up estimates of damage in particularly affected sectors such as agriculture or in relation to human health, more recent approaches have focused on top-down econometric estimates of the relationship between aggregate output and changes in regional temperatures. For the specific estimate, see NGFS (2022a), pp. 32–34 and, as a basis, Kalkuhl and Wenz (2020).

48 The data presented are generally based on the „IntegratedPhysicalDamages (median)" variant of the REMIND-MAgPIE model or, in the case of data from NiGEM based on REMIND-MAgPIE, on the „combined" variable variant, in each case taking into account effects of acute physical risks in addition to effects of chronic physical risks. Figures 8 and 9 on energy mix and energy investment (excluding effects of acute physical risks) constitute exceptions.

49 See NGFS (2022a), pp. 34–36, and Kalkuhl and Wenz (2020) and Schultes et al. (2021).

50 The basis is the EM-DAT database and the CLIMADA model at the level of individual countries.

2.4.2 Model uncertainty and model selection

All three models are well-established, complex models that have been used in a variety of scientific studies of climate change, and each has different advantages and disadvantages. For the purposes of climate change analyses in the ORSA, each of the three models is likely to be suitable in principle. In some respects – but by no means in all – the results are similar.

Figures 5, 6 through 7 show that CO_2 prices differ greatly across the three models. At first glance, the completely different development that the CO_2 price takes in the Delayed Transition, Divergent Net Zero and Net Zero 2050 scenarios in the last decades of the projection period starting in 2060/70 is striking. In the MESSAGEix-GLOBIOM model, it falls very sharply after a successfully completed transition, while in the GCAM and REMIND-MAgPIE models, prices remain broadly at their previously achieved levels or rise even further. The developments for the individual scenarios also differ between these two models.

More importantly, the respective CO_2 prices range in very different magnitudes over the entire period (note the divergent scales of the figures). Moreover, in the MESSAGEix-GLOBIOM model the Delayed Transition scenario is more severe relative to the other scenarios. The CO_2 price there in the years from 2035 to 2070 is initially higher by more than a factor of 9 and then consistently higher by factors of between 4 and 7 than in accordance with the GCAM model. Compared to the REMIND-MAgPIE model, the MESSAGEix-GLOBIOM price is higher by factors of between 5 and 7 most of the time, and finally almost by a factor of 11 in 2070.

This shows the extent to which the assumptions made in each model (including those regarding technological availability and political support for various climate change mitigation options) affect the results. For times very far in the future, almost any result seems possible. **In addition to the obvious arguments of data availability and decision relevance, this finding also argues for focusing on the near future in the analysis of transition risks.**

However, model uncertainty not only increases over time, but is enormous from the very beginning of the transition. Since the CO_2 price is the key variable affecting the evolution of the other economic and financial variables in the model, there are **significantly higher or lower transition risks depending on the choice of the Integrated Assessment Model. Moreover, the differences between the three models in this regard have widened significantly with the third vintage of NGFS scenarios compared to the previous generation.** In Section 4.6.2 , this is illustrated in Figure 16 using the example of equity.

The model uncertainty described must be taken into account in any case when interpreting the results. However, this does not change the fact that a decision must be made regarding the models in order to use the scenarios. The following – exemplary – explanations should also not be overloaded by way of the parallel presentation of the results of three models. There are no clear technical indications that one model per se would be more plausible than the others. The two general equilibrium models with a forward-looking information structure (REMIND-MAgPIE and MESSAGEix-GLOBIOM) may seem particularly appropriate. On the other hand, the results of the GCAM and REMIND-MAgPIE models are partly closer together, while MESSAGEix-GLOBIOM shows significantly different effects. For example, the decline in equity prices in the Delayed Transition scenario according to the GCAM and REMIND-MAgPIE models is only a fraction of the corresponding decline according to the MESSAGEix- GLOBIOM model – but this does not say which is "more correct".

In this situation, the GDV project group has opted for an agnostic approach in which **all three models are considered equally possible** and their results are considered to be of equal importance. In Chapter 4 on the impact on investments, we therefore present the **arithmetic mean of the results of the three models** in each case. Although this downstream averaging could in principle affect the coherence and interpretability of the results, this does not seem to be a major problem for the risks considered in Section 4.6. In any case, one advantage is the greater robustness of the results compared to the choice of a single model.

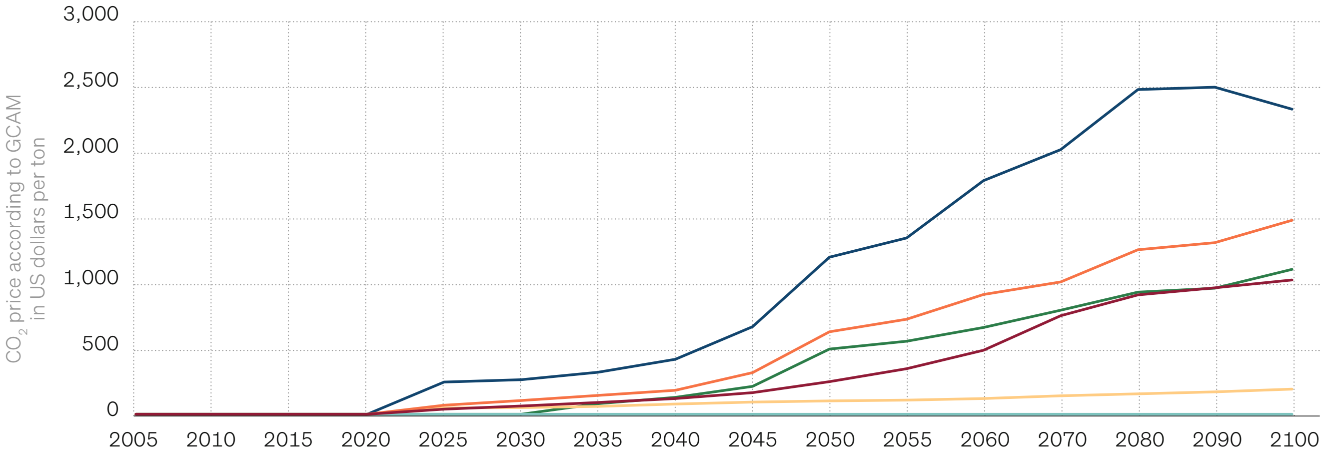
This decision, too, is of course not a determination in the sense that this is the only possible or sensible choice.[51]

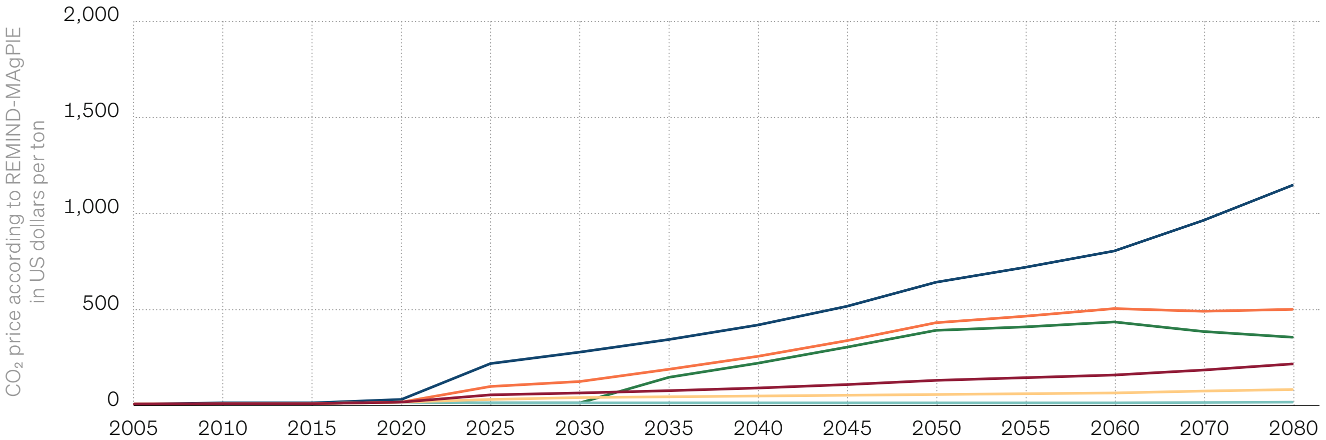
Data for all three IAMs is available via the NGFS Scenario Explorer.

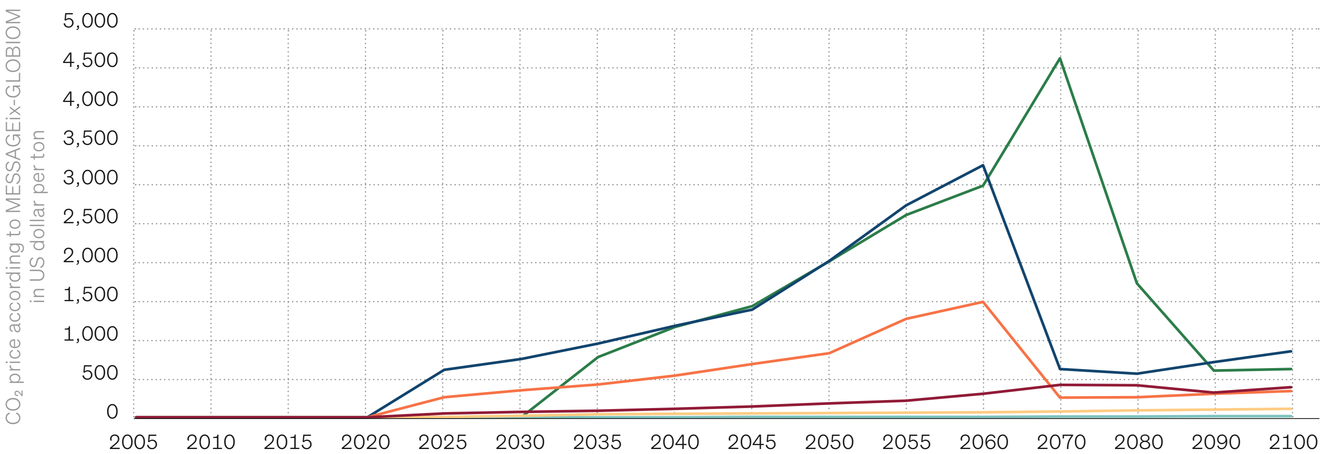
51 In Versions 1.0 and 1.1 of this paper, only results generated with MESSAGEix-GLOBIOM were presented. In the second vintage of NGFS scenarios used at that time, the differences in results between the three Integrated Assessment Models were still much smaller than in the current third vintage. At that time, the analogy with the Bundesbank's approach according to Schober et al. (2021) also played a role. However, the model choice in this approach may also not have had fundamental reasons but may rather have been situational.

Different CO_2 prices in the IAMs

Figures 5, 6 and 7 · Evolution of the CO_2 price in the six NGFS scenarios until 2100 (note: different scales, also 5-year increments until 2060, 10-year increments thereafter, unit: US dollars in 2010 prices per ton of CO_2 equivalent (mean price within scenario, if applicable), model: NiGEM NGFS v1.22, IAM: GCAM, REMIND-MagPIE (with physical damage) and MESSAGEix-GLOBIOM, respectively)







● Delayed transition ● Current Policies ● Net Zero 2050 ● Divergent Net Zero
● Nationally Determined Contributions (NDCs) ● Below 2 °C

Source Figures 5, 6 and 7: Own illustrations based on data from the NGFS Phase 3 Scenario Explorer

2.5 NiGEM model

In each of the various Integrated Assessment Models (IAMs) used to generate the NGFS scenarios, only a few, basic economic variables are modeled. To also provide answers to broader economic questions of climate change and transition, the NGFS then combines the primary scenario output of the IAMs with the NiGEM model.[52] Only this model provides as output data on the financial variables considered in Section 4.6, such as equity or interest rates. **Thereby, the data cover the period up to 2050. No corresponding data are available for later points in time.**

NiGEM is a global macroeconomic model that, independent of climate change issues, is used by many institutions in the public and private sectors for quarterly economic forecasts, scenario calculations and stress testing.[53] It consists of country models of major economies linked by international trade and integrated capital markets, with parameterisations estimated econometrically. The individual country models broadly exhibit a neo-Keynesian structure with many features of dynamic stochastic general equilibrium (DSGE) models. With sticky prices, rational or model-consistent expectations, endogenous monetary policy based on a Taylor rule or other standard specifications, and long-term fiscal budget constraint, they are consistent with standard macroeconomic assumptions. In each case, the country models are based on the national income identity and include the determinants of domestic demand, trade volume, prices, the current account balance and asset holdings, as well as a clearly specified supply side (labor, capital, energy) consistent with the long-term growth rate of the respective economy. In addition to different fiscal, monetary and exchange rate regimes, different types of expectation formation by economic agents, among others, can be specified in the model.

For purposes of the NGFS scenarios, NiGEM builds primarily on the economic output (GDP), population, energy, and CO_2 price data provided by the IAMs at the country or country group level. Temperature trends also affect economic variables in NiGEM over time via productivity.

Both the IAMs and NiGEM produce endogenous GDP estimates.[54] As a starting point, NiGEM estimates of GDP use the long-term GDP path in the Baseline scenario of the respective IAM, which is replicated by NiGEM, as are the associated population and energy consumption paths. After this adjustment of the NiGEM model to the results specified by the IAM has been made using the Baseline scenario, the calculations for the six climate scenarios are performed. To this end, the differences in the primary energy consumption by energy source and in the CO_2 price between the scenario under consideration and the Baseline scenario, as provided by the respective IAM, are modeled as corresponding shocks in NiGEM.

2.6 Excursus: Scenarios and the concept of risk

The individual climate change scenarios of the NGFS each describe a possible development path of the physical and economic state of the world. Taken together, the different scenarios are intended to show the spectrum of "possible futures." As individual development paths among an infinite number of possible paths, these scenarios are not associated with any probability of occurrence, but are to be understood only as examples. Only a qualitative assessment can be made as to whether the respective scenario is within a range that appears to be more or less realistic with regard to the assumed climate protection measures.

The full range of possibilities includes very different trajectories in terms of intensity of climate protection and climate change, which are accompanied by different levels of transition and physical risk. These different risks are mostly emphasised in the NGFS presentation of results. However, since the data provided for the scenarios usually refer to only one development path, it is necessary to clarify what is meant by the term "risk" in this context at all.

In financial and actuarial mathematics, uncertain future events whose uncertainty can be quantified are referred to as risks. Loss or damage that is certain to occur in the future does not represent a risk (anymore).

Mathematically, the value of a capital investment or an insurance contract can be described as a random variable that can be modeled using one or more risk factors. These risk factors, such as interest rates, spread, various natural hazards, mortality or lapse rates, are themselves random variables. For a given modeling and for given distribution assumptions of the risk factors, the

52 The NiGEM model was developed at the National Institute of Economic and Social Research (NIESR) in London.

53 See NGFS (2022a), pp. 37–50 and NIESR (2022).

54 The GCAM GDP estimate here is based on the endogenous response of the CO_2 price.

risk of the investment or insurance contract in question can be determined. It is composed of the unavoidable random risk and the model risk.

Climate change and mitigation measures do not fundamentally change this. In the mathematical description, no new risks are generally added either. What changes, however, is the (true) distribution of the random variables in question and their risk factors. Accordingly, the distributional assumptions with which one tries to describe these risk factors as well as possible also change. In this sense, physical risks of climate change consist of changes (in an adverse way) of distributions for risk factors that represent natural hazards. Accordingly, the transition risks of decarbonisation consist in adverse changes of distributions for risk factors of the capital market. As a result, both expected values and dispersions for the realisations of the relevant random variables (risk factors as well as specific investments and insurance contracts) may change.

However, the scenarios do not provide changing distribution assumptions, whole bundles of possible paths, or assertions about quantiles,[55] but usually only the evolution of some risk factors along a single path – i.e. only one realisation for each point in time. Thus, when the NGFS talks about the physical and transition risks that show up in a scenario, most of the time it is likely to mean simply the deviation of the realisations of the random variables in that scenario (the presented path) from their expected values in a comparative case. Specifically: In the scenario, capital investments or insured losses perform worse than expected in the (counterfactual) reference scenario. The deviation between these time series of simple numbers (not random variables) is referred to in this context as the "risk", which may be larger in one of the scenarios considered and smaller in another. In fact, then, this use of the term is not about how "risky" the situation would be, but rather how "bad" the situation would be if a particular scenario were to occur.

55 The temperature development is an exception. In addition to the median shown in Figure 2 , other quantiles would also be available in this case.

3. Methodology

3.1 Basic considerations

While today's assessments are mostly based on historical data, for climate change scenarios the assessment must be based on forward-looking data.

If we consider different climate scenarios (e.g. the NGFS scenarios, see Section 2.1, Figure 2 on temperature development) at different times in the future, they have a particular effect on

- balance sheets (especially own funds),
- solvency capital requirements (SCR) and
- Overall solvency needs (OSN).

In addition, profitability ratios (such as those in the income statement) are also touched upon, the consideration of which may also be helpful.

Note that the climate scenarios may already change the valuation as of the current date (2021) based on the scenario – depending on the expectation for the future (expected scenario). This is particularly the case for long-term biometric products, when the current calculation bases rather refer to the reference scenario.

Different possible approaches on how to methodically assess climate scenarios can be broadly divided into:

→ revaluation as of the current date (sensitivity analysis);

→ stress test as applied in the form of instantaneous shocks in the SCR calculation. In the context of climate scenarios, these are more like "time travel," i.e. shifting the portfolio (both assets and liabilities) into the future while maintaining the remaining maturities;

→ projection, roughly as in the BaFin Prognoserechnung (certain forecasts specified by the German supervisor) for life insurance companies. This projection can be static or, in a further evolution, include management rules that respond to climate scenarios.

Thus, these "time travel stress tests" do not normally assume any measures that would mitigate future risks from climate change. Such an approach is thus particularly suitable for assessing a society's fundamental vulnerability to climate change. It should thus also represent a suitable approach for assessing climate change scenarios in the ORSA. However, this approach does not provide a realistic indication of what the actual situation of the company would be if such a scenario were to materialise, as it can be assumed that appropriate risk management measures would be taken over time (e.g. adjustment of premiums or reinsurance protection).

Projections require a large number of assumptions to be made, in particular which risk-reducing measures are assumed for the future. This may complicate the assessment of the fundamental affectedness. However, intermediate solutions – especially as a complementary analysis – are also conceivable, e.g. if in a "time travel stress test" the taking of measures and other developments are also assumed at the same time. However, such adjustments should always be presented transparently to ensure the correct interpretation of the results.

Table 2 shows the specific differences between these approaches using 2021, 2030, and 2050 as examples.

Scenario_1 and **Scenario_2** here could represent, for example, the narratives of the Current Policies and the Delayed Transition scenarios, respectively. Whether and how much the stresses differ between the scenarios at a given time depends on the specific parameterisation.

It is important to note that a valuation as of a selected year always includes an expectation of the future, as the valuation bases also reflect the future path of the economy in the scenario under consideration due to the assumption of forward-looking expectations of market participants. This also applies to underwriting. In this sense, a more long-term view is then also given beyond the selected year.

Methodological approaches to the evaluation of the scenarios

Table 2 · Overview of the different approaches sensitivity analysis, stress test and projection

STOCK	PER	FUTURE	BALANCE SHEET	SCR	OSN	
2021	2021	Reference	Available	Available	Available	Sensitivity analysis
	2021	Szenario_1	New	New	New	
	2021	Szenario_2	New	New	New	
2021	2030/50	Reference	Available	Available	Available	„Time travel" stress test
	2030/50	Szenario_1	New	New	New	
	2030/50	Szenario_2	New	New	New	
2030	2030	Reference	Life insurance: e.g. BaFin-Prognoserechnung (forecast calculation)			Projection
	2030	Szenario_1	New	New	New	
	2030	Szeanrio_2	New	New	New	
2050	2050	Reference	New	New	New	Projection
	2050	Szenario_1	New	New	New	
		Szenario_2	New	New	New	

Source: Own illustration

Multi-period, projections and business development

Table 2 already indicates optional step-by-step development of the methodology. In a first quantitative step, the first two approaches can be sensitivity analysis and stress testing. The existing balance sheet without projection is used as a reference or starting value for the calculations. This is in line with supervisory requirements for analyses with a short-term time horizon. In addition, use of the current balance sheet as a simplification is also permissible with a long-term time horizon (see Chapter 1).

One possibility for further development would be (partial) projection of the balance sheet, if and to the extent it is deemed useful and necessary by companies, i.e. depending on the company-specific risk profile and the previous findings on climate scenarios. For further development, existing projections (e.g. BaFin Prognoserechnung (forecast calculation), medium-term planning) for the next 5–15 years could be used as a reference scenario.

These could then be adjusted or extended to form a (static) projection for the various climate scenarios. Depending on the result of this static projection, an addition of different business strategy measures would take place, possibly even dynamic management rules. In order to keep the complexity of the projection within manageable limits, it might be appropriate to restrict it to certain aspects, such as claims developments for different natural hazards or regions, looking at the asset side, in isolation from underwriting risks, to examine effects on the capital investment portfolio, or new business.

Projecting the full balance sheet would amount to a complex, challenging multi-period approach. This requires a large number of additional assumptions for points in time far in the future, including the investment universe.

In general, balance sheet projections using a multi-period approach are likely to be associated with some model error, which complicates the interpretation of the results. However, identifying vulnerabilities and deriving meaningful measures is also already possible with stress tests using "ceteris paribus analyses" based on the current balance sheet.

Depending on the company, strategic planning will tend to provide for a continuous ongoing concern or a dynamic change in the portfolio structure. Accordingly, the need to account for portfolio changes will vary from company to company. Irrespective of this, however, it should be noted that in the course of decarbonization or transformation, the economy can change very significantly – depending on the scenario – even in the course of a decade as a whole and especially for individual sectors. Historical events such as the spread of mobile communications to the mass market within less than five years illustrate this. Accordingly, depending on the scenario, customers may have to be acquired anew (cf. changed mobility, energy transition, energy-related building refurbishment, etc.). These effects may be material and must then be accounted for accordingly in the methodology.

As mentioned above, dealing with multi-period scenarios is an important methodological issue. Basically, this results in two dimensions of decision making: (1) the consideration of reactive management actions/rules (static vs. dynamic balance sheets), and (2) the application of an instantaneous shock at one or more selected points in time versus continuous consideration over a specified time interval. In terms of the evolution of methodological competence, the assumption of an instantaneous shock and a static balance sheet ("stress test" or "time travel") currently appears sufficient and appropriate for many companies in view of the implementation effort and the informative value and comparability. For this purpose, the scenarios for one or more selected points in time can be mapped as an instantaneous shock to the current balance sheet (or the balance sheet as of the reference date). This (quantitative) approach can be combined, for example, in a complementary manner with a separate (qualitative) forward-looking assessment of reactive management measures. In the future, extensions could be considered to include more dynamic approaches if they prove useful or necessary on a company-specific basis.

Time horizon

The time horizon of climate change risks is much longer compared to conventional stress tests or scenario analyses. The selection of the period/point of observation should take into account both the scenario narrative and strategic corporate planning. With regard to the first aspect, this can mean, for example, that scenarios with a focus on transition risks will tend to be considered in the short to medium term or at the assumed time of the strongest economic impact, whereas a more long-term view can be assumed for scenarios with a focus on physical risks. This may mean, for example, taking a "conservative" approach to physical risks in calibrating the scenarios by anticipating them in time.[56] At the same time, especially in the case of a dynamic approach and/or the consideration of management measures, the strategic relevance of the scenario horizon should be ensured in order to achieve plausible results.

[56] In the short to medium term, physical risks are similar in all scenarios. The measures adopted in the transition scenarios only reduce these risks in the long run. The timing for a comparison between a transition and a physical scenario should be chosen depending on the assumed narrative.

Quantification of the scenarios

For a quantitative assessment of climate change risks, scenarios need to be quantified with appropriate granularity. For this purpose, it is necessary to assess the impact on the main physical, macroeconomic and financial variables. The challenge here is, in particular, to translate high-level scenarios into detailed information on the most important economic variables. For this purpose, the variables of the NGFS/NiGEM scenarios described below can be used as modeling modules. The NGFS scenarios provide information on transition pathways as well as physical climate variables and macroeconomic indicators for key economic regions. The time series are available through the NGFS Phase 3 Scenario Explorer. As a target picture, both appropriate geographic and sectoral granularity would be desirable to adequately reflect the company-specific risk profile. Sectoral modeling in particular is significant for the analysis of transition risks, but has so far been available only to a very limited degree.

Deriving stresses

From the definition of the reference scenario, there are basically two possible approaches for deriving and implementing stresses. First, the applicable stress can be specified as the difference between the climate change scenarios and the reference scenario at the selected time. Second, a stress can be specified and implemented for all scenarios, including the reference scenario, as the difference between the selected point in time and the actual level (or balance sheet date), and then the deviation of the results between the climate scenarios and the reference scenario can be considered. The choice of approach depends on the specific company implementation. The first approach implicitly assumes that the reference scenario is priced into the current balance sheet, whereas the second approach has technical drawbacks in terms of implementation, since the changes in risk factors due to the general growth trend can be very high here depending on the choice of point in time (wide extrapolation).

Valuation ratios

To assess the impact of a scenario, a number of indicators can be used for which the stress scenarios are calculated. The aim of these indicators should be to provide a comprehensive picture of the impact of the selected scenarios on the risk and solvency position. These include, as mentioned above, balance sheets (especially own funds), solvency capital requirements (SCR), overall solvency needs (OSN) and profitability ratios. As explained above, additional analyses, such as partial projections or dynamic approaches, can also consider assets and liabilities in isolation, e.g. to map the impact of a scenario on the market value of the investment portfolio over time.

Interpretability and limitations
The interpretation of the results of quantitative analyses and the derivation of possible recommendations for action should take into account the high degree of uncertainty associated with climate change and the limitations of projections, especially when combining different models such as probabilistic climate and socio-economic models.

Sections 3.2 to 3.4 below add additional considerations for capital investment, property/casualty and personal insurance.

3.2 Special aspects of capital investment

For the assessment of the financial impact of climate change risks on capital investment, the above recommendations apply, particularly the consideration of the reference scenario (see Section 2.3).

With regard to transition risks, it seems important to consider the effects also on a sectoral level, since emitters or sectors with high CO_2 emissions will in principle be more affected (directly or indirectly) by an increase in the CO_2 price. Current approaches to stress testing have tended to deal with sectoral effects at the qualitative level or using heuristic approaches. This is due to the lack of availability of granular sectoral information in the common scenarios and models. Section 4.4 presents an approach, based in part on a similar analysis by the Deutsche Bundesbank, that could be used to derive sector-specific asset price developments from the macroeconomic NGFS/NiGEM scenarios.

However, in the absence of sectoral availability of the risk factors relevant for capital investment, the mapping of macroeconomic effects by means of stress factors for asset classes can be interpreted as a kind of baseline for an average portfolio allocation (i.e. sectoral allocation corresponds to sectoral distribution of gross value added in invested regions). Based on this, scaling factors for different portfolio allocations can be defined and applied, for example on the basis of expert estimates. A corresponding approach based on either macroeconomic or sectoral development is outlined in Section 4.5.

The background to this approach is that companies can also differ within an industry. Technology, individual climate strategies, financial resources, and capacities can significantly affect exposure to transition risks. Such issuer-specific factors can, for example, be taken into account through company-related sustainability data (e.g. ratings, etc.). At present, however, such an approach should clearly be seen as an add-on to the sectoral approaches, as there is no standardised method for this to date and sustainability data are largely commercially licensed and therefore available to insurance companies and asset managers to varying degrees.

3.3 Special aspects of personal insurance

The aim of considering climate change scenarios in the ORSA is to identify material risks for the company. The development of the insurance portfolio may play a role, particularly with regard to the long-term nature of obligations in life insurance. The different approaches mentioned above therefore result in different requirements for the underlying portfolio development:

- stress tests ("time travel"): Stress tests on the existing portfolio can be used to identify groups of portfolios that are exposed to increased risks.
- projection for a period of up to approx. 10 years: For a climate change scenario, the portfolio development from existing scenarios from the company's own medium-term planning or forecasting can be used for simplification.
- projections over a long-term period (multi-period approach): For a longer projection horizon, the development of new business could be projected using appropriate drivers, if and to the extent this is deemed useful and necessary by the companies. In particular, this would be consistent with a static approach to management measures/rules regarding new business management. Reactive management measures/rules could deviate from this and also take into account the product mix with regard to individual product groups (e.g. "green" products).

For the life insurance sector, a correlation with, for example, gross domestic product can be used as a driver for new business or individual portfolio groups. The volume of new business (by portfolio group, if applicable) can then be scaled with the development of the gross domestic product of the NGFS scenario and thus extrapolated year by year.

3.4 Special aspects of property/casualty insurance

For future periods, assumptions must be made regarding the development of the exposure.

Typically, at least for shorter periods, a valid approach is likely to be to update the exposure, e.g. with respect to natural hazards, on the basis of developments in recent years. For long-term periods, this extrapolation is likely to be less sustainable. For example, a "freeze" of an exposure in the near future might then be appropriate. Thus, only effects of changed external influences, such as changed extreme weather events, become visible for the more distant periods. Under certain circumstances, however, more significant shifts in exposure could already be expected than the simple extrapolation suggests. These would then have to be adjusted accordingly.

Three examples are given as suggestions:

- It may be that, as part of a corporate sustainability strategy, certain risks are to be underwritten more heavily and others less heavily. There could also be changes in the scope of coverage.
- Severe events lead to greater underwriting of natural hazards. For example, after the flash flood "Bernd" in mid-July 2021, the insurance density increased fundamentally market-wide by 4 percentage points; otherwise 1 to 2 percentage points is customary.
- A new regulatory framework for natural hazards insurance is leading to significant changes in the acquisition rate. Here, for example, reference can be made to the GDV-position paper entitled "Zukunft der Naturgefahrenversicherung" (Future of Natural Hazard Insurance).[57]

3.5 Materiality assessment

The previous sections of this chapter dealt with the methodological approach for assessing risks based on climate scenarios. The following suggests how the materiality assessment of climate change risks might be approached.

In the requirements of the Opinion[58] EIOPA clarifies its expectation that insurers should assess material climate change risks using at least two long-term climate scenarios. To do this, companies must first identify the material risks of climate change to their business.

Step 1: Set scenarios

The following factors make it very difficult to identify and assess climate change risks and, in particular, to assess their materiality:

- that some of the risks will only be realised in the (very) long term;
- that "climate change" is an abstract term whose concrete manifestations must first be considered before any impact on the individual company can be assessed;
- that there is a multitude of conceivable possible developments; and
- that one cannot derive these possible future developments on the basis of past data.

To address these challenges, risk assessment using a scenario approach seems to be a suitable procedure: With a very limited selection of scenarios, the various stakeholders in the company can be given a basis with which to replace the abstract term "climate change" with the most concrete description possible of a future environment. The scenarios are therefore not predictions, but are intended – as possible future development in each case – to help identify and assess the risks arising or changing in the respective scenario.

In order to ensure an appropriate identification and assessment of climate change risks in this way, the selection of the scenarios to be analysed is of particular importance. Since a distinction is typically made between transition and physical risks in the case of climate change risks – which is also advocated or specified by the supervisory authorities – it seems obvious to examine one scenario each with a focus on transition and physical risks. In this light, the two scenarios Delayed Transition and Current Policies were selected for this paper to provide an appropriate basis for the analysis of climate change risks (see Section 2.2).

57 Cf. GDV (2021).
58 Cf. EIOPA (2021a).

Step 2: Determine materiality

Regulators expect companies to determine the materiality of exposure to climate change risks through a combination of qualitative and quantitative analyses.

In an initial analysis, insurance companies can first look at their current and future planned insurance or capital investment portfolio. Here, it is necessary to assess which lines of business or (sub)portfolios can significantly influence the insurance company. This can then be used as a basis for identifying and assessing the new or changing risks that arise in the scenarios in the future. To do this, one can imagine that one is at a certain point in time in the future (e.g. in 2030 for the short term, 2050 for the medium term, 2100 for the long term in terms of EIOPA requirements[59]). Companies should now ask themselves what effects could occur in the insurance or capital investment portfolios for this point in time and roughly classify them in terms of their materiality. Examples of such effects could be increasing claims frequencies in natural hazards insurance due to climate change effects, lower mileage in motor vehicle insurance due to higher energy prices, or entirely new insurance requirements in engineering insurance due to new technologies to counter climate change. The risks that change (significantly) or are new compared to the current date can be identified and the change compared to the current date can be evaluated. This means that, compared to the usual risk identification and assessment as part of the "normal" risk management process, it is primarily the time horizon of observation that changes. In line with the EIOPA Opinion, the analysis of risks should be carried out using a combination of qualitative and quantitative elements. For this purpose, it is advisable to classify risks or risk changes in terms of their economic impact into size categories "low", "medium", "high", or "not material" (e.g. "not material" corresponds to an economic impact < EUR 10 million, "low" corresponds to an economic impact between EUR 10 million and EUR 50 million, etc.). The allocation of the various risks and effects to these size classes can be made on the basis of rough estimates.

The approach proposed here for climate change risk assessment (risk assessment of future situations described via scenarios using the current risk definition) can also be called the "time travel approach" (cf. Section 3.1). It should be emphasised that **materiality depends on the point in time under consideration**. For a number of risks, it can be assumed that they are not (yet) material, but that they will have a material impact at some point in the future.

Step 3: Carry out more detailed quantification or justify immateriality

Based on the above analysis, further quantification can then be performed: Extensive quantification appears to be reasonable and necessary only where a material impact (at the respective point in time) has been identified in the above analysis. The reasons for any waiver of quantification due to a lack of materiality should be documented by the companies. The EIOPA Opinion states that companies concluding that climate change is not a material risk should explain how they came to that conclusion. Possible approaches to quantification are explained in detail in Chapters 4 to 6.

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[59] At variance with EIOPA's requirements, BaFin currently allows shorter time horizons to be considered (see BaFin (2022)).

4. Effects on capital investments

In addition to climate change itself, the decarbonisation necessary to mitigate climate change in particular also affects the future development of the economy. The transformation phase of the global economy can be associated with significant transition risks for capital investments.

After presenting some basics, basic features of the transition are outlined below. In view of the expected differences in the degree of impact, approaches for sector- and portfolio-specific considerations are presented before the development of key financial and macroeconomic risks is examined in detail.

4.1 Qualitative analysis

Companies without previous experience could possibly start as a first step by analysing long-term climate change scenarios qualitatively to the greatest extent possible and making simplifying assumptions for the climate scenarios.

A qualitative risk analysis of the climate scenarios can be performed by scoring the individual scenario impacts on the capital investment. It is important to identify the main risks and consider where these risks could occur. One way to do this is to break down the risks and the impact on individual market risks and asset classes. In the scoring, for example, a distinction can be made between no impact, low impact, medium impact and high impact on the individual market risks and asset classes, in each case over time horizons of varying lengths up to the effects in 80 years' time. An essential step in this process is to define a scoring scheme, i.e. to determine the boundaries of the scoring categories. The limits specify, for example, the amount by which the market value of equity would have to fall in order to be classified as low, medium or high impact.

4.2 Premises of quantitative analysis

For quantitative analyses, the economic projections of the NGFS scenarios provide a good starting point.

4.2.1 Actuality and model focus

The projections are based on more or less current data and economic forecasts. In this regard, the current third vintage NGFS scenarios are based on the status as of the autumn of 2021.[60] Starting from these values, the economic variables are endogenously rolled forward in the model. New external shocks that are neither included in the data observed up to that point nor in the underlying assumptions do not appear in the modeling. Currently, this means that the values of economic variables such as inflation or interest rates projected in the model for 2022 deviate strongly from reality.

In general, models only represent certain aspects of reality in a simplified way anyway. Moreover, since their results depend on the data and assumptions used as inputs, it is inevitable that unforeseen drastic events, such as Russia's full-scale war against Ukraine that broke out in early 2022, may cause such discrepancies.

However, this should not be seen as a serious detriment. The NGFS scenarios explicitly do not represent forecasts that will happen exactly as predicated with a certain degree of probability. Rather, they are projections intended to show the space of possibilities in terms of climate change impacts and mitigation actions. The focus here is on the developments associated with this particular topic over the course of the next decades. It goes without saying that there will also be many other events and developments during this period that cannot be anticipated today. Shocks triggered by this at the micro and macro level will continue to influence the economy, so that real development will always be the result of a large number of different, overlapping influences.

However, the climate change scenarios are intended to abstract from all possible other unpredictable shocks and deliberately focus only on climate change and decarbonisation. The analysis then provides insights specific to this topic that contribute to an understanding of the fundamental relationships and potential developments in this area. This also applies when reality and

60 See also Section 2.1.

the (necessarily partial) model differ significantly in a snapshot, as in 2022.

4.2.2 Systematics of the presentations

The counterfactual NGFS Baseline scenario[61] provides the basis for adjusting the NiGEM model[62] to the results of upstream calculations using the Integrated Assessment Models. In addition, it also serves as a basis of comparison for the other scenarios, in order to distinguish transitory or permanent effects related to climate change from otherwise anticipated "normal" development. Accordingly, NGFS publications usually do not present original results for the economic variables for the individual scenarios at all, but instead present the deviations from the Baseline scenario in each case. With the NGFS Scenario Explorer, it should also be noted that the data provided depending on the data series considered are in part absolute and in part relative deviations.

However, the actual results for the two scenarios considered and for the NGFS Baseline scenario are presented in the following rather than these deviations. This avoids concealing "normally" rising economic developments.

4.3 Main features of the transition

As background, we will first outline key aspects associated with decarbonisation. The real transformation of the economy and its effects on economic performance and capital markets differ significantly in terms of their severity and time frame.

In the models, the transition is essentially driven by the CO_2 price. For purposes of simplification, this stands for the entirety of political measures to combat climate change.

Figure 4 in Section 2.2.2 shows how the CO_2 price evolves in all six NGFS scenarios on average across the three Integrated Assessment Models (IAMs). In all scenarios, the price increases in the long run. In the two 1.5°C scenarios (Net Zero 2050 and Divergent Net Zero), the peak is reached in 2060; in the Delayed Transition scenario, the peak is not reached until 2070. After that, there is a decline in each case. This can be interpreted to mean that by then the decarbonisation of the global economy will be completed to such an extent that low (net) CO_2 production methods will be established across the board and will be so cost-effective that re-carbonisation will no longer occur even if CO_2 prices drop again. Comparing the scenarios, the previous peak of the price is by far the highest in the two disorderly scenarios (Divergent Net Zero and Delayed Transition).

As already explained in Section 2.4.2 on model uncertainty and model selection, the results of the individual IAMs vary significantly.[63] On the one hand, this concerns the development of the CO_2 price after 2060/2070.[64] However, this development, which is far in the future, is generally not relevant to the impact on (current) capital investments. For the analysis of transition risks in the context of the ORSA, it is primarily the extent of the initial economic upheavals that is important. On the other hand, prices in the three IAMs are at significantly different levels across the entire timeline. This is relevant and affects the results. However, since the pattern of the price path to 2060 does not differ significantly between the models, this should not pose a major problem for the interpretation of the results. Therefore, the following discussion focuses on the results averaged across the three IAMs.[65]

61 See Section 2.3.
62 See Section 2.5.

63 Figures 5 to 7 show the corresponding results for the three Integrated Assessment Models there.
64 According to the MESSAGEix-GLOBIOM model, prices would fall very sharply after their peak. According to the GCAM model, on the other hand, prices would mostly continue to rise, falling slightly only in the divergent Net Zero scenario toward the end of the century. According to the REMIND-MAGPIE model, the development from 2060 onward would be mixed, with a decline under the Delayed Transition scenario and a further increase under the Divergent Net Zero scenario.
65 An exception can be found in Section 4.6.2, where the differences between the IAMs are once again illustrated using the example of equity.

4.3.1 Long-term changes in the energy sector

The progress of decarbonisation in the Delayed Transition Scenario from 2030, which can already be seen in the CO_2 prices, is also reflected above all in the energy mix. Figure 8 shows how total primary energy consumption develops in this scenario and how it is divided among individual energy sources.

After rising steadily up to that point, total energy consumption declines significantly between 2030 and 2035 with the onset of the transformation, with the contribution from coal-fired power generation being the main factor to decrease sharply. Thereafter, total consumption continues to decline at a decreasing rate, before slowly starting to rise again from 2050 and reaching new highs from 2080.

At the same time, the energy mix is changing completely. From 2050, solar energy, wind power and biomass together account for more than half of the primary energy mix, and from 2055 each of these three energy sources will have overtaken oil as the most important primary energy source by then.[66]

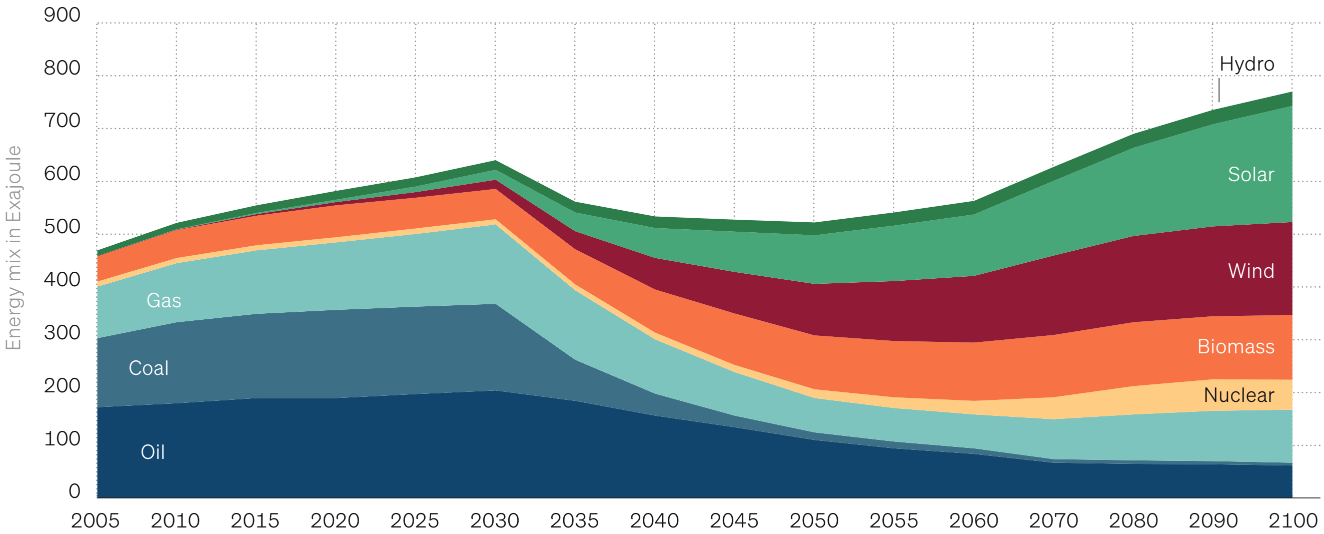
Behind the evolution of the energy mix are huge global investments in energy, both in energy production capacity (i.e. energy supply) and in the energy efficiency of other sectors (i.e. energy demand). Figure 9 shows that in the Delayed Transition scenario, total investment increases rapidly to more than two-and-a-half times by 2045 after the transition begins in 2030. After a slight decline in 2050, investments then rise permanently to ever new highs. During the transformation, investments in energy efficiency as well as investments in all categories of energy generation (except fossil energy sources) increase. The previously virtually non-existent investments in CO_2 capture, transport and storage (CCS)[67] are replacing the disappearing investments in fossil energy. However, investments in wind and solar power are the most significant after energy efficiency. The main particularity among the results of the individual IAMs is that in the

66 In 2070, compared to the start of the transition in 2030, with total consumption again nearly the same, energy production from wind has increased to the 9-fold, from solar to the 7.5-fold, from nuclear to the 4-fold, from biomass to the 2-fold, and from hydro to the 1.5-fold. At the same time, energy production from fossil fuels has fallen massively (natural gas only half, oil only a third, and coal only 4% of 2030 levels). The trajectories in the three IAMs are very similar in this regard, with the only notable difference concerning the development of nuclear power in the second half of the century. While nuclear power generation in the REMIND-MAgPIE model slowly phases out after the transition peaks, it notably increases in the GCAM model. In the MESSAGEix-GLOBIOM model, the importance of nuclear power actually rises sharply. By the end of the century, with generation increased to 14 times today's level, nuclear power becomes one of the four energy sources that also play a significant role after solar power, which leads by a wide margin, and are relatively close to each other (wind power, biomass, nuclear power, and natural gas).

67 For CCS in general, see Footnote 34; specifically, for the breakdown of energy investment data, see Note * to Figure 9.

Energy mix

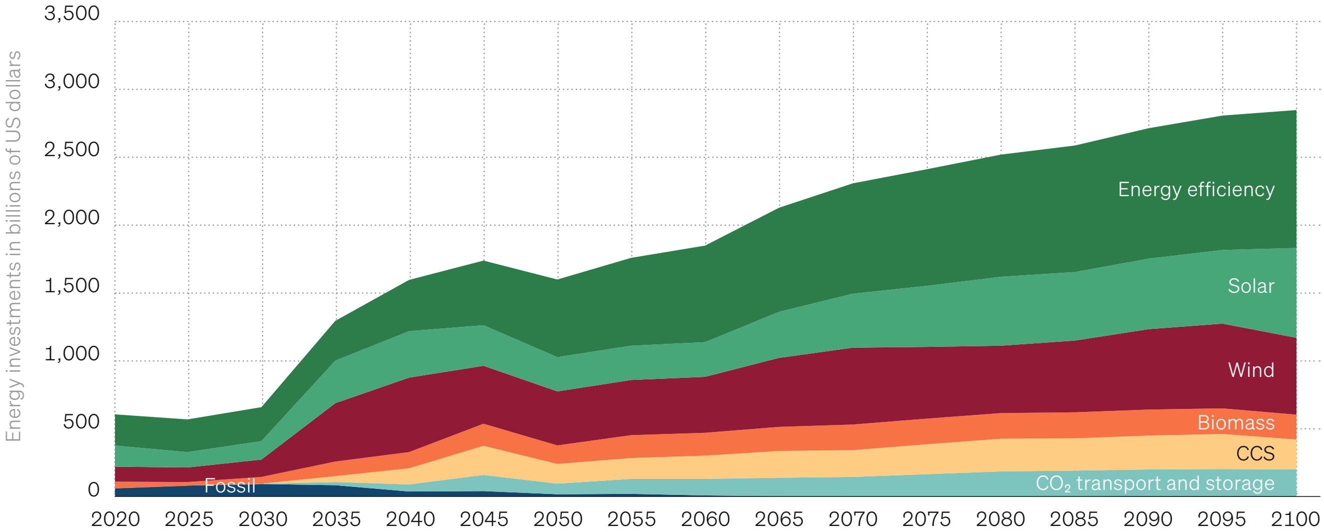
Figure 8 · Global consumption of different primary energy sources in the Delayed Transition scenario until 2100 (until 2060 5-year steps, thereafter 10-year steps, unit: Exajoules per year (1 EJ ≈ 278 TWh), model: NiGEM NGFS v1.22, IAM: Mean of the three Integrated Assessment Models)



Source: Own illustration based on data from the NGFS Phase 3 Scenario Explorer

Energy investments

Figure 9 · Global investments related to power generation and energy efficiency in the Delayed Transition scenario by 2100 (Unit: billions of US dollars in 2010 prices per year, model: NiGEM NGFS v1.22, IAM: For energy efficiency, mean value of REMIND-MAgPIE and MESSAGEix-GLOBIOM models, otherwise mean value of all three Integrated Assessment Models)*



* In the GCAM model, demand-side investments in energy efficiency are not included in energy investments. Why the NGFS distinguishes between "CCS" and "CO_2 transport and storage" in the data here is not comprehensible for us.

Source: Own illustration based on data from the NGFS Phase 3 Scenario Explorer

MESSAGEix-GLOBIOM model, both the increase in total investment from 2030 to 2040 and the subsequent temporary decline are much larger. [68]

The model projections with decades of high investment on the supply and demand side of energy are in line with basic expectations. It is well known that electrification and the hydrogen economy enable sector coupling in the transformation to a carbon-neutral economy. This means that only secondary energy sources (electric power as well as hydrogen and its derivatives, such as ammonia) that are largely produced without CO_2 will allow the decarbonisation of almost all sectors of the national economy.[69] Of particular importance are the sectors of industry (especially the hitherto very CO_2-intensive industries such as steel, cement, basic chemicals and glass, but also all other production sectors), transport and buildings. The prerequisite for sector coupling is a massive expansion of CO_2-neutral electricity generation. In principle, different renewable energies, nuclear power and fossil fuels with CCS/CCU technology can be considered as primary energy sources.[70] However, the natural and political conditions for this vary widely around the world.

68 In addition, solar energy investment is particularly high in the MESSAGEix-GLOBIOM model and wind energy investment is particularly high in the REMIND-MAgPIE model. In contrast, investments in CO_2 capture, transport, and storage are extremely low in the REMIND-MAgPIE model and very high in the GCAM model.

69 The decarbonisation of agriculture in particular remains difficult.

70 When hydrogen is generated from natural gas, CO_2 or solid carbon arises as a waste product (depending on the process technology), which can either be stored in fossil deposits that are no longer used (carbon capture and storage, CCS) or used as a raw material (carbon capture and use, CCU). So far, hydrogen has only been produced in relatively small quantities from natural gas and coal without CCS/CCU taking place, i.e. the resulting CO_2 is released into the atmosphere. Hydrogen production using renewable energies or nuclear energy via electrolysis from water, on the other hand, is basically CO_2-free.

For comprehensive decarbonisation, much more thoroughly CO_2-neutral electricity is needed on the energy supply side, as well as a corresponding infrastructure for the transmission and storage of energy, especially in the form of hydrogen and its derivatives. In addition, on the energy demand side, industry, transport and buildings that have so far used other energy sources and/or are not sufficiently energy-efficient will have to be converted at great expense. This is not only very cost-intensive, but also difficult to implement in a short period of time for technical and capacity reasons (from planning and approval to material procurement and implementation by qualified workers): Some of these are complex large-scale plants, whereas in the case of mass products such as vehicles or building services, capacities and accumulated investment funds are geared to the normally relatively long life cycles with a low renewal rate. The later the transformation begins and the less time is then available, the more difficult and costly the transition becomes. Within the NGFS scenarios, this is reflected in the Delayed Transition scenario.

4.3.2 Expected consequences for economic output

How climate change and decarbonisation will affect economic output over time is not clear per se.

Advancing climate change is leading to temporary productivity losses, e.g. due to heat waves or water shortages, which not only affect agriculture but also power plants and inland waterways, among other things. This reduces the current economic output. In addition, parts of the capital stock of the national economy can be destroyed, for example, by flooding after heavy rainfall events or by rising sea levels.

The transformation of the economy in the course of decarbonisation, which means that some economic activities are no longer worthwhile or even possible in their previous form, also devalues parts of the existing capital stock. The losses to the capital stock that occur as a result of climate change and transformation both reduce potential economic output (and thus consumption opportunities) in the subsequent period.

If the economic activities initially prevented by climate change-related destruction or transformation are subsequently to be continued in a new form or replaced by other economic activities, this will require corresponding investments. These investments in new equipment temporarily increase output until the level of the capital stock returns to a state of equilibrium. The additional contribution of increased investment activity during this period can more than compensate for the loss of economic activity prevented by climate change or transformation, allowing for even temporarily higher economic growth.[71] The "forced" modernisation of the capital stock can also lead to an increase in productivity and higher economic performance of the national economy in the long run. Only if certain activities are eliminated without replacement in the future will there be no such compensation.

In the course of the transition, therefore, a negative effect on economic performance is perhaps to be expected initially, but not necessarily permanently. Even though the real transformation of the economy may take decades, this does not mean that output will have to grow more slowly as a result. A "green boom” is just as possible.[72]

4.3.3 Expected impact on capital markets

The decarbonisation of national economies is initially associated with a very high capital need for the immense investments in the energy, industrial, transport and building sectors, which are accompanied by losses in the value of the existing capital stock.

From the start of the transition, the high capital need is likely to lead initially to rising interest rates, deteriorating financing conditions and increased discount rates for the valuation of future profits. In general, this will weigh on the value of equities and bonds.

[71] The German „Wirtschaftswunder“ of the 1950s with its strong, long-lasting boom is a vivid example of temporarily higher recovery growth after the (war-related) loss of part of the capital stock.

[72] In terms of welfare, both the damage from climate change and the consumption constraints from lost production and redirection of resources in favour of investment play a role.

In an overall economic view, taking into account the damages and losses avoided, the investments will later pay off. In an individual view, on the other hand, specific economic activities may become either cheaper or more expensive than before. Particularly in the case of a late and unexpected start of the economic transformation, as in the Delayed Transition scenario, this would result in a sudden shift between the earnings prospects of different sectors and companies, with corresponding consequences for valuations. For own funds and debt capital, profits can be expected in some cases, but also considerable losses or even total losses (stranded assets) in others. For this purpose, the most granular view possible is essential.

If the transition were anticipated in whole or in part, corresponding gains and losses in value would take place beforehand. Transition risks of capital investments therefore depend not only on when the real transformation begins, how it takes shape and how long it lasts; just as important is the question of when and to what extent market participants' expectations regarding an upcoming transition will change. This can also happen at short notice. In the Delayed Transition scenario, a sharp turnaround takes place in 2030, for example, although an earlier or later point in time would be equally possible. The risks of a sudden transition are not tied to this date.

In addition to exposures to companies, losses in value are also likely to affect existing properties whose operation is associated with high emissions. Section 4.6 therefore considers property risks in addition to equity, interest rate and spread risks.

However, the different outlooks for individual investments cannot be assessed using the NGFS scenarios alone, as they are not nearly as granularly modeled. This issue will be addressed in the following sections.

4.4 Sector-specific considerations and derivation of spreads

The NiGEM model primarily provides macroeconomic variables and relatively few financial market variables. The results include projections for equity prices that are differentiated by region but not by economic sector. There are no assertions at all on the development of corporate bonds or their spreads. These must therefore be determined using additional sources and methods.

Figure 10, which comes from a recent EIOPA discussion paper on the methodological issues of dealing with sustainability risks, compares different approaches of European supervisors for sector-specific considerations.[73] With regard to the pattern of effects of a transition shock on individual sectors or technologies, the picture is very mixed. This shows the considerable model uncertainty that also exists with respect to sectoral impacts.

Three of the approaches presented in the EIOPA paper are based on a classification by NACE sectors.[74] In the fourth approach, a sensitivity analysis by EIOPA,[75] transition risks are estimated only for some particularly CO_2-intensive technologies and their expected equity price declines in the medium term are quantified (for a single point in time). With a blanket assumption, EIOPA has also derived value losses for corresponding bonds from this.[76]

In addition, in a special chapter of its 2021 Financial Stability Report,[77] the Deutsche Bundesbank also examined how transition risks might affect portfolios in the German financial system. The NGFS scenarios are likewise the starting point. Building on the results from the NiGEM model, sector-specific projections for equities and bonds are determined in further steps.[78]

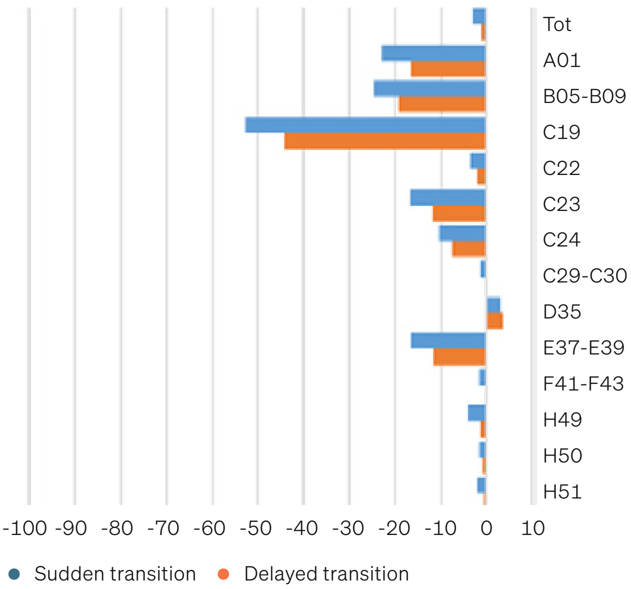
In the following a possible procedure is described that is partly based on this approach of Bundesbank.

73 Cf. EIOPA (2022b), pp. 52–59.
74 The NACE classification forms the basis of economic statistics in Europe.
75 Cf. EIOPA (2020).
76 The effect on corporate bonds is assumed to be 0.15 times the effect on equities (see EIOPA (2020), p. 27). The same assumption had already been used by the Bank of England in its 2019 stress test (see BoE (2019)).
77 Cf. Deutsche Bundesbank (2021), pp. 83–110.
78 Details can be found in the supplementary paper Schober et al. (2021).

Different assessments of sector-specific impacts

Figure 10 · Comparison of sector- or technology-specific declines of equity value in disorderly scenarios from ACPR/Banque de France, DNB, ESRB/ECB and EIOPA

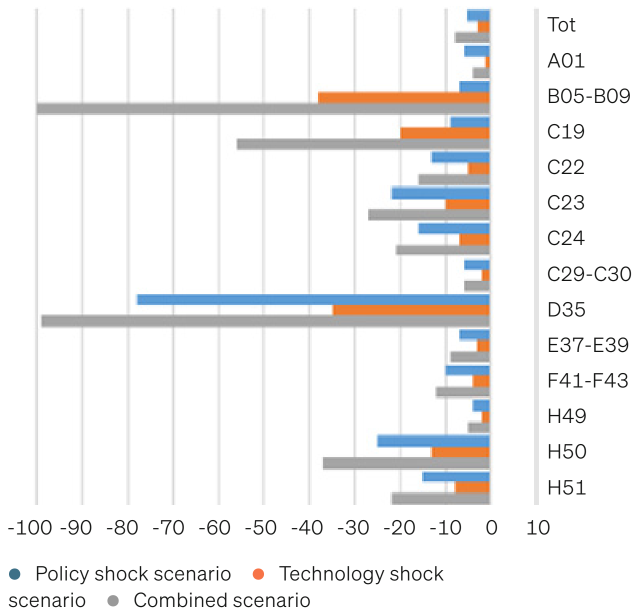
ACPR/BANQUE DE FRANCE[A] in percent



A Equity shocks relate to EU stock markets, excluding France.

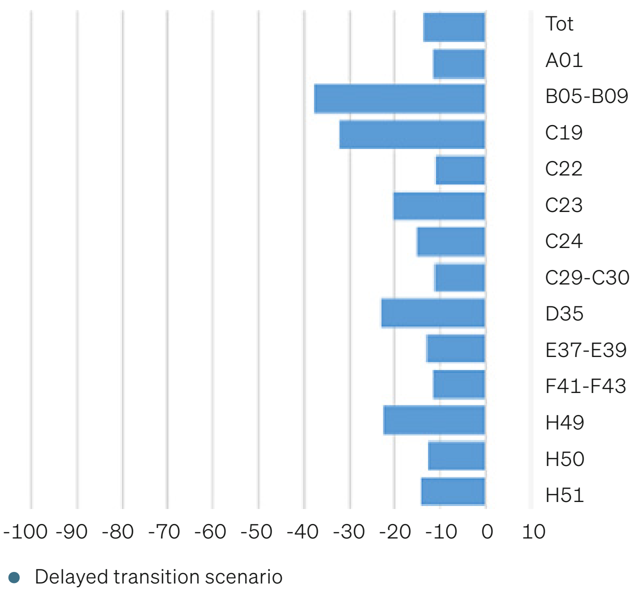
Source: ACPR (2020)

DNB in percent



Source: DNB (2018))

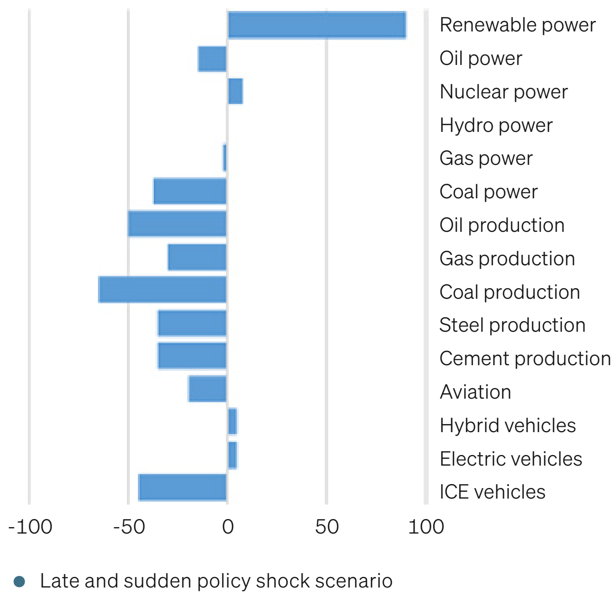
ESRB/ECB[B] in percent



B Total equity shocks relate to the weighted average of the shocks by NACE-activity using value added taken from Eurostat as weights. Note on NACE-activities – the 13 NACE activities are shown, where available, for which equity prices are most impacted by the transition scenarios of ACPR, DNB and ESRB/ECB.

Source: ESRB (2022)

EIOPA in percent

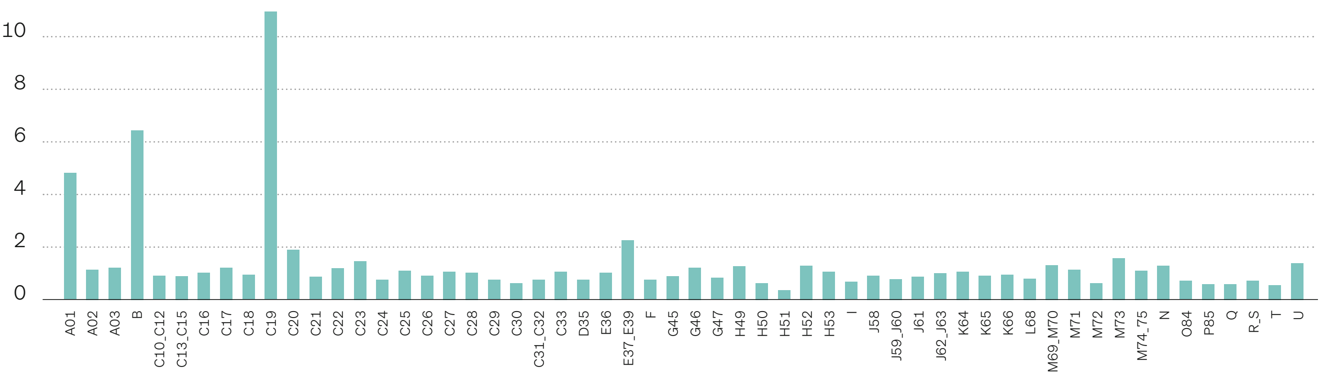


Source: EIOPA (2020a)

Source: EIOPA (2022b), p. 55, Figure 3

Scaling factors for the different sectors

Figure 11 · Scaling factors from the Bundesbank's input-output model for individual sectors (corresponding to NACE classification). Example: A transition-related decline in aggregate output of 1 % would be associated with a decline in output in the coking and refining sector (C19) of about 11 %.



Source: Schober et al. (2021), S. 15

4.4.1 Scaling factors and application to equity

Deutsche Bundesbank first uses a sector model to determine how strongly the various sectors of the economy might be affected by declines in their outputs in the course of decarbonisation.[79] The result is the scaling factors shown in Figure 11, which can be used to convert a macroeconomic change in output (gross domestic product, GDP) to the individual sectors affected above- or below-average.[80]

If current and, in all likelihood, expected future output declines, the profit expectations of the companies concerned will also fall. Since the enterprise value in the model is derived from discounted future profits, share prices fall accordingly. To determine the expected sector-specific price development in the course of the economic transformation, the scaling factors from the sector model are applied to the development of the equity indices from the NiGEM model.[81] This results in sector-specific equity price developments that take into account the systematic risk of the various sectors.

However, these scaling factors only refer to the transition phase, during which there is a temporary decline in market valuations. They are not suitable for the subsequent rebound and for phases with unchanged CO_2 prices – i.e. the entire Current Policies scenario and the first years in the Delayed Transition scenario: In the event of suddenly initiated decarbonisation leading to a general decline in equity prices, a far disproportionate drop in equity prices can be expected in "brown" sectors such as coal and petroleum processing (C19). In the event of a subsequent general recovery, however, an equally disproportionate rebound in prices in this area is by no means to be expected. Special scaling factors would actually also be needed for the upswing phase of the transition, but these are not currently available.[82] As a substitute, all sectors could be assumed to recover at the same rate.[83] This is equally true for the years prior to the start of the transition and for the entire Current Policies scenario. As a result, the scaling factors from the Bundesbank's sector model would only be applied for the years 2030 to around 2034 in the Delayed Transition scenario, while otherwise the sector-specific

79 This is a production network model (input-output model) that, in addition to sectoral emissions data, primarily maps international and intersectoral value chains (calibrated with data from the World Input-Output Database) using substitution and demand elasticities to simulate the consequences of introducing a general CO_2 price (see Schober et al. (2021), pp. 13–15, and specifically Frankovic (2022)).

80 See separate file for data. The basic procedure using an input-output model to determine scaling factors is the same as in DNB (2018a) and DNB (2018b), wherein a somewhat simpler input-output model is used and the scaling factors are called Transition Vulnerability Factors (TVFs).

81 The scaling factor could be interpreted as the beta factor of capital market theory.

82 Strictly speaking, a differentiation between „brown" and „green" areas would be necessary overall: Brown areas would probably not continue to grow „normally" even after the transition peaked, while green areas did not shrink even at the beginning of the transition. One problem with the sector-level analysis, however, is that the current NACE classification does not differentiate between brown or green. For example, the electricity production sector (D.35.11) includes equally fossil fuel-fired power plants, nuclear power plants and power plants using secondary or renewable energy sources.

83 Databases such as the OECD's Trade in Value Added (TiVA) Database, which in turn is based on its Inter-Country Input-Output (ICIO) Database, provide detailed information on the current state and history of international and intersectoral value chains, but they do not provide an immediate indication of the sensitivities to changing conditions that would prevail during transition.

equity price development would be identical to the general equity price development.

4.4.2 Transfer to corporate bonds

The Bundesbank then derives corresponding developments for corporate bonds from the sector-specific equity price developments. To this end, empirical equity returns and corresponding changes in CDS spreads are first determined for suitable indices. Then, the percentiles of the inverted distribution of stock returns[84] are assigned the corresponding percentiles of CDS spread changes.[85] This is in line with the empirical observation that rising spreads are typically accompanied by falling stock prices.[86] For this assignment, a linear approximation can then be determined that assigns to each change in a sector-specific equity price a matching opposite change in the sector-specific CDS spreads (see Figure 12).[87]

However, the Bundesbank's approach as described so far still leaves open the step of determining corresponding bond spreads with the help of CDS spreads. These do not depend exclusively on the respective default probabilities, whose assessment is reflected by the CDS spreads. Thus, an additional assumption would still have to be made about the relationship between CDS and bond spreads.

Instead, in our view, it makes sense to examine the relationship between bond and stock indices directly, without taking the intermediate step via CDS spreads. In principle, it would also be possible to consider percentiles here.[88] However, by assigning percentiles, implicit assumptions would be made about the joint distribution, which in the end would not only feign a too close relationship between the two data series, but also lead to a notably different linear approximation (see Figure 13). Thus, it seems more meaningful to us to simply look at the original data.

84 The return is defined here as the relative change in value over three months.
85 The reason for looking at percentiles is supposed to be data outliers.
86 Cf., e.g., Fama and French (1993). Elton et al. (2001) further show that only a small fraction of corporate bond spreads can be explained by expected defaults, while about half of the spread represents compensation for systematic risk, which is subject to the same influences as systematic risk in the stock market. On a short-term time scale, spreads are moreover a leading indicator of macroeconomic variables such as output and unemployment (cf., e.g., Gilchrist et al. (2009) or Karlsson and Österholm (2020)).
87 Table 3 presents the results of a corresponding ordinary least squares (OLS) estimation for various CDS spreads using data from the last ten years. For reasons of data availability for iTraxx Europe and CDX Investment Grade, the observation period 11/01/2011–30/11/2021 (daily data) was chosen uniformly.
88 In the case of bond indices, the inversion step would be omitted.

Ordinary least squares estimation for different CDS spreads

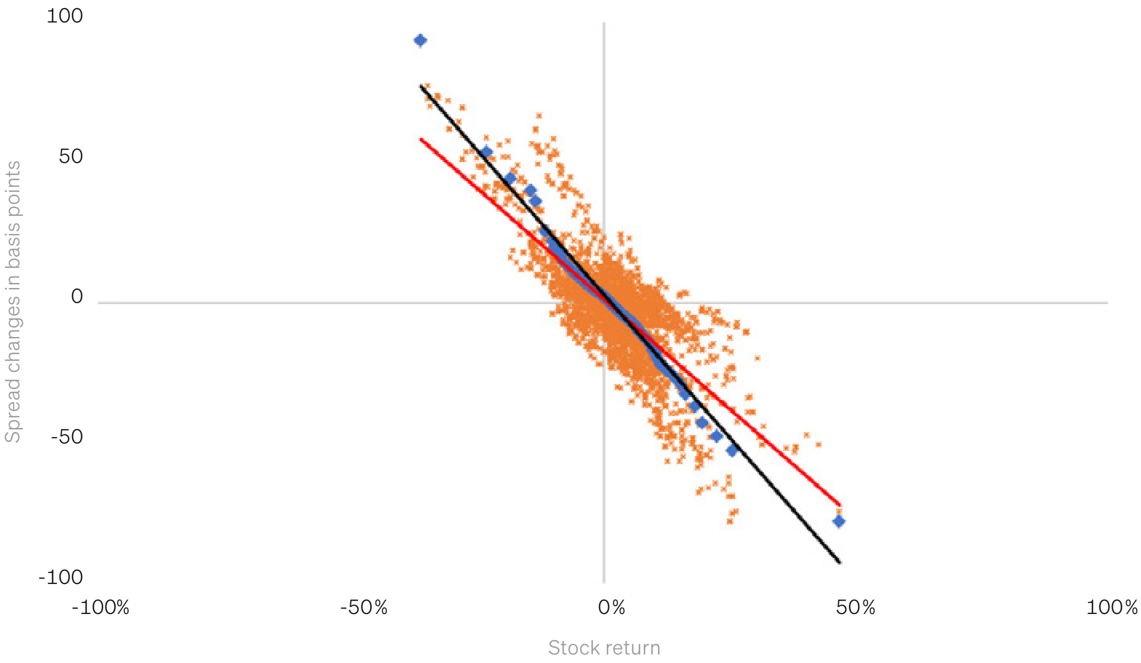
Table 3 · Own calculations: Correlations, results of an OLS regression $y = mx + b$, and coefficients of determination R^2 for the original data and the percentiles of the data series on CDS spreads and stock indices; country groups and data series in the manner of Schober et al. (2021), p. 18, Table 2. The very high correlations and coefficients of determination for the simulated data are likely an artifact of considering percentiles, which implicitly makes additional assumptions about the joint distribution. It seems to us that it makes more sense to look at the original data here.

COUNTRY-GROUP	DATA		ANALYSIS WITH ORIGINAL DATA				ANALYSIS WITH PERCENTILES			
	y	*x*	*ρ*	*m*	*b*	R^2	*ρ*	*m*	*b*	R^2
DE	iTraxx Europe	DAX	-0.758	-157.3	1.253	0.575	-0.988	-204.7	2.897	0.977
US	CDX Investment Grade	S&P 500	-0.873	-223.2	5.893	0.761	-0.985	-251.7	7.223	0.970
RoEUR	iTraxx Europe	Euro Stoxx 50	-0.757	-168.3	-0.084	0.573	-0.992	-223.9	1.178	0.985
ODC	CDX Investment Grade	MSCI World	-0.887	-215.2	3.890	0.787	-0.986	-243.4	4.961	0.971
EMDC (WD)	CDX Emerging Market	MSCI EM	0.607	26.23	-0.624	0.369	-0.859	-38.7	0.072	0.738

Source: Own calculations

Relationship between spread changes and equity returns

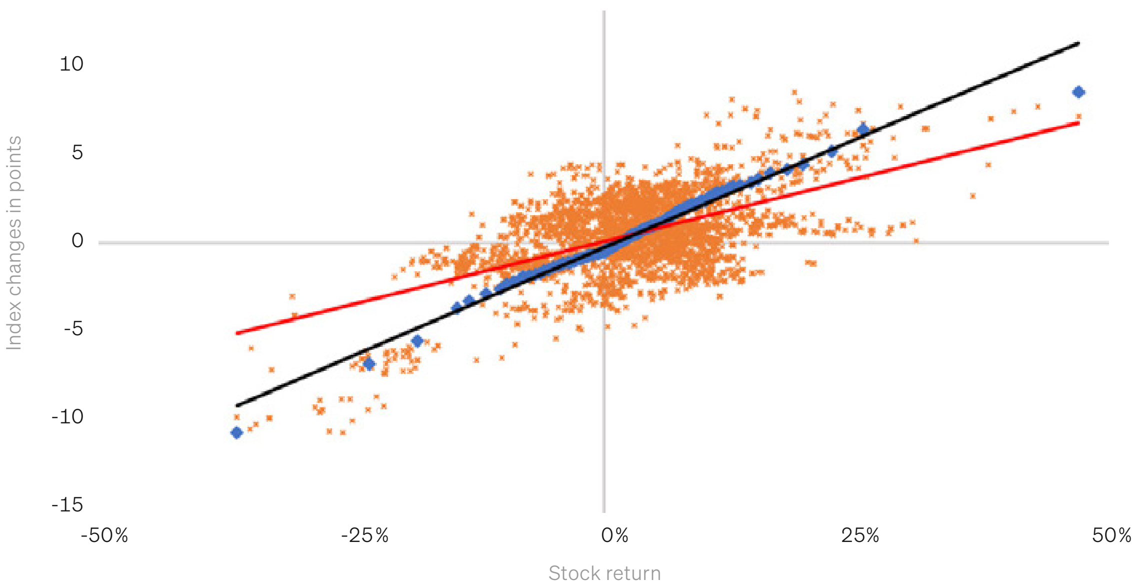
Figure 12 · Relationship between spread changes and equity returns for Germany. Illustration as in Schober et al. (2021), p. 19, Figure 10, subgraph top left (data points: Original data („empirical") in orange, percentiles („simulation") in blue; linear approximations (OLS): for original data in red, for percentiles in black). The slight deviations from Schober et al. (2021) are probably caused by a slightly different observation period.



Source: Own calculations

Relationship of bond index changes and equity returns

Figure 13 · Relationship between changes in a bond index and equity returns for Germany. Illustration as in Schober, et al. (2021), p. 19, Figure 10, subgraph top left (data points: Original data („empirical") in orange, percentiles („simulation") in blue; linear approximations (OLS): for original data in red, for percentiles in black). The different orientation of the data cloud than in Figure 12 results from looking at index changes instead of spread changes.



Source: Own calculations

Ordinary least squares estimation for various bond indices

Table 4 · Correlations, results of an OLS regression $y = m\,x + b$ and coefficients of determination R^2 for the original data and the percentiles of the data series on bond and stock indices

COUNTRY-GROUP	DATA		ANALYSIS WITH ORIGINAL DATA				ANALYSIS WITH PERCENTILES			
	y	*x*	*ρ*	*m*	*b*	*R²*	ρ	m	b	R²
DE	iBoxx Euro Corporates 5–7Y Overall Index	DAX	0.553	13.44	0.129	0.305	0.989	23.23	-0.18	0.978
US	iBoxx USD Corporates 5–7Y Price Index	S&P 500	0.442	16.79	-0.334	0.196	0.991	36.74	-1.037	0.981
RoEUR	iBoxx Euro Corporates 5–7Y Overall Index	Euro Stoxx 50	0.517	13.46	0.262	0.267	0.995	25.49	0.012	0.990

Source: Own calculations

Table 4 provides exemplary ordinary least squares (OLS) estimation results for various bond indices using data from the last ten years. A longer observation period would yield lower correlations (and coefficients of determination), whereas a shorter one would yield higher ones.[89] Such estimates can be made in the same way for other indices (e.g. non-financials or other maturity bands).

The results of the OLS estimation (e.g. $y = 13.44\,x+0.129$ with respect to the DAX) can finally be applied to the previously determined sector-specific equity price developments. This results in a sector-specific estimate of the development of corporate bonds.[90] Just as with equity prices, this performance takes into account the systematic risk of the various sectors in the course of the transition.

Idiosyncratic risks – the "alpha" – of individual companies or of the equity and debt instruments they issue cannot be determined in a view oriented to economic sectors. To do this, the vulnerability of all investee companies in the course of the economic transformation would first have to be determined, for example (simplistically) on the basis of their CO_2 intensity. Such an approach would not only be much more laborious , but would above all require appropriate data. Possibly, it could be envisaged at a later stage when relevant data are readily available.

4.5 Portfolio-specific considerations

The risk factors considered so far are either at the macroeconomic or sectoral level. When applying such stresses to the investment portfolio, ultimately only an assessment of the systematic, but not the idiosyncratic risk of the individual securities can be made. This means, for example, that benchmarking approaches within regions or sectors cannot be taken into account. For a first estimate, granularity at the level of macroeconomic factors and sectoral impacts seems appropriate. However, for further analysis and in order to make climate scenarios useful for the investment process in perspective, it may be beneficial to consider the implications at the level of individual issuers.

89 Daily data from the observation period 01/01/2011–30/11/2021 were used for the table (similar to the analyses for CDS spreads), with an obviously erroneous data point from 04/08/2016 removed.

90 Though the correlation between bond and stock market developments is not particularly close, ignoring it would be the bigger mistake. Compared to the blanket assumption in EIOPA (2020), this relationship is at least somewhat better (and comprehensibly justified) mapped by the linear approximation.

4.5.1 Adjustment factors based on expert estimates

This could be achieved, for example, by enriching the "top-down" scenarios (macroeconomic, sectoral) with "bottom-up" (portfolio- or issuer-specific) information. The latter is, for example, company-related sustainability data (e.g. ESG ratings, CO_2 emissions) or internal ESG criteria in the selection process. Firstly, the market value loss by applying the macroeconomic and, if necessary, sector-specific effects could be assumed and considered as a baseline for an "average" portfolio allocation. Based on this, a portfolio-specific exposure estimate could then be made in the next step on the basis of the available "bottom-up" information.

For transition risks, for example, this can be realised by adjusting the scaling factors presented in Section 4.4.1. For each of the NACE sectors, as shown in Figure 11, in which the company is invested, in-house experts provide a point estimate of the scaling factor in relation to the company's own portfolio in that sector.[91] Here, the scaling factor shown in Figure 11 can be interpreted as the mean value of the distribution of risk exposure within the sector to transition-related economic declines. The experts use their industry knowledge and the available information for this purpose. In this context, EIOPA's assessment of some areas within larger sectors that will be particularly affected by the transformation and have contrary effects (such as power generation or automotive manufacturing) could possibly also be used.[92] If a company's own portfolio within the sector is considered to be relatively low in emissions, a lower scaling factor is chosen. After the individual estimation for all sectors, the ranking and relation of the adjusted scaling factors between sectors should also be checked.

4.5.2 PACTA

Another conceivable approach for certain portfolio-specific considerations is the Paris Agreement Capital Transition Assessment (PACTA) developed by the 2° Investing Initiative (2DII).[93] This is a freely available and open source tool that measures the adaptation of financial portfolios to climate change scenarios in climate critical sectors. PACTA provides information on the transition risk of listed shares, corporate bonds and, where applicable, corporate loans, in order to help drive emissions reductions in the real economy in this way.[94] Funds are broken down into their constituent parts and could also be included in the analysis if information on portfolios within a fund is available.

The assessment of the portfolio's adaptation to a climate scenario is based on forward-looking production values of the real economy. This distinguishes it from strict CO_2 accounting systems, which are often based on historical data. Seven climate-relevant sectors are covered (oil and gas, coal, electricity, automotive, transportation, cement, steel), which are responsible for 80–90% of the CO_2 emissions of common financial portfolios and for 75% of the CO_2 emissions of the entire economy. Therefore, the analysis limited to the relevant parts often covers only about 20–30% of a portfolio, but still about 70–80% of its total greenhouse effect.

In the findings report prepared by PACTA, the first part summarises the portfolio's exposure to business activities that are potentially affected by decarbonisation and thus have transition risk. In particular, the portfolio's percentage of low and high CO_2 activities in the fossil fuel, energy and automotive sectors is quantified and compared with the market average. The second part of the report quantifies the extent to which the portfolio contributes to achieving or failing to achieve a Below 2°C scenario over the next five years.

Even though PACTA is a free offering for portfolio analyses, the GDV project group believes that its use is only conditionally recommended. One positive feature is the easy use. A file with portfolio data (identification of assets by ISIN) in csv format is uploaded to the tool and then analysed. The result is presented in a simple and understandable way. The disadvantage is that the analysis only covers listed shares, corporate bonds and, where applicable, corporate loans from seven sectors, so that the entire portfolio is never considered. In addition, many companies are likely to have reservations about uploading detailed data on their own portfolio to an external server (presumably in the United States).

91 Instead of a point estimate, a distribution-based estimate (e.g. estimation of the quantile) could also be made. However, this first requires an assumption about the distribution of risk exposure within the sector under consideration.

92 Cf. EIOPA (2020), in particular Figure 14 on page 56.

93 The 2° Investing Initiative (2DII) is a non-profit organisation in Berlin and Paris that coordinates various sustainable finance projects. In the meantime, however, PACTA is managed by the RMI. The RMI (formerly Rocky Mountain Institute) is a non-profit organisation in the US primarily concerned with transformation in the energy sector.

94 The interactive online tool *PACTA for Investors* can be used to analyse stocks and corporate bonds. For corporate loans, the stand-alone software package *PACTA for Banks*, also free of charge, is required.

In principle, the tool could be helpful to get a first overview (if necessary with modified test data) – but for the purposes of the ORSA or for steering purposes it seems to be suitable only to a limited extent.

4.6 Specific financial and macroeconomic risks

Following the preceding general remarks on transition and issues of possible more granular considerations, this section presents trends in key economic variables provided by the NGFS and some lessons learned. In this context, the NiGEM model provides data in one year increments up to 2050. No corresponding data for points in time further in the future are available.

If, despite the modeling in the NGFS scenarios being associated with considerable uncertainties, the development of the risks within the meaning of Pillar 1 of Solvency II that result in the scenarios was also to be examined, the risk factors of the SCR standard formula could simply be applied to the values resulting in the NGFS scenarios in order to assess the respective equity, spread, property and exchange rate risk. In the case of interest rate risk, the situation is somewhat more complicated, as risk factors would have to be applied at the level of the yield curve. For the various market risks, scaling of the prior capital requirements according to the market value changes in the NGFS scenarios would also be conceivable as an alternative.

4.6.1 Gross domestic product

In the NGFS scenarios, in addition to CO_2 price and energy consumption, economic output in the form of gross domestic product (GDP) is the key economic variable, which is already calculated in the Integrated Assessment Models (IAMs) and forms the basis of the more detailed modeling in NiGEM.

If required, the GDP data can also be used as an auxiliary variable to derive other economic variables or, for example, to derive lapse probabilities in life and health insurance.

In the NGFS Scenario Explorer, data on GDP are available in the variable "NiGEM|Gross Domestic Product (GDP)" both at the country level and for various aggregates (e.g. Europe, Africa, Asia, World) over the 2022–2050 scenario horizon.

Figure 14 shows the development of GDP averaged over the three IAMs for the NGFS scenarios Baseline, Delayed Transition and Current Policies with Germany as an example.

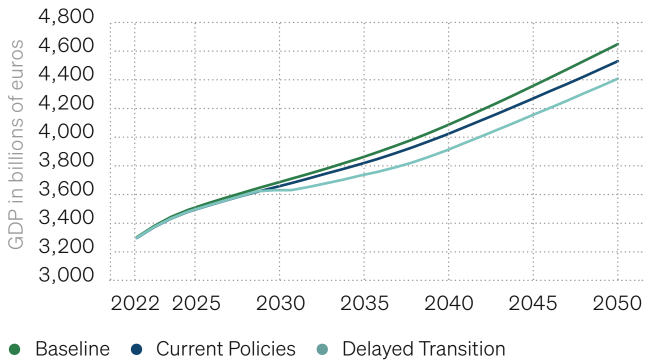
In the Baseline scenario,[95] German GDP grows after slightly higher growth rates in the first three years (2022: 2.4%, 2023: 1.9%) subsequently along a long-term trend by approx. 1% per year. In the 2040s, the growth rate increases slightly to about 1.3%.

In the Current Policies scenario, negative consequences of advancing climate change slowly become apparent over time. However, this is hardly reflected in the annual growth rates, which are only nine basis points lower on average, and this effect also hardly accelerates (average of the 2040s: 11 basis points). Only the cumulative effect of lower long-term growth leads to slight differences in the level of GDP (2040: –1.5%, 2050: –2.6%)

95 In the case of GDP, the projected data differ between the three IAMs even in the Baseline scenario. In particular, the results according to REMIND-MAgPIE differ notably from the other two models. What could be the reason for this is not comprehensible for us.

Gross domestic product

Figure 14 · Development of gross domestic product (GDP) in Germany in the NGFS scenarios Baseline, Delayed Transition, and Current Policies until 2050 (unit: billions of euros in 2015 prices, model: NiGEM NGFS v1.22, IAM: Mean of the three Integrated Assessment Models)



Source: Own illustration based on data from the NGFS Phase 3 Scenario Explorer

compared to the Baseline scenario.[96] Compared to the level of short-term cyclical fluctuations in GDP growth observed in reality, this difference in the level of GDP after almost 30 years seems rather small. It should be noted, however, that so far only part of the negative effects of climate change on the economy have been taken into account in the model at all, and this effect may thus be systematically underestimated.

In the Delayed Transition scenario, transition suddenly begins in 2030 with strong policy measures. As a result, growth declines in the short term and is about 0.7 percentage points lower in 2030 and about 0.9 percentage points lower in 2031 compared to the Baseline scenario, but without a recession (zero growth in 2031). From 2032 to 2038, annual GDP growth is still about 0.3 percentage points lower on average, before the difference to the Baseline scenario is reduced to about 0.1 percentage point for the remaining period. The comparison with the Current Policies scenario shows that the cumulative effect of the transition from 2030 to 2038 results in GDP being 2.7% lower in 2038. In the remaining years, GDP grows in parallel again in the Current Policies and Delayed Transition scenarios, so that the difference of 2.7% persists until 2050.

This means that when looking at aggregate output, the sudden and rather violent transition only leads to a short-term slowdown in long-term growth. The decline in growth mainly affects the first two years and completely disappears after ten years at the latest. Its level is in the order of normal cyclical fluctuations, although it lacks the upswing with temporarily higher growth that usually follows a downturn. Anyway, it is remarkable that there is no accelerated growth after the initial GDP decline, but with GDP continuing to develop steadily at a lower level. The total transition effect of 2.7% happens to be equal to the cumulative magnitude of the effect of the portion of the adverse consequences of climate change by 2050 considered in the model.

As a result, at the macroeconomic level, no effects of the transformation are to be expected that would significantly exceed the scope of normal economic fluctuations. Unlike climate change itself, which leads to a (slight) flattening of the long-term growth trend, the transformation represents a one-off effect. At least when considering the NGFS Delayed Transition scenario in its currently available model vintage and taking into account the average of the three Integrated Assessment Models, the effect of the transition in 2030 and 2031 is also smaller than the declines in major crises in recent years.[97]

However, this view of the economy as a whole must not obscure the fact that specific sectors and, even more so, specific companies develop quite differently from the average. On the one hand, economic activities that are already climate-friendly or that are needed to implement the transformation (capital goods, construction, etc.) could benefit. On the other hand, particularly in areas where a lot of CO_2 is emitted so far or where emissions are difficult to reduce, significantly greater and longer-lasting negative effects of the transformation are to be expected. Therefore, in order to examine the potential impact on specific capital investments, it would actually be necessary to take the most granular view possible, going beyond the macroeconomic results from the NGFS scenarios. However, mainly for reasons of data availability, this is currently only possible to a limited extent.

4.6.2 Equity

Comprehensive equity price data for 30 different countries up to 2050 are available via the Scenario Explorer of the NGFS in the variable "NiGEM|Equity prices".

96 In comparison: The study Flaute et al. (2022), commissioned by the German Federal Ministry of Economics and Climate Protection (BMWK) and conducted by the Gesellschaft für wirtschaftliche Strukturforschung (GWS) together with Prognos and the Institut für ökologische Wirtschaftsforschung (iöw), concludes that in their „strong climate change" scenario, GDP in Germany may be 1.8% lower in 2050 than in the reference scenario. This loss corresponds to just under 70 billion euros. The figure of over 900 billion euros that has been at the forefront of press coverage is the cumulative real GDP loss for the years 2022–2050. The conclusion reached in the study (p. 82) that the loss of 1.8% would be so high that the economy would shrink rather than continue to grow is not comprehensible for us. Apparently, the long-term growth trend in the reference scenario is incorrectly neglected at this point. The study refers only to Germany and is not based on the NGFS scenarios, but uses a different model, INFORGE/PANTA RHEI.

97 In Germany GDP dropped by 5.7% in the global financial crises of 2009 and by 3.7% in the Covid 19 pandemic of 2020. In particular in 2010/11, however, there was also significantly above-average growth in subsequent years. In the crisis of 2002/03 after the bursting of the dotcom bubble, growth was slightly negative at −0.2% and −0.7%, while in the euro crisis of 2012/13 growth remained positive at 0.4% in both years (see Statista.com).

Data are at hand for all major markets inside and outside Europe (e.g. USA, China, Japan). The variables describe the development of major indices for the individual countries, e.g. the NYSE Composite for the US and the FTSE 100 for the UK. Only one overarching index is available for each country, so data for the TecDAX, for example, cannot be derived.

Calculation method

In the Scenario Explorer of the NGFS, equity price developments are given in the Baseline scenario as the value of an index set to the value 100 for base year 2017. For example, to calculate the DAX level in 2040 in the Baseline scenario, the DAX level at the end of 2017 must be multiplied by the factor resulting from the index level $x_{Baseline,2040}$:

$$DAX_{Baseline,2040} = DAX_{2017} \cdot \frac{x_{Baseline,2040}}{100} \approx 12{,}917.64 \cdot \frac{152.194}{100} \approx 19{,}659.85$$

For the other scenarios, the share price developments are given as percentage deviations from the Baseline scenario.[98] Using the percentage deviation $x_{Delayed,2040}$ for example, the DAX level in 2040 can be calculated for the Delayed Transition scenario as follows:[99]

$$DAX_{Delayed,2040} = DAX_{2017} \cdot \frac{x_{Baseline,2040}}{100} \cdot \left(1 + \frac{x_{Delayed,2040}}{100}\right) \approx 12{,}917.64 \cdot \left(1 + \frac{-9.4416}{100}\right) \approx 12{,}917.64 \cdot \left(\frac{137.824}{100}\right) \approx 17{,}803.65$$

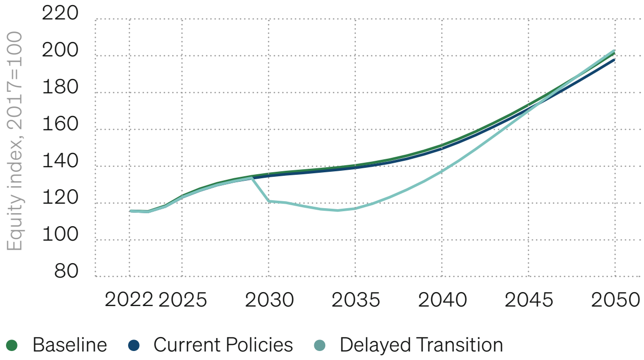
Course

Figure 15 shows the development of equity prices in the average of the three Integrated Assessment Models for the NGFS Baseline, Delayed Transition and Current Policies scenarios for the example of Germany.

In the Baseline scenario, equity prices rise throughout, although the increase in the 2030s is somewhat weaker than in the years before and after. The development in the Current Policies scenario hardly differs from this.

Equity

Figure 15 · Equity price development in Germany in the NGFS scenarios Baseline, Delayed Transition and Current Policies until 2050 (unit: Index 2017=100, Model: NiGEM NGFS v1.22, IAM: Mean of the three Integrated Assessment Models)



Source: Own illustration based on data from the NGFS Phase 3 Scenario Explorer

The effects of advancing climate change have only a minor dampening effect on prices (via productivity).

In the Delayed Transition scenario, equity prices initially fall by 9.5% at the start of the transition in 2030, followed by a phase of slightly further falling prices lasting several years. In the mid-2030s, the difference between the Baseline and Current Policies scenario caused by the diverging developments reaches its maximum at just under 17%. From this point on, an accelerated price increase begins in the Delayed Transition scenario, leading to the level of the other scenarios being reached again and eventually exceeded in the second half of the 2040s.

Model parameters

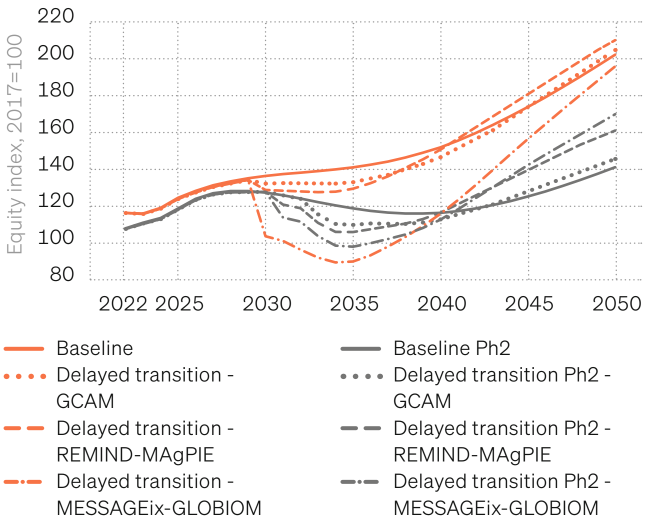
However, as discussed in Section 2.4.2 on model uncertainty and model selection, the results generated with the three different Integrated Assessment Models (IAMs) can vary significantly. Using the equity price development as an example, Figure 16 illustrates this once again for the entire capital investment area. Moreover, as the additional comparison with the results from the previous second vintage of NGFS scenarios shows, the differences between the three IAMs have become much larger in the third vintage of NGFS scenarios. This has made the question of model selection much more important.

98 In the data provided as a supplement to this paper (for GDV members only), we have already combined the factor resulting from this percentage deviation with the factor resulting from the index level in the Baseline scenario, allowing the value given there (corresponding to the 137.824 in the example calculation) to be applied directly to the DAX level from 2017.

99 The sample calculation is based on the values that result from the average of the three Integrated Assessment Models.

Equity in comparison of models and model vintages

Figure 16 · Equity price development in Germany in the NGFS Baseline and Delayed Transition scenarios until 2050 (unit: Index 2017=100, Model: NiGEM NGFS v1.22 (NGSF Phase 3)/ NiGEM NGFS v1.21 (NGFS Phase 2, here referred to as Ph2 for short), IAM: all three Integrated Assessment Models in their respective versions from Phase 2 and Phase 3)



Source: Own illustration based on data from the NGFS Phase 3 Scenario Explorer and the NGFS Phase 2 Scenario Explorer

In particular, the decline in prices (relative to the current Baseline scenario) under the third-vintage NGFS MESSAGEix-GLOBIOM model is very large, both compared to the corresponding declines under the other two models and compared to the declines (relative to the Baseline scenario at the time) under the three second-vintage NGFS models.[100] If there are no comprehensible technical reasons, it would therefore seem somewhat arbitrary and not very sensible to use this clearly different model, of all things, as the sole basis, as was still the case in the previous version of this paper. Instead, this Version 2.0 generally presents the mean of the results from the three models. This takes an agnostic view that does not give the false appearance of knowing which of the models presented equally by the NGFS would in fact be the "correct" one. The results are more robust than would be the case if a single model were selected.

When comparing the results from the second and third NGFS vintages, it is not only notable that the range between the IAMs is wider, but also that the Baseline scenario, which is unaffected by climate aspects, is now much more optimistic than before. The long-term stagnation of equity prices, which was previously difficult to comprehend, has given way to the sustained increase described above.[101] As a more technical aspect, it should be noted that the price decline in the Delayed Transition scenario now already starts in 2030 and not in 2031.

Sector- and portfolio-specific developments

For the crisis years 2030 to 2034 of the Delayed Transition scenario, sector-specific equity price developments can be derived using the scaling factors described in Section 4.4.[102] For example, if share prices generally fell by 9.48% from 2029 to 2030, share prices in the manufacturing of food products sector (C10) would fall only by 0.92 * 9.48% = 8.72%. In subsequent years, too, they would continue to fall slightly less than the overall market (by 0.92 times in each case). With the slow onset of recovery starting in 2035, the scaling factors should no longer be applied. The sector-specific price level achieved would then have to be extrapolated in line with the general price trend, as was already the case in the years before 2030.

The only special case is the manufacturing of coke and refined petroleum products sector (C19). If share prices were to fall 10.98 times as much as the overall market, a total loss would be assumed in the Delayed Transition scenario as early as 2030 (10.98 * 9.48% > 100%).[103]

Building on the sector-specific calculation, a somewhat closer portfolio-specific consideration (as described in Section 4.4) could possibly take place.

In the Current Policies scenario, prices should generally be updated with the general price development. No sector-specific development will then take place.

[100] In the MESSAGEix-GLOBIOM model, the decline from 2029 levels is 23% in the first year and increases to nearly 34% in 2024. Compared to the level then achieved according to the other two models, the gap is over 36%.

[101] The course in the Baseline scenario of the second NGFS vintage was at odds with the usual expectations of long-term rising stock prices based on financial market empirics and economic theory.

[102] For scaling factors, see separate file (for GDV members only) and Figure 11.

[103] In the event of much larger declines in the general stock market, such as those provided by the MESSAGEix-GLOBIOM model, there might be further instances of total losses.

4.6.3 Interest rates

Bonds and other interest-sensitive investments typically make up the largest part of the asset side of an insurance balance sheet. In the case of life insurance policies, interest also plays a prominent role in the valuation of technical provisions. For the Solvency II calculations, EIOPA therefore provides a risk-free yield curve based either on swap data (as for the euro) or on government bonds and extrapolated beyond the 20-year maturity (in the case of the euro).

There is no directly comparable quantity in the NGFS/NiGEM scenarios. Instead, these include three other interest rate variables that are available both at the country level and for different aggregates (e.g. Europe or World) up to 2050:

- "NiGEM|Central bank intervention rate (policy interest rate)". Key interest rate, which can be understood as short-term nominal interest rate
- "NiGEM|Long-term interest rate": Long-term nominal interest rate in the form of the yield on 10-year government bonds
- "NiGEM|Long-term real interest rate." Long-term real interest rate, which is the yield on 10-year government bonds less inflation

As a substitute for the risk-free interest rate from Solvency II, it would be possible to build on the (nominal) yield of 10-year German government bonds (Bunds), which are the benchmark on the European bond market. For comparable maturities, this is a very good approximation. However, a complete yield curve is required in particular for the valuation of technical provisions.

The Solvency II risk-free yield curve is based on current interest rates for swaps up to a maturity of 20 years (in the case of the euro). For longer maturities, an extrapolation takes place whose algorithm currently in force uses the forward rate from year 15 to year 20 and a ultimate forward rate (UFR) of currently 3.45%.[104] If the results from the NGFS scenarios are to be used to generate a similar yield curve, a whole series of additional assumptions must necessarily be made with regard to extrapolation procedures, market data and UFR.

For example, for the range up to the 20-year maturity, interpolation between the ECB key interest rate and the 10-year government bond yield could be performed (linearly) for maturities 1 to 9 years before the 10-year rate is rolled forward flat. Another option would be, for example, to shift an existing yield curve in line with the development of the 10-year interest rate. In both cases, forward interest rates could be determined from this and an extrapolation could be performed. The UFR, which is also required for this purpose, is expected to decrease somewhat in the next few years. In the long run, it could stabilise on the order of 3.00% in the Baseline and Current Policies scenarios and even rise again in the Delayed Transition scenario, given the development of real interest rates, which is important for the UFR calculation (see Figure 19). If the UFR and the forward interest rate addressed are not far apart, possibly the application of the extrapolation algorithm could also be omitted and a simpler continuation be chosen. In the simplest case, the interest rate structure could then be completely flat from a maturity of 10 years at the latest. However, a highly simplified yield curve can have a significant impact on the valuations of long-term investments and insurance obligations.

Figures 17, 18 and 19 show the evolution of the three available interest rate variables in the Baseline, Current Policies, and Delayed Transition scenarios.

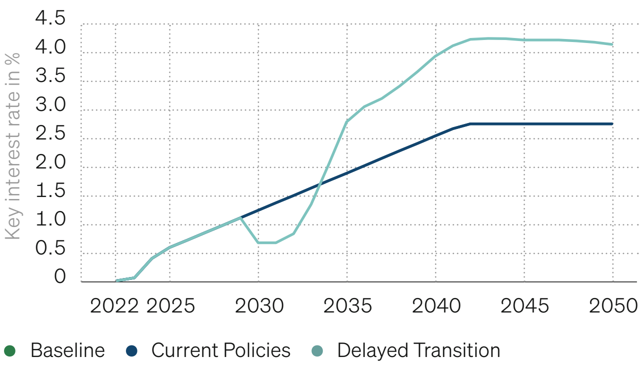
In the case of interest rates, it is particularly evident that reality has developed completely differently since 2022 than was foreseeable when the third vintage of NGFS scenarios was created (with data from 2021). In fact, the starting point of the developments in the Baseline and all other scenarios is much too low. Section 4.2.1 discusses issues of model actuality and model focus in more detail in this context.

In both the Baseline and Current Policies scenarios of the NGFS, the key interest rates, which are still at 0% in 2023, rise very slowly to 2.75% by 2042 and then remain at this level. In a quite similar, but initially somewhat faster development, the long-term (nominal) interest rate on the market also rises from 0 to 2.75%. Combining this with the key interest rate as the short-term interest rate results in a completely flat interest rate structure for 2022 and then again from 2042 onward, and only a slightly rising (normal) interest rate structure in the years in between.

[104] In the course of the Solvency II review currently underway, a change in the extrapolation procedure is to be expected. In the future, additional forward interest rates may be required, among other things.

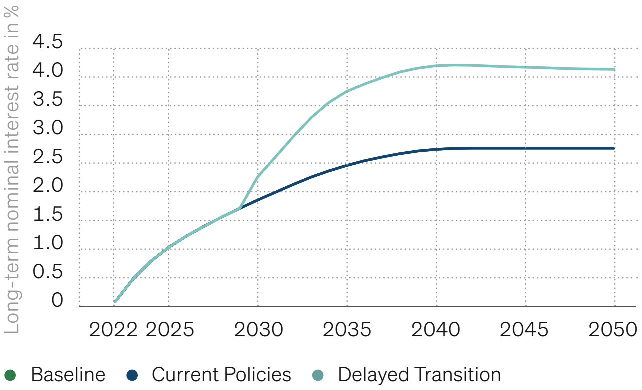
ECB key interest rate

Figure 17 · Development of the central bank's key interest rate in Europe in the NGFS scenarios Baseline, Delayed Transition and Current Policies until 2050 (unit: Percent, Model: NiGEM NGFS v1.22, IAM: Mean of the three Integrated Assessment Models)



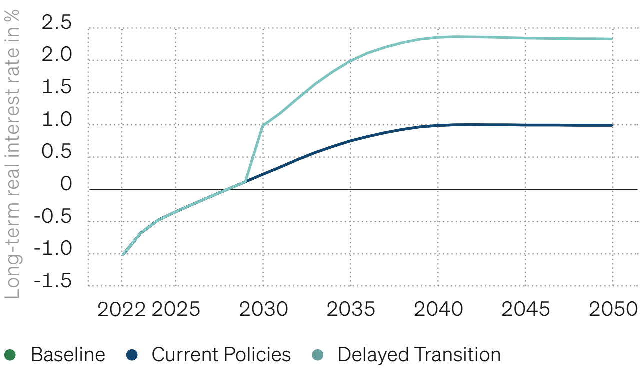
Long-term nominal interest rate

Figure 18 · Development of the long-term nominal interest rate in Europe in the NGFS scenarios Baseline, Delayed Transition and Current Policies until 2050 (unit: Percent, Model: NiGEM NGFS v1.22, IAM: Mean of the three Integrated Assessment Models)



Long-term real interest rate

Figure 19 · Development of the long-term real interest rate in Europe in the NGFS scenarios Baseline, Delayed Transition and Current Policies until 2050 (unit: Percent, Model: NiGEM NGFS v1.22, IAM: Mean of the three Integrated Assessment Models)



Source Figures 7, 8 and 9: Own illustration based on data from the NGFS Phase 3 Scenario Explorer

In the Delayed Transition scenario, by contrast, ECB key interest rates and long-term market interest rates show contrary developments. With the onset of the transition and the associated economic turbulence (falling economic growth, falling share prices), key interest rates will initially be cut by almost 50 basis points in 2030. However, in view of rising inflation rates (see Section 4.6.7), continuous interest rate hikes will begin as early as 2032, raising the key interest rate to 2.8% by 2035 and to 4.2% by 2042. Thereafter, the rate remains largely at this level, which is about 1.5 percentage points higher than in the Baseline scenario, until 2050. Long-term market interest rates, on the other hand, will not decline at all. In view of the capital required to transform the economy, a stronger increase in long-term interest rates than in the Baseline scenario will begin as early as 2030, despite the reduction in the key interest rate, also leading to a level of 4.2% by 2041. From the start of the transition until the end of the 2030s, the interest rate structure is steeper than in the Baseline scenario – very significantly so in the first half of the transition. In the 2040s, also in the Delayed Transition scenario, the interest rate structure is again largely flat and, in a way, shifted upward in parallel with the Baseline scenario.

Taking inflation into account, long-term real interest rates in the Baseline and Current Policies scenarios increase from −1 to 1%. In the Delayed Transition scenario, real interest rates rise by almost one percentage point at the start of the transition in 2030 due to a simultaneous drop in inflation and rise in interest rates in one year, but otherwise show broadly the same trend as nominal interest rates, remaining constant at around 2.3% in the 2040s.

Overall, the various developments show that, in terms of interest rates, the transition will lead to significant changes – initially contrasting at the short and long ends of the maturities – especially in the early years, but will be completed by the end of the 2030s. Subsequently, when the interest rate structure is flat again, a significantly higher interest rate level will prevail on a steady basis than in the scenarios in which no transition takes place.

4.6.4 Spreads

To the extent that no prices can be observed on the market, suitable interest rates are required for the valuation of bonds and other interest-sensitive securities (mark-to-model). These interest rates correspond to the interest rate assumed to be risk-free plus an issuer- or issue-specific spread.

The NiGEM model provides 10-year government bond yields (see Section 4.6.3). If the German Bund yield is used as the risk-free interest rate, this directly results in the spreads of other countries' **government bonds** (at least for this maturity). This also corresponds to the standard market terminology for spreads in Europe.

For **corporate bonds**, spreads can be estimated using the procedure described in Section 4.2.2 on the basis of equity price developments for individual sectors.[105] In the delayed-transition scenario, this actually produces sector-specific results for the first phase of the transition with falling prices for equities and corporate bonds. For other points in time and for the Current Policies scenario, the relationship between equity and spread development should only be applied to the general equity price development.[106] This results at least in spread developments for the overall market.

If spreads are derived from equity prices in this way, the development of corporate bonds in the various scenarios logically follows the pattern of the respective development of equity.

If certain spread changes actually occurred in the market, the amount of the volatility adjustment (VA) would also change. In principle, a recalculation of the volatility adjustment in the respective climate change scenarios would provide more realistic results.[107] However, it would be quite laborious and would also require additional assumptions for points in time far in the future.[108]

In order to deal with the consequences of climate change in the context of the ORSA, a recalculation of the volatility adjustment should generally not be necessary. When interpreting the results, however, it should then be noted that the effects of spread changes tend to be overestimated and the results are accordingly conservative.

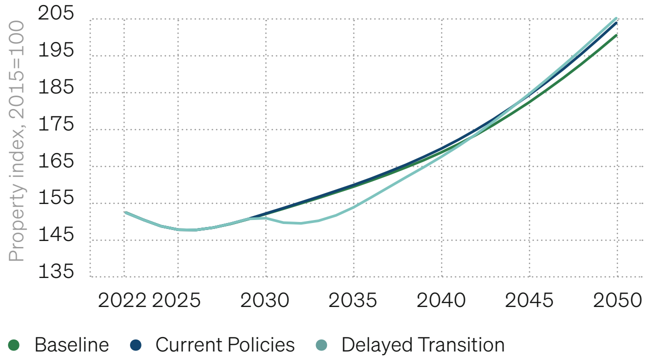
4.6.5 Property

Property also represents a not inconsiderable part of the capital investment of German insurance companies. The focus is on office and retail properties, which account for well over 50% of property investments. Depending on the company, however, there may be other areas of focus. Overall, however, the property ratio of primary insurers is below 5% of capital investments, so that in most cases property risks are likely to be less important than equity or interest rate and spread risks with regard to the ORSA.

In the NGFS Scenario Explorer, data on property prices are available in the variable "NiGEM|House prices (residential)" for all relevant countries. However, these are exclusively prices for residential property, the development of which is shown in Figure 20 by an index. In order to be able to transfer the development to commercial property, additional assumptions would have to be made.

Property

Figure 20 · Development of a residential property index for Germany in the NGFS scenarios Baseline, Delayed Transition and Current Policies until 2050 (unit: Index 2015=100, Model: NiGEM NGFS v1.22, IAM: Mean of the three Integrated Assessment Models)



Source: Own illustration based on data from the NGFS Phase 3 Scenario Explorer

105 For sector-specific equity price developments, see Section 4.6.2.
106 Cf. Section 4.6.2.
107 When determining the SCR, a so-called dynamic volatility adjustment, which responds to the changed spreads assumed for determining the capital requirement for spread risk, is only accepted for internal models. In EIOPA stress tests, on the other hand, scenarios with widened spreads regularly also included an adjusted (higher) value for the volatility adjustment.
108 For the calculation of the volatility adjustment, not only spreads for the respective point in time but also their long-term (thirty-year) averages (LTAS) as well as corresponding portfolio weights are required for the entire EIOPA reference portfolio (see EIOPA (2022c)).

In the Baseline scenario, after an initial decline in (residential) property prices from 2022 to 2025, a steady increase is observed thereafter, accelerating somewhat in the 2040s.

In the Current Policies scenario, development in the 2040s begins to lag slightly behind that of the Baseline scenario. From then on, negative effects of climate change seem to have such a strong impact on the value of some properties that it becomes notable in terms of the overall market. This could be related, for example, to insufficient structural adaptation measures to weather extremes, to risks becoming too great in locations particularly prone to flooding, or to inner-city locations becoming less attractive, where heat stress is becoming too great.

In the Delayed Transition scenario, housing prices fall slightly in 2031 and 2032 after the start of the transition, but then a somewhat faster increase follows. Towards the end of the 2040s, prices even gradually exceed the level from the Baseline scenario. The reason for the development is likely to be that the suddenly initiated transition necessitates previously unintended investments (insulation, heating, photovoltaics, possibly also adaptation measures such as facade or roof greening) in existing properties that are not yet climate-friendly, temporarily depressing their price. Given the high CO_2 prices, much of this investment should then pay off in the long run and increase property values.

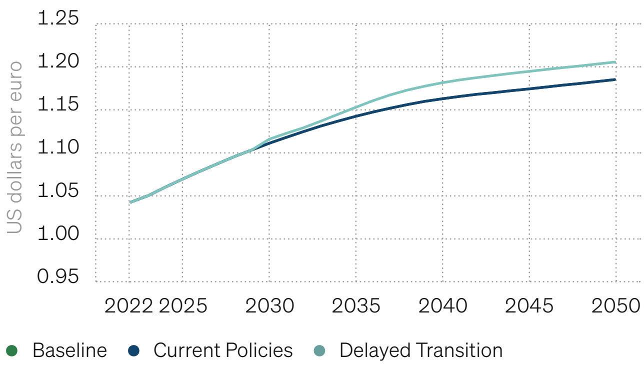
Overall, in the model used, the performance of residential property does not seem to depend too much on climate aspects. Depending on the location and energy efficiency of the property, however, there could be notable differences in value development.[109]

4.6.6 Exchange rates

The NGFS scenarios include data on exchange rates from the underlying NiGEM model in the variable "NiGEM|Exchange rate." The data are available at a country level up to 2050 for Europe and key markets outside Europe. The variable describes the exchange rate as the price of the domestic currency expressed in US dollars (quantity quotation).

Exchange rate against the dollar

Figure 21 · Development of the EUR-USD exchange rate in the NGFS scenarios Baseline, Current Policies and Delayed Transition until 2050 (unit: US dollars per euro, model: NiGEM NGFS v1.22, IAM: Mean of the three Integrated Assessment Models)



Source:Own illustration based on data from the NGFS Phase 3 Scenario Explorer

Figure 21 shows as an example the development of the euro exchange rate against the US dollar for the three NGFS scenarios Baseline, Current Policies and Delayed Transition.

The external value of the euro against the dollar rises slowly over time in both the Baseline and Current Policies scenarios. Effects of climate change do not appear. In the Delayed Transition scenario, by contrast, the transformation gradually leads to a somewhat higher value of the euro in the 2030s.

4.6.7 Inflation

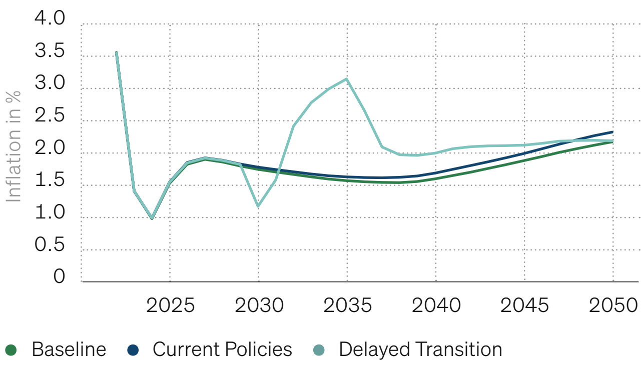
Inflation is closely related to interest rate developments and helps us to better understand the corresponding model results. In addition, data on inflation can be used as an auxiliary variable outside the investment area, e.g. to derive lapse probabilities in life and health insurance.

Inflation data for all major markets such as Europe, North America or Asia up to 2050 are available via the NGFS Scenario Explorer under the variable "NiGEM|Inflation rate" and are also available at the individual country level. Figure 22 shows the inflation development in Germany for the Baseline, Current Policies and Delayed Transition scenarios.

[109] Cf. ter Steege and Vogel (2021).

Inflation

Figure 22 · Development of the inflation rate in Germany in the NGFS scenarios Baseline, Delayed Transition and Current Policies until 2050 (unit: Percent, Model: NiGEM NGFS v1.22, IAM: Mean of the three Integrated Assessment Models)



Source: Illustration based on data from the NGFS Phase 3 Scenario Explorer

As with the interest rate, inflation also shows a particularly large discrepancy with reality in 2022 and 2023.[110] Thus, inflation in the Baseline scenario falls from just 3.6% in 2022 to 1.4% and then 1.0% in 2024, before approaching the ECB's target value of close to 2% again and remaining steadily between 1.6 and 2.2%. In the Current Policies scenario, inflation very gradually starts to be marginally higher. However, the difference is barely more than 0.1 percentage points even by the end of the 2040s.

In the Delayed Transition scenario, on the other hand, there are significant reactions to the transition. After their onset, inflation initially falls by 65 basis points in 2030 before rising by a total of 2 percentage points to over 3% in the subsequent years up to 2035. In 2036 and 2037, it then declines significantly, subsequently ranging steadily at or just above 2%, which is higher than in the other two scenarios for a long time. The initial decline in inflation in 2030 is likely to be a consequence of the notable slowdown in the economy. In the following years, supply shortages in transformation-serving investments are likely to fuel inflation. The rise in inflation is also fostered by the initial easing of monetary policy.[111] After key interest rates have been increasingly raised, 2036 marks the end of the rise in inflation. Interest rate hikes will nevertheless continue, but will proceed at a somewhat slower pace from this point on.

110 See Section 4.2.1.
111 See Section 4.6.3.

4.6.8 Unemployment

In the context of the ORSA, unemployment is probably most likely to serve as an auxiliary variable for determining and checking the plausibility of other risks, such as lapse risk in life and health insurance. For capital investment projections, it is negligible.

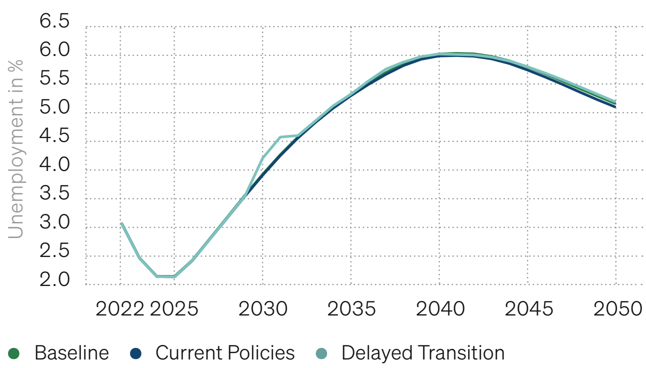
Data on unemployment through 2050 are available through the NGFS Scenario Explorer under the variable "NiGEM|Unemployment rate". Figure 23 shows the values for Germany. Data are also available for Europe, but not for Asia or the entire world.

In the Baseline scenario,[112] unemployment rises significantly from the mid-2020s until around 2040, before slowly declining again.[113] The course in the Current Policies scenario is almost identical. In the Delayed Transition scenario, the sudden transformation of the economy leads to a slight additional increase in unemployment in 2030 and 2031. As early as 2033, however, there is no longer any discernible difference from the other scenarios.

112 In the case of unemployment, the projected data according to MESSAGEix-GLOBIOM differ significantly from the other two models even in the Baseline scenario. What the reason for this could be, is not comprehensible for us.
113 In view of demographic trends, the increase does not necessarily seem plausible.

Unemployment

Figure 23 · Development of unemployment in Germany in the NGFS scenarios Baseline, Delayed Transition and Current Policies until 2050 (unit: Percent, Model: NiGEM NGFS v1.22, IAM: Mean of the three Integrated Assessment Models)



Source: Own illustration based on data from the NGFS Phase 3 Scenario Explorer

5. Effects on personal insurance

Climate change inevitably alters people's living conditions and can thus affect their health. Therefore, personal insurance is also fundamentally affected by climate change. In addition to climate-related risks to life and health, lapse and cost risks can also arise, especially in the course of the transition.

5.1 General affectedness

Climate change may have an impact on the underwriting of life and health insurers in Germany, for example, through the following issues that may affect the **health and life expectancy** of insured persons (partly transferable to the whole of Europe):[114]

- More frequent, longer-lasting heat waves associated with higher temperatures (in July 2022, for example, death rates in Germany were 12% higher than the average for previous years).[115]
- Increase in frequency and severity of other hazardous extreme weather events
- Decrease of cold phases
- Increased UV radiation
- Warming-facilitated spread of infectious diseases (e.g. Lyme disease, avian flu, meningitis, dengue fever, and tropical bacterial and viral infections)
- Decrease in air pollution as a side effect of decarbonisation
- Dietary changes (especially less meat consumption) due to changing preferences or changes in agriculture related to climate change mitigation

In addition to direct effects on the health of policyholders, indirect effects on future cash flows are also possible via new business and lapse rates – triggered primarily by changes in economic development in connection with the fight against climate change. In this respect, in addition to acute and chronic physical risks, **transition risks** can also play a role for personal insurance. Changing macroeconomic conditions can potentially affect the behaviour of all policyholders. Employees in companies particularly affected by the economic transformation could suffer above-average economic detriment, including unemployment. Contracts for the occupational pension scheme of employees there could therefore represent a cluster risk with regard to transition risks.

Due to the discounting of future payments, the valuation of technical provisions in life insurance is also heavily dependent on **interest rate developments**. Capital market development also plays a role in the amount of the expected payments for the contracts with surplus participation that are customary in Germany. This is also primarily a question of interest rate developments. Reference is made to Chapter 4 in this respect.

The effects of climate change and its mitigation (apart from the interest rate issue) may ultimately be reflected in realisations of the usual underwriting risks:

- Mortality risk
- Longevity risk
- Disability risk (life insurance: occupational incapacity, long-term care, disability, dread disease, etc.)
- Morbidity risk (health insurance)
- Lapse risk
- Cost risk

However, it must be examined whether possible effects on the underwriting of personal insurance would also be **material** and whether they can be quantified at all in a meaningful way. This can be done by first analysing qualitatively the risks relevant to one's own insurance portfolio and what impact they could have. Depending on the results, quantitative analyses may follow.

[114] Cf. e.g. Federal Environment Agency (2021), Chapter 4.
[115] Cf. Federal Statistics Office (2022).

In this case, the biometric assumptions / second-order actuarial assumptions must be adjusted for climate scenario-related effects in the projections for determining the best estimate of the technical provisions in a climate scenario (such as Delayed Transition or Current Policies).

If it is to be determined how high the **SCR** would be in this scenario (and at this point in time), the usual (standard formula) stresses must then additionally be applied to the biometric calculation bases/assumptions already adjusted for the climate effects.

Particularly for the long-term studies, an adjustment of the standard formula stresses to the changed conditions applicable in the respective climate scenario would also be conceivable in principle. However, it should be noted that the uncertainty of the analysis increases further if not only central values (best estimates), but also values of future mortalities and the like far out in the distribution (99.5th percentile) have to be determined. Even if stochastic methods were to deliver corresponding values, there is still the problem that changes in risks cannot be translated one-to-one into changes in regulation. When, to what extent, and whether at all standard formula risk factors will be adjusted in the future depends on political processes and cannot be predicted purely on the basis of risk data. Therefore, an adjustment of the standard formula stresses within the calculations can generally not be expected.

In the following, the relevant effects of climate change on the underwriting of personal insurers are described.

5.2 Risks to life and health

This section, which deals with risks to life and health, is not structured according to the classic risk categories, but according to influencing factors such as temperature and air pollution. The reason for this is that the risks of mortality/longevity, disability and morbidity can in principle all be affected by the respective influencing factors.

5.2.1 Temperature

Within certain limits, the human organism can adapt relatively well to different temperature conditions as they prevail in the various current climatic zones of the earth. As climate change progresses, however, these limits could be exceeded during hot spells in some already hot parts of the world.[116]

Apart from these extreme situations, short-term, unfamiliar changes have a particularly stressful effect on the organism. In Central Europe, it is not so much the increase in average temperature, but primarily a decrease in cold waves and an increase in the frequency and magnitude of heat waves that are directly relevant to health. Both acute cold and acute heat stress affect mortality. In the case of heat waves, it is not only the height of the temperatures but also the duration that leads to an increase in the number of deaths. If it is primarily older and weakened people who fall victim to the temperature stress, increased mortality may at the same time lead to a decrease in medical costs for insurers.

Heat as a major threat to human health in Europe is the subject of a recent report by the European Environment Agency.[117] Taken from this report, Figure 24 shows the regional distribution of the increase in heat-related mortality in Europe over the last twenty years. In fact, the effects are likely to differ much more at the local level, since especially densely built-up inner cities heat up more and in particular cool down much less at night than their surroundings.

For an analysis of the further impacts of climate change expected in the future on mortalities in heat waves or cold waves, see Gasparrini et al. (2017). It is shown that in all global warming scenarios, as expected, the excess mortalities caused by cold waves decrease, which have so far been worldwide much more significant than heat-related excess mortalities. Conversely, excess mortalities caused by heat waves are increasing, depending on the scenario and region, even very significantly.

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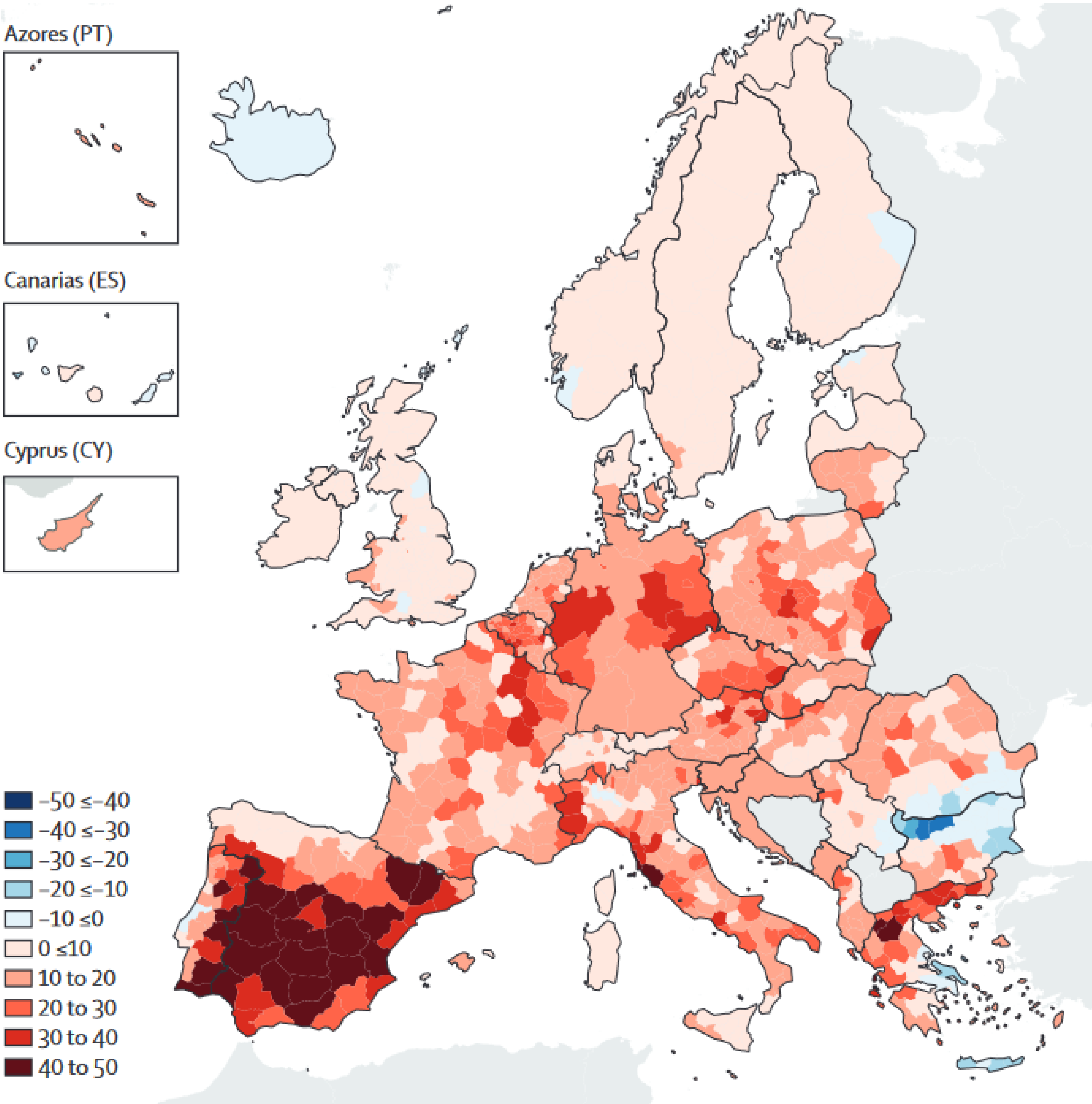
116 This impending development in other parts of the world will not be discussed further here, as it is generally not directly related to the ORSA of German insurance companies. However, this thematic focus should in no way obscure the human suffering involved.

117 Cf. EEA (2022), pp. 16–34.

Regional distribution of heat-related excess mortality

Figure 24 · Regional distribution of increase in heat-related mortality in Europe from 2000 to 2020, expressed as change in annual deaths per 1 million inhabitants per decade



Source: Van Daalen et al. (2022)

The ORSA should therefore examine the extent to which a company's insurance portfolio is exposed to excess mortality from heat and/or cold waves. In life insurance, opposite effects are to be expected in principle: While higher mortality rates for annuity insurance policies result in financial relief for the insurance company (focus on age 65+), there are burdens for death benefit insurance (focus primarily on the age range 20 to 60, in principle also contracts with funeral expenses insurance in the age range 65+). Which effect predominates is company-specific and may well be relevant in the case of monoliners, for example, while in the case of a highly diversified portfolio it may also be appropriate to assume that on balance there are no relevant effects.

Figure 25, taken from Gasparrini et al. (2017), provides a possible approach to quantification. It shows heat- and cold-related excess mortality by decade in nine regions and under three IPCC climate change scenarios (RCP 2.6, RCP 4.5, and RCP 8.5). Estimates are given as average decadal proportions of the general-circulation model ensemble. The shaded areas represent 95% of the empirical confidence intervals. The IPCC scenario RCP 2.6 can be used as an approximation for the Delayed Transition scenario. The Current Policies scenario corresponds to the IPCC RCP 6.0 scenario not shown here, but an averaging between RCP 4.5 and RCP 8.5 should provide a good approximation, resulting in a steady increase to about 5% excess heat wave mortality in the long run for Central Europe.

5.2.2 Air pollution

In recent decades, air quality in Germany and Europe has improved greatly with regard to most pollutants. At least the days of significantly increased sick leave and mortality during periods of winter smog are over in this country. Nowadays, especially pollution with particulate matter (PM), and partly also with nitrogen dioxide (NO_2) and ground-level ozone (O_3), pose a health risk.[118] High and/or prolonged exposure to pollutants can in particular lead to respiratory and cardiovascular diseases, and continues to notably increase mortality.

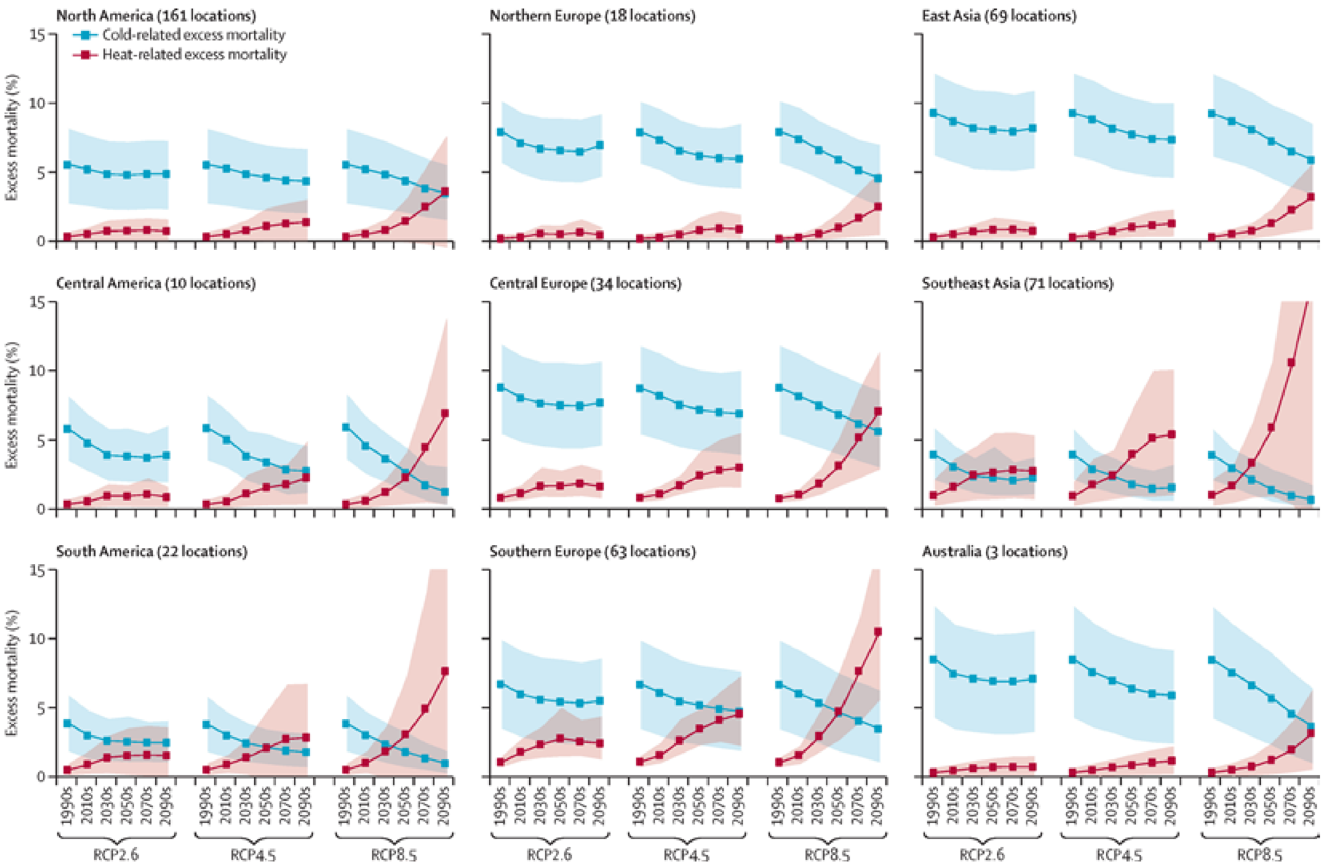
Globally, the loss of life years due to air pollution is estimated at an average of nearly three years per person, exceeding even the effects of tobacco smoking.[119] For Europe, the estimate is 2.2 years, including 1.7 years from preventable man-made sources. This corresponds

118 For an initial overview of air pollutants in Germany see Umweltbundesamt (Germany's Federal Environment Agency).

119 This applies to all people (smokers and non-smokers taken together). Cf. Lelieveld et al. (2020).

Heat and cold-related excess mortality

Figure 25 · Development of heat- and cold-related excess mortality in different regions and IPCC scenarios



Source: Gasparrini et al. (2017), p. E365 to almost 800,000 and just over 600,000 premature deaths in Europe per year, respectively.

Should a decrease in air pollution occur as a side effect of measures to limit global warming, correspondingly notable influences on mortality or disability/morbidity are conceivable. For insurance companies, declines in illnesses caused by air pollution could have a positive impact on underwriting results. Declines in premature deaths, on the other hand, could have different effects in annuity and death cover.

With regard to possible quantifications, reference is made to Figure 26 taken from Silva et al. (2016) as an example.[120] The graph shows ozone-related mortality in 2030, 2050, and 2100 for ten regions and under four IPCC climate change scenarios (RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5) compared to year 2000 levels.[121] The global projected change in ozone-related mortality is significantly influenced by developments in India and East Asia, whereas the impact in Europe and other regions is more modest. Moreover, the estimates currently available in the literature are fundamentally subject to a high degree of uncertainty. If, for example, the estimation uncertainty (in the form of confidence intervals) is used for the values shown for the RCP 8.5 scenario, it cannot be ruled out for Europe that the projected mortality will be the same as in the Baseline scenario.

With respect to particulate matter, effects caused by climate change mitigation measures are even more difficult to assess. This is because particulate matter comes from many different sources (agriculture, bulk material handling, industry, road transport, energy, wood firing), whose emissions should decline only in part in the course of decarbonisation.[122]

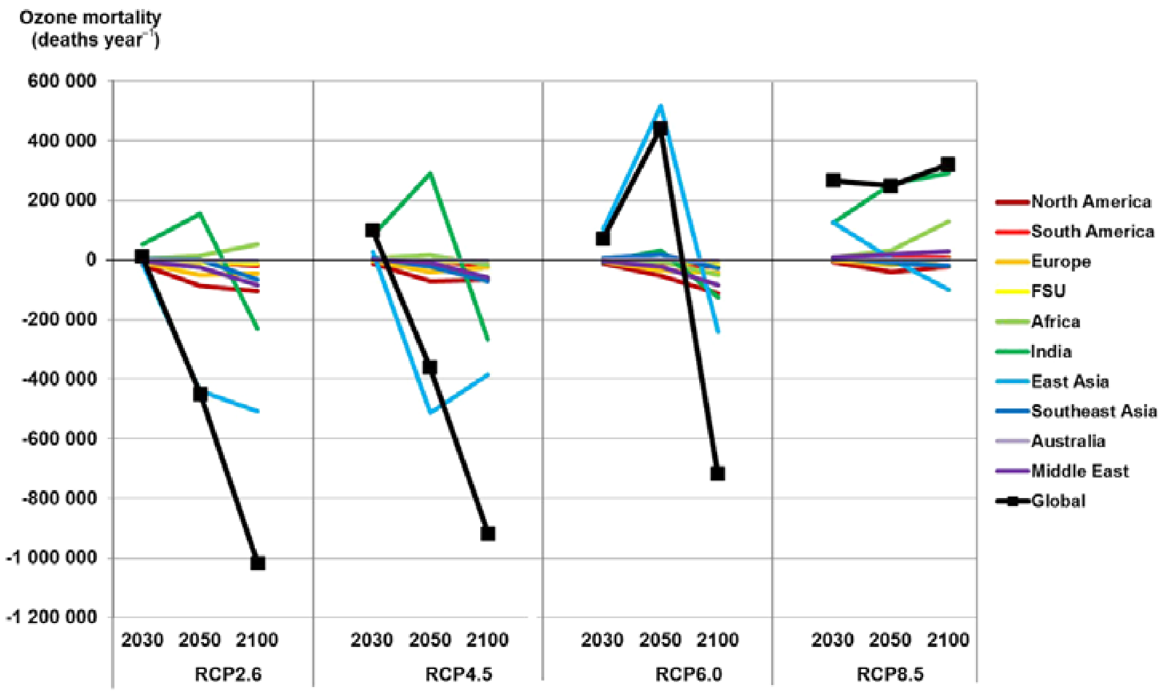
120 See also von Schneidemesser et al. (2020) for a review of the current state of the literature.

121 The IPCC scenario RCP 2.6 can be used for the Delayed Transition scenario; the Current Policies scenario corresponds to the IPCC scenario RCP 6.0 (see Section 2.2.1).

122 For the various sources of particulate matter, see e.g. Umweltbundesamt (Germany's Federal Environment Agency).

Pollutant-related excess mortality using the example of ozone

Figure 26 · Evolution of excess mortality caused by ozone pollution as an example of excess mortality caused by different air pollutants in different regions and IPCC scenarios



Source: Silva et al. (2016), p. 9853

5.2.3 Other potential health hazards

In addition to the at least rudimentary quantitative analyses presented in Sections 5.2.1 and 5.2.2 above, it is conceivable that further aspects could be taken into account on a qualitative basis for individual companies.

Increased exposure to UV radiation

Climate change can, also in Germany, lead to an increase in UV radiation exposure. Causes include influences of greenhouse gases on the stratospheric ozone layer and declining cloud cover. In addition, there may be human behavioural changes with more time spent outdoors due to higher temperatures.[123] As a result, the risk of skin and eye cancer increases.

In principle, this could have an impact primarily on disability (occupational disability insurance) and medical costs (morbidity), with professions practiced outdoors being affected first and foremost.[124]

Spread of infectious diseases

The spread of novel infectious diseases may become relevant primarily for the development of disease costs (morbidity), but also for mortality under certain circumstances. The temperature changes ensure that pathogens will penetrate new areas and bring corresponding risks for the people living there. In addition, the changes in precipitation, wind, and heat may also alter threats from other diseases (not transmitted by new pathogens).

Climate change may now allow species that were unable to establish viable populations under historical and current conditions to become established outside their previous range. If insects are involved that harbor pathogens that are problematic for humans (viruses, bacteria, parasites) and can transmit them, e.g., through bites, then their spread also creates a health problem.[125] However, high temperatures can also limit pathogens in some circumstances.

The likelihood that various diseases will become more widespread is increasing, according to the Lancet Countdown report[126] on the impact of climate change on health. Thus, outbreaks of dengue or Zika fever are also becoming more likely in Europe. According to the studies, more bacteria are also settling in northern Europe and the United States, which can lead to wound infections, among other things.

More detailed accounts of the growing threat of climate-sensitive infectious diseases in Europe can be found in the European Environment Agency report already referred to in Section 5.2.1.[127]

Extension of the growing season and spread of neophytes

The spread of neophytes and an extension of the growing season may have an impact on the development of disease costs (morbidity), e.g. through increased and prolonged exposure to allergens to allergies or increasing chronic respiratory diseases (asthma). In the case of mainly outdoor occupations, this could also affect incapacitation.

Human factors

In the context of climate change, an increase in **mental illness** is also conceivable. Causes may lie in individual consequences of economic development as well as in the recognition of climate change and the way mankind deals with it. In addition, increased acute mental health problems, including suicide, may occur during heat waves.[128]

On the other hand, health-promoting changes may also occur. In addition to the reduction in air pollution already discussed, in particular behavioural changes that serve to mitigate climate change could also have a positive impact on health at the same time. These include, above all, a healthier **diet** with less meat consumption, as well as greater **physical activity**, when more trips are made by bicycle or on foot.

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123 See e.g. Bundesamt für Strahlenschutz (Germany's Federal Office for Radiation Protection).
124 Cf. GERICS Climate Service Center Germany (2020).
125 Diseases can be transmitted by birds or mammals in addition to insects.
126 See Romanello et al. (2021) and Sustainable Insurance Forum (2021).
127 See EEA (2022), pp. 36–52.
128 Cf. Thompson et al. (2018).

Climate-induced **migration** can also become relevant in principle to the calculation of technical provisions.[129] Although the effect is difficult to measure due to the complexity and multi-layered nature of migration processes, climate change is one of the key factors that can set migration movements in motion. Mass migration may, in turn, trigger a change in social structures in destination and origin areas that might increase the uncertainty of calculation bases.

Overall, a large number of – in some cases contrary – climate-related effects on health are conceivable, but these cannot be meaningfully quantified with current knowledge. They merely increase the uncertainty of future developments. Thus, at least in the Delayed Transition scenario with lower global warming, no adjustment in disability and medical costs should generally be required. Even in the case of a stronger temperature increase in the Current Policies scenario, an adjustment does not appear to be absolutely necessary, but potential special exposure, e.g. in the case of many insured persons with outdoor occupations, should be checked.[130]

5.3 Lapse risk

Lapse probabilities are part of non-biometric actuarial assumptions and have a significant impact on a company's cash flows.

Effects of cancellation changes

The cancellation of an insurance contract, i.e. the unilateral termination of the contract by the customer, can represent a financial loss for the insurance company. Cancellation not only results in a loss of future profit opportunities, but also interferes with the existing risk balance in the insurance collective, be it through an emerging anti-selection or through a change in the intergenerational balance of risk capital.[131] However, depending on the conditions of the contract and its term, the cancellation of an insurance contract by the policyholder can also represent an opportunity for the company. A lapse risk arises for a company when a change in lapse behaviour in the insured collective results in a financial disadvantage.

A change in lapse behaviour primarily affects endowment life insurance policies. For occupational disability insurance, the drivers mentioned here are not expected to influence lapse probabilities, since the repeated health check-up makes it difficult for a customer to take out occupational disability insurance again at a later date, and a lapse therefore offers little advantage, especially if the customer's financial situation is unfavourable.

Triggers of cancellation changes

In practice, it can be observed that policyholders do not primarily follow financially rational considerations in the sense of capital market theory in their lapse behaviour, but that their lapse behaviour is primarily related to their personal situations and their personal acute need for capital.[132] In addition to drastic private life events that balance out in the insured collective, the experienced economic situation of an insured person is in particular also related to his or her income situation and therefore correlates with the situation on the labor market, described by the current unemployment rate. The overall economic situation in the form of gross domestic product can also influence the economic situation experienced by a policyholder if a recession causes order books to deteriorate or if a hoped-for improvement in the economic situation fails to materialise. As already addressed in Section 5.1, occupational pension contracts of employees who work in companies that are particularly affected by the transition and who are accordingly threatened with economic disadvantages could therefore possibly represent a cluster risk with regard to transition risks.

In addition, natural catastrophes can also lead to acute capital requirements on the part of policyholders and thus to the cancellation of insurance contracts. A correlation with flooding events as a result of heavy rainfall, wildfires close to settlements, or extreme windstorms would be conceivable in this regard. However, since all these events are regionally confined, a regionally well-diversified portfolio should only be affected to a minor degree by them.

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129 Rising temperatures, rising sea levels, changing precipitation patterns, melting glaciers and thawing permafrost, increasing extremes of weather, and more frequent natural catastrophes (such as floods or wildfires) can threaten livelihoods, exacerbate (resource) conflicts, and make the homes of millions of people temporarily or permanently uninhabitable.

130 People with chronic diseases as well as the elderly, pregnant women, infants and children may also be affected more severely under certain circumstances.

131 Cf. DAV (2022).

132 Cf. DAV (2019).

Procedure and classification

Companies can determine whether their portfolios correlate with historical time series relating to unemployment or gross domestic product (GDP) in terms of lapse probabilities. If a correlation is found, the currently valid best-estimate assumptions can be extrapolated using NGFS projected drivers (such as unemployment or GDP).[133] In the context of a complete scenario, this method can be used to identify advantages and disadvantages resulting from the development of lapse behaviour.

In Germany, as a result of the global financial crisis (GDP change −5.7% in 2009), there was a certain wave of cancellations in life insurance around 2010, while no wave of cancellations was observed in the wake of the Covid 19 pandemic, which was also associated with a significant decline in GDP (−3.7% in 2020). In the Delayed Transition scenario, GDP merely stagnates in 2031 (no decline). In principle, the shock of the unexpected start of the transition might nevertheless have an influence on lapse behaviour, however, a pronounced wave of cancellations analogous to the financial crisis is rather not to be assumed. Another question is for which contracts and in which situations a higher lapse rate would be disadvantageous for the insurance company at all or possibly also advantageous.

5.4 Cost risk

Cost risk captures the risk of loss or adverse change in insurance liabilities resulting from changes in the amount, trend or volatility of costs incurred in the administration of insurance contracts. Fluctuations in all costs used to fulfill insurance contracts are taken into account.

The standard SCR formula assumes a 10% increase in the costs taken into account in the calculation of technical provisions and a 1% p.a. increase in the cost inflation rate.

To estimate the impact of climate change risks on cost risk, the evolution of inflation rates according to NGFS scenarios could be used (see Section 4.6.7). In particular, under the Delayed Transition scenario, assumptions with higher cost inflation in 2032–2036 could be at issue. The appropriateness of these assumptions should be reviewed on the basis of the specifics of the individual company.

133 See Section 4.6.8 and Section 4.6.1 respectively.

6. Effects on property/casualty insurance

6.1 Approaches to quantifying the risk of change in physical risks

The climate models provide quite concrete statements about the development of mean temperatures. Somewhat less concrete assertions can be made about other climate parameters, with the assertions referring predominantly to the mean values of these variables. For the risk assessment by insurance companies, however, not only the development of the mean values is decisive, but so is the development of the probability distributions, with a very special focus on the more extreme part of the distribution ("tail"; in the context of Solvency II often the 1-in-200 year event). There are significantly fewer conclusions in this regard. Moreover, these are usually formulated in a much more vague manner. Suggestions will be made below as to how certain assertions about insurance risk can be derived from the available conclusions about climate parameters. These are of the nature of model calculations, as are the approaches in the previous chapters.

For example, the following types of assertions about climate parameters can be found in the literature (see also Section 6.2):

- The frequency of *xxx* events is likely to increase.
- The frequency of *xxx* events is increasing by *a*% per degree of warming.
- The frequency of *xxx* events is increasing by x_1%, up to a severity of y_1 and by x_2% from a severity of y_2.
- The expenditure for *xxx* events is increasing on average by *a*% per degree of warming..

The placeholder *xxx* can stand for windstorm, hail or heavy rain, for example.

The following approaches can be taken to "translate" these assertions into actuarial terms:

The risk is also usually described in the ORSA by a cumulative probability distribution $F(x)$. The variable x describes the damage and the function F the probability of not exceeding the damage x. Usually, one considers the annual damage x and the function F only for such high x that $F(x)$ is already "close to 100%". Then 100% – $F(x)$ describes the probability of exceeding the annual loss x in one year. The reciprocal is the often-discussed "return period" or "annuality." In many cases, the probability distribution of individual (cumulated) events is also considered, which can be reconciled into total annual losses.

- It is assumed that all loss events increase homogeneously by a fixed factor a . This would be one way to map a corresponding projected increase in expected value. Instead of the damage x, it is natural to consider in the scenario the damage increased correspondingly by the factor a, i.e. $a * x$: This has the same probability as the damage x today, so consider $F(x/a)$ as the probability distribution in the scenario vs. $F(x)$ in the current risk assessment.

  This is the right approach, especially when accounting for inflation, increases in value, and increases in portfolios. This can be combined with other approaches to account for these effects.

- It is assumed that (only) the frequency of events changes. This can be implemented in an obvious way in the risk assessments:

  - If a combination of (cumulative) distributions of number of claims and loss amounts is used, it is natural to implement the increase in the expected number according to the climate model in the parameters of the distribution (of number of claims) used.

- If a loss-event table is used to model the total annual loss, an adjustment equal to the increase in the expected number anticipated by the climate model can be implemented when calibrating the frequency.
- If a the distribution function is represented analytically to approximate the total annual loss distribution in high quantiles, the overshoot probability can be adjusted accordingly.

→ A change in the distribution of the individual accumulatedloss is assumed. Then, a predicted change in accumulatedloss amounts is not to be mapped by changing a scale parameter, as the latter is more appropriate to map volume or price changes. In return, any used distribution of accumulated loss amounts would have to be adjusted beyond a mere change of scale:

- To reflect an increase of the expected value that the climate model predicts, a suitable change of the parameters, e.g. of the exponent of a Pareto distribution, can be calculated.
- To account for a shift of, for example, two data points of the accumulative loss distribution that the climate model predicts, a suitable change of the parameters of the two- or multi-parameter distribution can be determined.

When using loss-event tables, different weighting of modeled events can be considered depending on their modeled return period.

6.2 Physical risks

For an in-depth, quantitative analysis of physical risks, information on severity, frequency, return periods for all risks to the affected lines of property/casualty insurance and for the different time horizons would be necessary. This information is not included in the NGFS climate change scenarios. Using the methodological approaches from Section 6.1 above and the information from this section, the impacts of climate change can be estimated to some extent. The risks of windstorm, flood, hail, and forest fire/drought are considered in the subsections below. For the risks flooding and hail, possible approaches for quantification are explained as examples.

6.2.1 Windstorm

The effects of climate change on windstorm risk can be considered both in aggregate and in a differentiated manner. A distinction can be made between extreme events such as tropical cyclones, general windstorm events, and short-term events such as tornadoes. Different granularities in approach can be found in the various studies on the topic of windstorms.

Windstorm risks affect property insurance by way of their private and commercial risks. Other affected lines include motor (vehicle) own-damage insurance and transport insurance.

The studies do not paint a consistent picture of the future development of windstorm risk. Particular attention is paid below to the NGFS scenarios and the "JRC PESETA IV" study (JRC, 2020), since extensive data material on the various temperature increase scenarios is available in them.

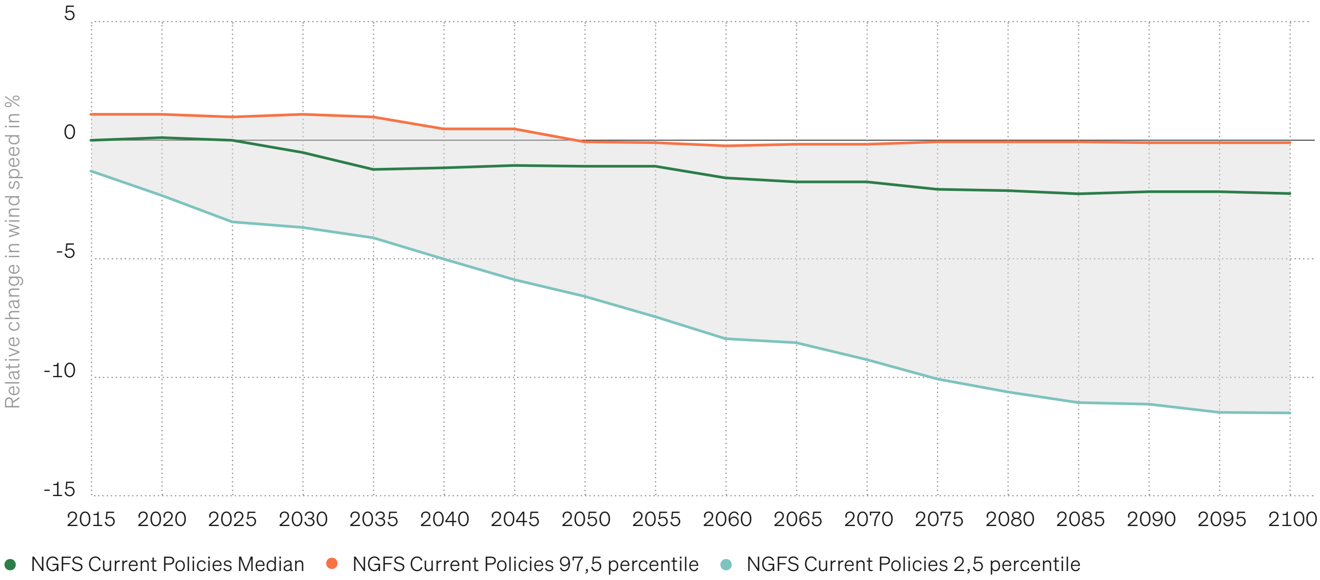
When assessing trends in terms of general windstorm events, it is helpful to look at the number and intensity.

For the NFGS scenarios, the relative change in wind speed was modeled for Germany and per federal state. The years from 1986 to 2006 were used as a reference value. In the relevant NGFS scenarios, the median relative change nationwide falls below 0% from 2025 onward. The upper limit remains at 1% or decreases (see Figure 27).

The JRC PESETA IV study analysed, among other things, the number of calm days and the change in wind speed during 100-year events in Europe. Europe was divided into four areas: "northern", "central western", "eastern" and "southern" Europe. In central western Europe, which includes Germany, the number of calm days increases in most regions in all three scenarios, according to the results from this study. For the 100-year events, wind speed remains the same or decreases in some regions. In only a few regions, however, an increase of more than 0.3 m/s is simulated (see Figure 28). Mean annual windstorm expenditure in Germany is seen to be 0.03% of GDP in all three temperature scenarios (excluding socio-economic changes, see JRC PESETA IV Task 13).

Wind speed in the Current Policies scenario

Figure 27 · Development of wind speed (changes in percent) in the Current Policies Scenario

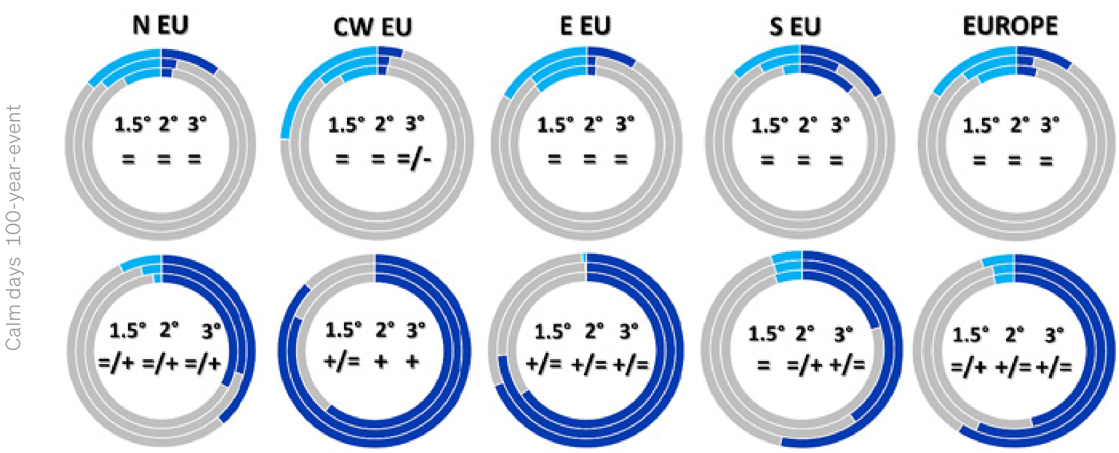


Source: Own illustration based on data from the Climate Impact Explorer

For tropical cyclones, there is no robust trend in Europe according to the JRC PESETA IV study. Meanwhile, the models behind the NGFS scenarios also yield insights into tropical Cyclones in Germany, after which significant increases are to be expected. However, this finding is not considered robust by the scenario creators. According to them, the related results will be removed from the NGFS Scenario Explorer. Tropical cyclones in Germany are therefore still to be classified as unlikely.

Wind speed in different warming scenarios

Figure 28 · Development of wind speed during 100-year events and number of calm days in Europe. The figure indicates the area fraction (as a %) for each region (northern Europe, central western Europe, eastern Europe, southern Europe) with significant increase (dark blue), no change (gray) and decrease (light blue)). The change in 100-year wind speed is significant if it is greater than 0.3 m/s and 2/3 of the models agree on the sign of the change. The change in the number of windless days is significant if it is more than 5 days and 2/3 of the models agree on the sign of the change. The inner circle represents 1.5°C, the middle one 2°C, the outer one 3°C warming.



Source: JRC (2020), Figure 7

Tornadoes are short-term storm events that affect a limited area. No assessment regarding a possible increase in frequency or intensity for Germany due to climate change is currently apparent.[134]

The results of the studies considered certainly do not provide a conclusive picture of the influence of climate change on windstorm risk. They are even inconsistent in terms of their basic message, but suggest an unchanged to lower windstorm risk. Qualitatively and intuitively, this can be justified by the convergence of temperature between the poles and the equator. The temperature increase caused by climate change is highest at the poles and lowest at the equator. Because of the temperature convergences, there is less temperature equalisation through storms. However, extreme events with violent windstorms may still occur.

There are other studies (see separate collection of materials*) dealing with the development of windstorm risk, from which a wide range of conclusions can be drawn.

Companies should therefore focus on the particular objective of the scenarios when designing their ORSA scenarios, as well as consider the materiality of the impact of climate change on windstorm risk. In particular, companies must individually determine the impact of climate change on the windstorm risk assumed in the ORSA.

Only the development of the average annual expenditure from windstorm damage can be seen from the aforementioned studies. In terms of volatility, standard deviation, annualities, return periods, etc., the available data are very thin. In order to nevertheless be able to make assertions on this in the ORSA scenario, assumptions must be made. One possible assumption would be to assume that the coefficient of variation for windstorm risk remains unchanged, i.e. the standard deviation increases as much as the mean annual windstorm loss due to climate change. More generally, one can say that the coefficient of variation increases by a factor to be determined by expert estimation. Given the development of mean windstorm expenditure as well as the development of the standard deviation, statements on the development of windstorm risk can then also be made, e.g. by moments estimation of a suitable extreme value distribution such as lognormal, Pareto or (inverse) Burr distribution and evaluation of the 99.5% quantile.

6.2.2 Flood

Flood risk considers the risk of damage caused by normally dry ground area being completely covered by water. Flooding occurs whenever surface waters overflow or ground is inundated by heavy rain events. Reasons for flooding are manifold. They range from snowmelt and sewer backups to heavy rain events. Only heavy rainfall and river flooding are considered below, as they are of high importance. Heavy rainfall is rather analysed qualitatively, whereas riverine flooding is also treated quantitatively because of the relatively solid data available.

Flood risks particularly affect property lines, i.e. building insurance, content insurance, motor (vehicle) own-damage insurance, but also commercial property insurance including business interruption insurance.

Heavy rain

In the study by Knist et al. (2020), the change in extreme precipitation in central Europe was simulated for the RCP 4.5 scenario for the middle of the century (MOC) and for the end of the century (EOC). The simulations were performed with a spatial resolution of 12 km and 3 km, respectively. The relative change in simulated hourly precipitation at the 99.9% quantile in summer (JJA) and winter (DJF) mid- and late-century, respectively, is shown in the more detailed spatial resolution in Figure 29. The RCP 4.5 scenario closely resembles the Current Policies scenario in its temperature trajectory through mid-century. Therefore, for an observation period up to 2050, the results simulated in the study can be used for a predicted change in heavy rainfall. According to this, the amount of precipitation increases in the geographic mean by about 5% in the 99.9% quantile for both summer and winter. It can be seen from the left graphs in Figure 29 that there are considerable regional differences, ranging from 40% decreases to 40% increases. In even more extreme quantiles, the increase for summer in the geographic mean is even much higher, e.g. more than 10% in the 99.99% quantile (see Figure 30, WRF3_12 MOC curve).

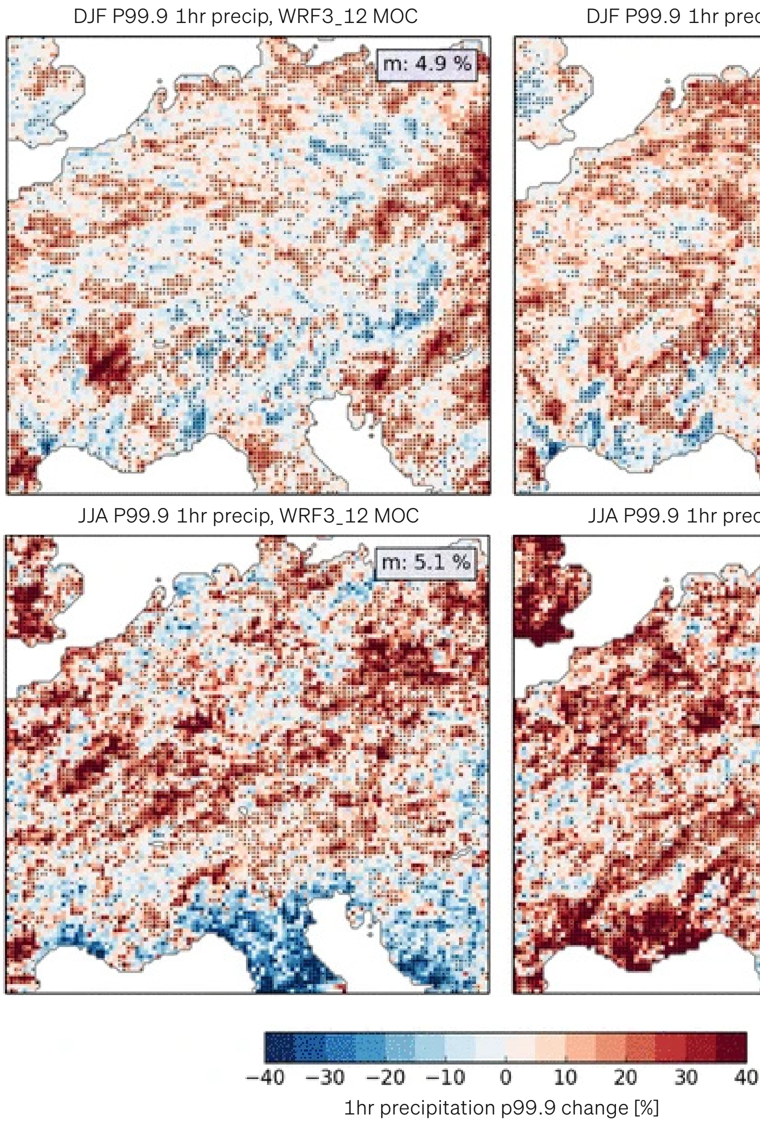
[134] Cf. Germany tornado list .

*as of the beginning of 2022, and only available for members of the German Insurance Association

For winter, on the other hand, the simulations predict a percentage increase of about 5% even in the more extreme quantiles. This information can be used to estimate future exposure to heavy rain events. For a quantitative analysis, the assumption of a correlation between the change of precipitation amounts and the change of loss amounts would still have to be made. Here, it can be assumed that the amount of loss increases disproportionately to the amount of precipitation. By the end of the century, the temperature increase of the RCP 4.5 scenario is far below that of the Current Policies scenario. Therefore, the results included in the study through the end of the century (right graphs in Figure 29) with a geographical mean increase in hourly precipitation of more than 10% and an increase of more than 20% in the 99.99% quantile (Figure 30, WRF3_12 EOC curve) can only be used to estimate a minimum change in the Current-Policies scenario.

Change in hourly precipitation in the 99.9% quantile

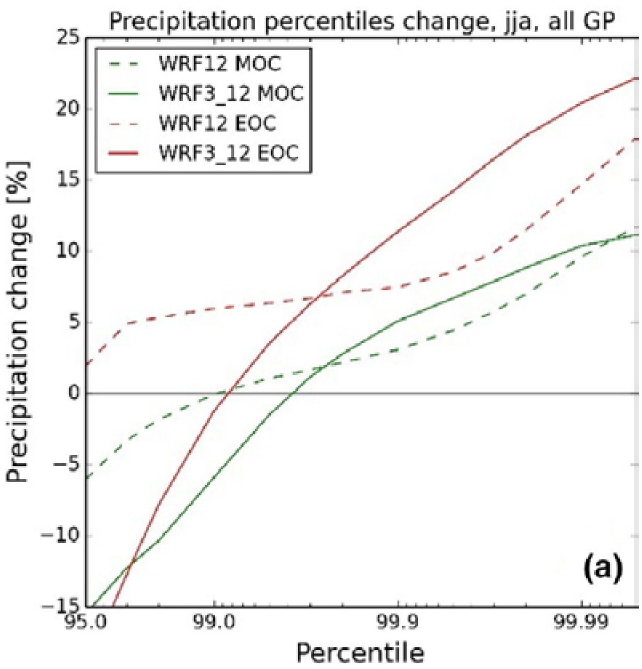
Figure 29 · Percent change in hourly precipitation at the 99.9% quantile at a spatial resolution of 12 km (calculated as mean values from simulations at a spatial resolution of 3 km) in winter through mid-century (top left graph) and end of century (top right graph), respectively, and in summer through mid-century (bottom left graph) and end of century (bottom right graph), respectively, from Knist et al. (2020). The meaning of the colors in the cards can be found in the legend below. Geographical mean values in the graphs at the top right.



Source: Knist et al. (2020), Fig. 8

Change in hourly precipitation in different quantiles

Figure 30 · Percent changes in hourly precipitation at various extreme quantiles in summer in simulations with a spatial resolution of 12 km calculated as averages from simulations with a spatial resolution of 3 km (solid curves) and also 12 km derived directly from simulations with a spatial resolution of 12 km (dashed curves) by middle of century (MOC) and end of century (EOC) from Knist et al. (2020).



Source: Knist et al. (2020), Fig. 11, subfigure on the left above

River floods

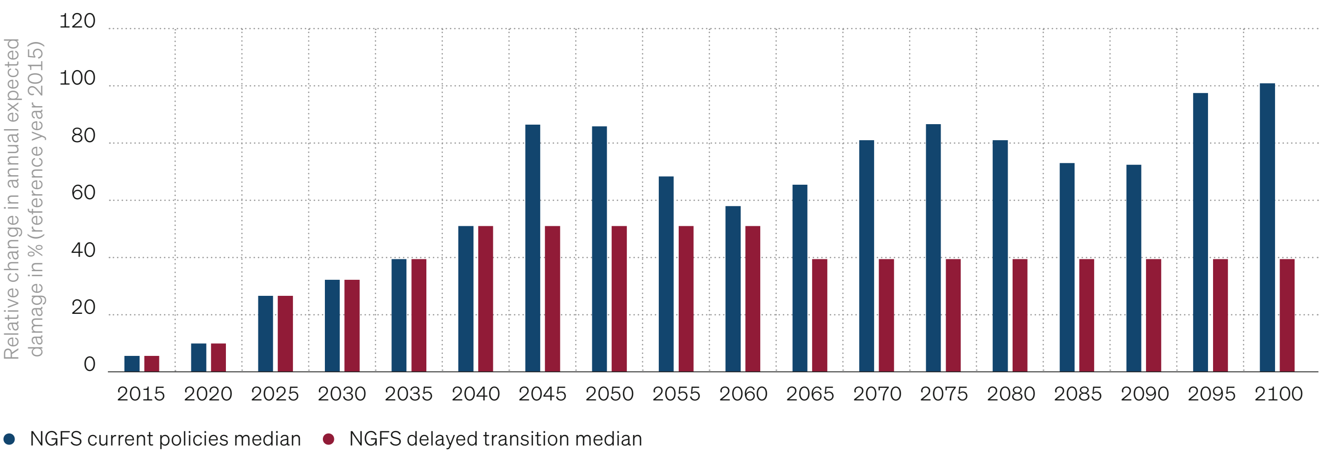
The Climate Impact Explorer provides detailed information on river flooding for the NGFS scenarios, as is discussed in more detail below. Of particular note here is the modeling of the change in annual expected damage from riverine flooding for the various climate trajectories. The data (Figure 31) are provided at five-year intervals for the whole of Germany and a large number of other countries, using 2005 as the reference year. In the Delayed Transition scenario, the median relative change increases to +51% by 2040. From the year 2060, the median slowly decreases again until it reaches +39% in the year 2100. In the Current Policies scenario, the median relative change increases to +86% in 2045. While it moves in a corridor between +58 and +86% for the following 30 years, it always reaches new highs of +97% in 2095 and +101% in 2100.

The evolution of these variables can be interpreted as the evolution of the gross loss requirement for river flooding. Assuming that the loss requirement in all regions (or CRESTA zones) of Germany develops in the same way, companies could therefore extrapolate their loss demand for floods from the reference year 2005 according to the relative change in the annual expected loss to obtain the gross loss requirement for the two climates under consideration. The effect of reinsurance can then be taken into account in a second step using one of the approaches from Section 6.3.

With regard to volatility, standard deviation, quantiles, annualities, return periods, etc., no data are available in the Climate Impact Explorer. In order to be able to provide information on this in the ORSA scenario,

Damage from river floods

Figure 31 · Evolution of annual expected damage from river flooding for the Current Policies and the Delayed Transition scenarios in Germany



Source: Own illustration based on data from the Climate Impact Explorer however, assumptions must be made. Possible assumptions are presented in Section 6.1. For example, the following assumptions seem plausible:

- It could be assumed that the coefficient of variation for flood risk remains unchanged, i.e., the standard deviation increases as much as the mean annual flood loss due to climate change.

- A Pareto distribution with a suitable expected value and standard deviation could be assumed for the actual loss distribution. The parameter of the Pareto distribution could now be adjusted in such a way that the change in the expected value given by the NGFS data is reproduced. The change in quantile values can then be read approximately from the adjusted distribution.

  The same approach could be used to parameterise a Gumbel distribution, which may even seem to be a better fit from a scientific point of view. The advantage of the Pareto distribution is that it is particularly tail-heavy and thus conservative. If a Gumbel distribution is used instead, more effort should be put into diagnosing that this distributional assumption is appropriate.[135]

Sample implementation:
Below, we outline two possible approaches A and B for quantifying climate change risks for flood risk before reinsurance. Many other approaches seem equally appropriate, especially hybrids of A and B. For consideration of reinsurance, please refer to Section 6.3.

In **Procedure A**, we consider the impact of a 200-year flood event on the regulatory solvency situation in the Current Policies scenario at future points in time, e.g. in 2100, compared to the current situation. We calculate a 200-year flood event in 2100 in our own risk assessment. We further assume that this 200-year flood event materialises during 2100 and then perform an SCR and own funds calculation on the reporting date of 31 December 2100 in accordance with the standard formula, in which the event that has occurred shows up as an capital investment outflow assuming rapid settlement. The resulting coverage ratio is compared to that which would result after the hypothetical occurrence of a 200-year flood event in the current year.

In **Procedure B**, we consider the overall solvency needs in Pillar II. Again, we calculate a 200-year flood event in a future year, such as 2100. This time, we perform a calculation of the overall solvency needs and own funds on the reporting date of 31 December 2100, taking into account the change in flood risk. In this approach, we primarily see a changed risk and, as a consequential effect, a changed risk margin and changed own funds.

The following data apply to our sample company:

Assumptions for sample company

Table 5 · Selected notional assumptions. The average annual flood loss is determined from the company's loss history for the last 10 years, for example.

VARIABLE	VALUE
Scenario considered	Current Policies
SCR	100
SCR_Flood	20
OSN	80
OSN_Flood	15
Risk margin_SCR	30
Risk margin_OSN	24
Own funds_SCR	200
Own funds_OSN	206
Mean annual flood loss	2

[135] For the example figures used below, the result is a Gumbel distribution whose distribution function at the zero point has the value 0.3134, i.e. the probability of negative expenditure from flood damage is more than 30%. Thus, it would have to be demonstrated here that this distribution assumption nevertheless leads to appropriate quantile assertions.

Procedure A

Step 1: To determine the 200-year flood event in our own risk estimate for 2100, we first fit a Pareto distribution to our current expected value 2 and current 99.5% quantile 15. To do this, let our random variable be X Pareto-distributed $Par(k,x_{min})$ with parameters $k>0$ and $x_{min}>0$. For example, using the solver in Excel, we can solve the following system of equations:

$$E(X) = 2 = x_{min} \cdot \left(\frac{k}{k-1}\right)$$

$$99.5\% = 1 - \left(\frac{x_{min}}{15}\right)^k$$

We receive[136]

$$k = 1.93029$$

$$x_{min} = 0.96388.$$

Now, the parameters are to be changed so that the distribution in 2100 reflects the increased mean annual flood loss of[137]

$$2 \cdot 182.6\ \% = 2 \cdot \frac{1 + 100.5\%}{1 + 9.8\%} = 3.65267.$$

As suggested in Section 6.1, we do this by adjusting the parameter k of our distribution and leaving x_{min} unchanged. Via the equation

$$E(X) = 3.65267 = x_{min} \cdot \left(\frac{k}{k-1}\right)$$

we determine analytically or again with the Excel solver the adjusted value $k_{new} = 1.35848$. Thus, we obtain the adjusted OSN_Flood_new =47.7 as the new 99.5% quantile of the distribution.

Step 2: We now assume that the damage in the amount of OSN_Flood_new is realised in the year 2100. This reduces our own funds (excluding possible effects from deferred taxes) by the amount of 47.7 to

own funds_SCR_new = 152.3.

The SCR is recalculated taking into account the capital investment outflow of 47.7 and decreases to 96 as the market risk decreases, whereas the other risks, in particular the underwriting risks, remain unchanged. In this constellation, any need for action will now be examined.

Procedure B

Step 1: First, we determine the 200-year flood event analogous to Procedure A with OSN_Flood_new = 47.7.

Step 2: We aggregate our adjusted OSN_Flood_new with the other risks to form a new OSN_new = 89. The risk margin is also recalculated on the basis of the changed risk to risk margin_OSN_new = 27. This results in own funds_OSN_new (excluding possible effects on deferred taxes) of 203. In this constellation, any need for action will now be examined.

Table 6 presents the determined flood risk OSN_flood_new and compares it with the alternative approaches of assuming a constant coefficient of variation and parameterising a Gumbel distribution. Particularly worth mentioning here is the enormous range of results that can be generated with plausible assumptions.

Determined flood risk OSN

Table 6 · Newly determined flood risk OSN under different assumptions

YEAR	PARETO ASSUMPTION	GUMBEL ASSUMPTION	VARIATIONS COEFFICIENT*
2030	23.1	18.8	18.0
2050	42.6	27.7	25.3
2100	47.7	30.2	27.4

* We assume here, as suggested above, a change in the expected value corresponding to the NGFS data with a constant coefficient of variation. To derive a quantile, a further assumption is required. The assumption of a lognormal distribution is suitable. Under this assumption, the value-at-risk scales with the expected value.

136 Note that for a given expected value and 99.5% quantile, there are generally two solutions to the resulting system of equations, i.e. two possible Pareto distributions with this expected value and 99.5% quantile. If further data on the real loss distribution are available, the distribution that better fits the data can be selected from the two solutions. Alternatively, the more conservative solution can continue to be used, i.e. the solution that leads to a higher quantile and thus stronger climate change effect when the expected value is adjusted. In this calculation example, exactly this latter approach was followed. The second solution of the system of equations is k=1.05095 and x_{min}=0.09697.

137 We assume here that the 10-year average is an appropriate estimate for the current situation. Further, we assume that the NGFS figures for 2020 well reflect the current situation. The figures are derived from the bar chart and/or the underlying data as index 2100 divided by index 2020.

6.2.3 Hail

Hail risk considers the risk of damage caused by precipitation consisting of ice nuggets. These so-called “hailstones” are formed when supercooled water freezes into ice on crystallisation nuclei within a thunderstorm cell. Strong updrafts and a certain amount of vertical wind shear are then needed to allow hailstones to grow to a size that can do potential damage. The resulting hailstorms, which denote the impact of hailstones on the ground, can cause considerable damage.

The damage mainly affects agricultural insurance, which can be affected by hailstones as small as 2 cm in diameter. Larger hailstones with a diameter of 5 cm or more can also affect motor (vehicle) own-damage insurance, residential building insurance and commercial property insurance.

The NGFS does not provide information on hail events. There is no information applicable to hail in the Climate Impact Explorer. However, a review of other sources provides insight into how and whether hail risk is changing due to climate change. Several studies indicate that the risk of hail in Germany will increase as a result of climate change.

For example, Raupach et al. (2021) describe that the severity and frequency of hailstorms in Europe are increasing, but also point out that the topic is still associated with a great deal of uncertainty.

A Munich Re study (2020) goes a step further and shows concrete figures for two climate change scenarios:

- The first climate change scenario succeeds in keeping the temperature increase within 2.4°C compared to pre-industrial times. Such a temperature increase would lead to a 30–40% increase in hail events larger than 5 cm in diameter in Europe, or a 10–20% increase in hail events between 2 cm and 5 cm in diameter.

- The second climate change scenario assumes a temperature increase of 4°C by the end of the century compared to pre-industrial times. At the same time, the temperature will not yet have reached its maximum by the end of the century. Assuming this scenario, an increase of hail events larger than 5 cm in diameter (between 2 cm and 5 cm) of 100% (80%) is expected in central Europe.

Munich Re's study does not provide any data regarding volatility, standard deviation or quantiles. In order to be able to provide information on this in the ORSA scenario, however, assumptions must be made (see Section 6.1). The following seems plausible, for example:

- It could be assumed that the coefficient of variation for hail risk remains unchanged, i.e. the standard deviation increases as much as the mean annual hail loss due to climate change.

- A suitable distribution (e.g. Pareto distribution) with a suitable expected value and standard deviation could be assumed for the actual loss distribution. The parameter(s) of the selected distribution could now be adjusted to reproduce the change in expected value specified by the Munich Re study. The change in quantiles can then be approximated from the adjusted distribution.

If, in addition to volatility, the average or expected development is also of interest, another option would be to create a simplified income statement taking into account an increase in expenditure due to hail damage, as explained in the following example. For this purpose, a simplified income statement and the assumptions made are described in the first step. The second step adds the impact of climate change to the expenditure and resulting increases in premiums.

Table 7 shows precisely these for the observation period from 2023 to 2100 from Step 1, i.e. without taking climate change into account. An income statement is also available for the years not shown, but is not presented for purposes of clarity. For the sake of simplicity, the private residential building insurance line is shown for the sample calculation. If the "premium hail" is not explicitly available in specific lines of business, an estimated premium share for hail can be used, for example.

The assumptions made in this sample calculation are shown in Table 8. The individual items in Table 7 show the respective dependence on assumptions a)–f). The assumptions can be selected individually depending on the needs and plans of the insurance company and are of a strictly exemplary nature here, which is why the values assumed in the example are not discussed in more detail.

Income statement without consideration of climate change

Table 7 · Simplified, compact economic income statement as an example for the private residential building insurance (PRBI) line (for assumptions made, see Table 8) without taking climate change into account

	2023	2024	2025	2026	2027	...	2035	...	2100
Premium income hail PRBI a)	50	51	52	53	54		63		230
Premium income residual risks PRBI b)	500	510	520	531	541		634		2297
Expenditure hail incl. regulation a)	35	36	36	37	38		44		161
Expenditure residual risks incl. regulation b)	375	383	390	398	406		476		1723
Costs for administration c)	110	112	114	117	119		140		505
Miscellaneous underwriting result d)	-11	-11	-11	-12	-12		-14		-51
Gross result	19	19	20	20	21		24		87
Reinsurance premium e)	5	5	5	5	5		6		23
Share of reinsurance in hail f)	5	5	5	5	5		6		21
Reinsurance result	-0.5	-0.5	-0.5	-0.5	-0.5		-0.6		-2.1
Net result	19	19	19	20	20		24		85

Source: Own assumptions and calculations

Assumptions for the income statement

Table 8 · Assumptions made in the income statement with and without consideration of climate change

	2023	2024	2025	2026	2027	...	2035	...	2100
a) Growth hail PRBI		2%	2%	2%	2%		2%		2%
b) Growth of residual risks PRBI		2%	2%	2%	2%		2%		2%
c) Cost ratio	20%	20%	20%	20%	20%		20%		20%
d) Miscellaneous underwriting result as % of gross	-2%	-2%	-2%	-2%	-2%		-2%		-2%
e) Reinsurance premium as % of gross premium	10%	10%	10%	10%	10%		10%		10%
f) Expected reinsurance share for hail	13%	13%	13%	13%	13%		13%		13%

Source: Own assumptions and calculations

Table 9 shows the income statement from Table 7 with additional consideration of climate change. For 2100, a +35% increase in expenditure was assumed in this example (see Table 10). This value corresponds to the results of the first climate change scenario from the Munich Re (2020) study, which was discussed in more detail above in this section. The +35% was chosen because insured objects in the private residential building insurance line are primarily vulnerable to hail with a diameter greater than 5 cm. This value is only exemplary and must be adjusted depending on the climate change scenario considered. Table 8 assumes a linear increase from 2023 (0%) to 2100 (+35%). Also useful would be to use an exponential increase from 0% to 35% in 2100, where the effects only become relevant later in the 21st century.

The premium income for hail to private residential building insurance could be adjusted based on need and planning. In the example shown, an explicit premium adjustment due to increased expenditure for climate change was assumed after ten years starting in 2033 (Table 10, row h). This assumption should be chosen individually depending on the needs and planning of the insurance company.

The changed own funds due to the consideration of climate change are shown in the last two items of Table 9, broken down into the impact per year and the cumulative impact.

Income statement with due regard to climate change

Table 9 · Simplified, compact economic income statement as an example for the private residential building insurance line (for assumptions made, see Tables 8 and 10), taking climate change into account

	2023	2024	2025	2026	2027	...	2035	...	2100
Premium income hail PRBI a), h)	50	51	52	53	54		66		286
Premium income residual risks PRBI b)	500	510	520	531	541		634		2297
Expenditure hail incl. regulation a), g)	35	36	37	38	39		47		217
Expenditure residual risks b)	375	383	390	398	406		476		1723
Costs for administration c)	110	112	114	117	119		140		505
Miscellaneous underwriting result d)	-11	-11	-11	-12	-12		-14		-51
Gross result	19	19	19	19	20		24		87
Reinsurance premium e)	5	5	5	5	5		7		29
Share of reinsurance in hail f)	5	5	5	5	5		6		28
Reinsurance result	-0.4	-0.4	-0.4	-0.4	-0.4		-0.5		-0.4
Net result	18	19	19	19	19		24		87
Change in result = impact on own funds	-0.1	-0.3	-0.4	-0.6	-0.7		-0.1		-1.7
Cumulative change in result	-0.1	-0.4	-0.8	-1.4	-2.2		-8.3		-33.9

Source: Own assumptions and calculations

Additional assumptions for the income statement

Table 10 · Additional assumptions made in addition to assumptions a)-f) (see Table 8) in the income statement as an example for the private residential building insurance line, taking climate change into account

	2023	2024	2025	2026	2027	...	2035	...	2100
g) Growth hail	0.4%	0.9%	1.3%	1.8%	2.2%		5.8%		35%
h) Growth residual risks	0.0%	0.0%	0.0%	0.0%	0.0%		4.1%		24.5%

Source: Own assumptions and calculations

6.2.4 Wildfire/drought

Periods of heat with a lack of precipitation lead to droughts, which increase risk in various areas:

- Increased likelihood/intensity of forest and slope fires (e.g. from sparks along rail lines). Forest fires in particular can cause significant cumulative fire damage to buildings adjacent to the affected forest area.
- Lower river levels with corresponding disruptions to inland waterway traffic
- Crop failures

The lines of business affected are thus buildings, transport and crop failure insurance.

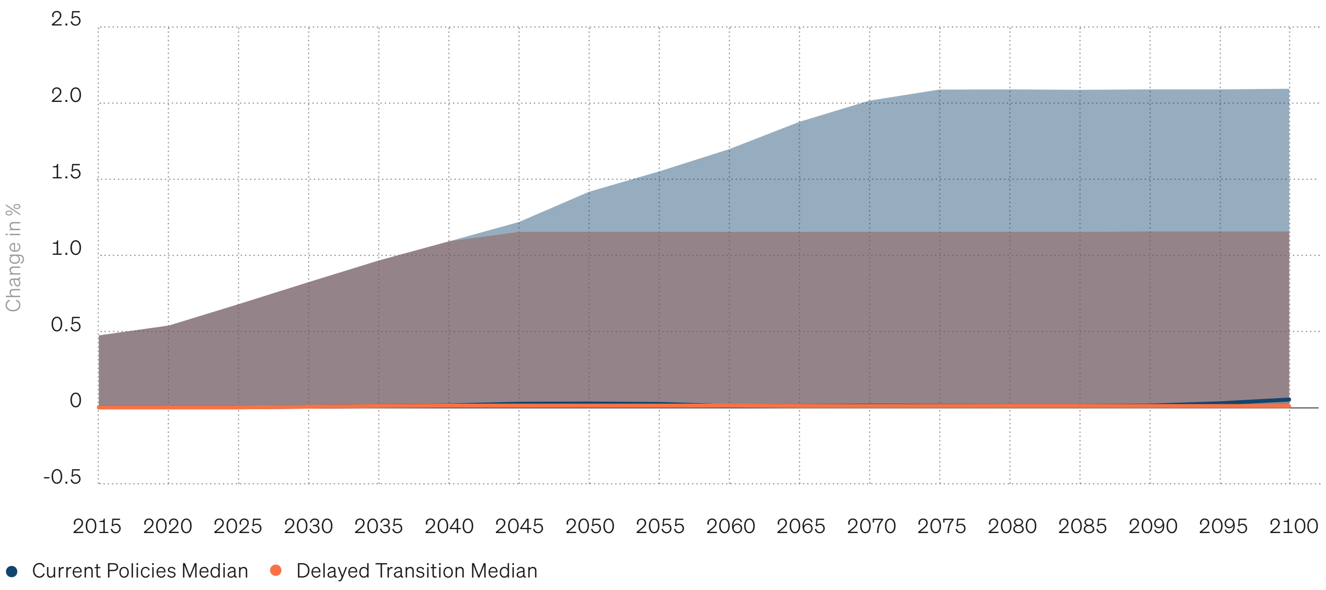
Usable indicators from the NGFS scenarios:

- **Drought**: Information can be derived indirectly on changes in temperature, precipitation, and yields of wheat and corn
- **Forest fire**: Change in the proportion of land exposed to wildfires in Germany each year (1.2 to 2% change in the 97.5th percentile, depending on the scenario), see Figure 32

The current condition of soils in Germany is shown by the Germany Drought Monitor of the Helmholtz Centre for Environmental Research (UFZ). A drought occurs when the current soil moisture falls below the long-term 20 percentile. The period 1951–2015 is used as a reference.

Wildfires

Figure 32 · Percent change in area exposed to wildfire annually in Germany compared to the 1986-2006 reference period for the NGFS Current Policies and Delayed Transition scenarios. The coloured areas show the range between the 2.5 and 97.5 percentiles of change. The median is represented by the two lines.



Source: Own illustration based on data from the Climate Impact Explorer

The rise in temperature associated with climate change means that droughts in southern and western regions of Europe are becoming more frequent, longer lasting and more intense.With the degree of warming, the likelihood of a high to extreme risk of forest fires also increases accordingly almost everywhere in Europe. In central and eastern Europe, however, projected trends show more climate variability and are more uncertain.[138] It can therefore be concluded that no reliable information on future developments is possible for Germany.

However, a first approach for companies could be to identify the affected portfolios in the aforementioned lines. Using forest fire as an example, this could be done by intersecting one's insured building portfolio with a land use map and identifying the sub-portfolio that is within a certain corridor around the forest area. Subsequently, one could consider radii in which a total loss due to forest fire is assumed and – analogous to the requirements of Solvency II – define the radius with the highest insurance portfolio as the potential accumulation risk.

6.3 Reinsurance

Reinsurance contracts are usually concluded with a term of one year. The terms and conditions for the next calendar year are negotiated annually in the fall. Concluded reinsurance contracts or known reinsurance conditions are thus usually only available for the immediate following year. That is, when projecting into the future, you have to make assumptions about the reinsurance protection you will have in the future and the price.

So the following questions would need to be addressed: How is the company adapting its reinsurance structure to developments in natural hazards? And are reinsurers prepared to cover the adjusted reinsurance structure and at what price? Even if the reinsurance coverage is not adjusted, there is a question about the price. As a trend, the price will probably rise as the damage increases.

One possible assumption would be that there are no changes; coverage and price would therefore remain unchanged. In the case of the climate change scenario, though this does not seem to be a reasonable assumption at first. (Initial) insurance premiums would then also be considered as constant and the argument can be made that the two effects ultimately cancel each other out.

138 Cf. JRC (2020).

Another possible assumption would be that the gross risk in the climate change scenario is reduced by reinsurance in the same proportion as in the current situation. In other words, reinsurance protection is purchased implicitly. The price of reinsurance could then be increased in the same proportion as the effect of reinsurance increases.

A first point of reference for making robust assumptions on these issues could be the last round of negotiations, which was strongly influenced by the "Bernd" loss event in 2021 and a severe shortage of reinsurance supply. Companies can use this as a guide or to justify the assumptions. The assumptions made should be derived as plausibly as possible and be well documented.

6.4 Transition risks

Transition risks can arise from changes in economic, political, social or legal conditions. A key driver of these risks is action in the context of a shift to a low-carbon economy.[139] In addition, there are direct interactions between physical risks and transition risks. Thus, on the one hand, the physical consequences of climate change become more severe the later society reduces its greenhouse gas emissions. On the other hand, potential policy adaptation strategies may have a faster and stronger impact as a result of natural events, which in turn may increase transition risks.[140] Transition risks can be disruptive and turn out to be "...more severe, the more severe the change in policy direction."[141] Therefore, the results of company-specific analyses of the impact of transition risks are subject to greater uncertainty than analyses of other risks.

According to DAV's assessment, the impact of transition risks in the context of climate change is high, particularly in the areas of capital investments, counterparty default risk, and strategic risks, while the consequences for underwriting risks, operational risks, lapse risks, and reputational risks are classified as medium.[142]

In principle, all composite lines and customer groups are affected by transition risks. For example, private customers are directly affected by changes in the legal framework as a result of statutory changes in the energy-related refurbishment of buildings or in energy costs. In addition, transition risks affect both mobility, and thus motor insurance, and socioeconomic factors (e.g. urbanisation), and thus the housing portfolio.

However, transition risks are likely to be much more pronounced in the commercial or industrial insurance sector. In particular, emissions-intensive industries are disproportionately affected by value-added losses, such as agriculture and the energy industry.[143] DAV cites other direct impacts such as the loss of business and assets for credit and surety insurance. In addition, there are indirect effects for the liability lines of business when people injured by climate change file compensation claims against companies that are held directly or indirectly responsible for the damage caused by climate change.[144]

With regard to the initial assessment of transition risks for a composite insurer, the capital investment is of particular importance. But transition risks can also have a direct impact on the insured portfolio, products, claims settlement and sales. Thus, it can be risk-increasing with regard to transition risks if

- the insurance portfolio is not very diversified and there are focal points in the insured portfolio for products and/or industries that are likely to be strongly affected by changes in the political environment. This can be lapse-increasing and premium-reducing for revenue-based plans. In addition, secondary effects on sales partners may arise if changes in the sectors also have an impact on the retail business brokered as a result of a change in the focus of the portfolio;
- products include cost items that will increase claims settlement expenses in the future as a result of legal / regulatory adjustments.

139 Cf. BaFin (2019).
140 Cf. BaFin (2019), p 14.
141 Deutsche Bundesbank (2021), p. 93.
142 Cf. DAV (2021), p. 26.
143 Cf. Deutsche Bundesbank (2021), pp. 94 ff..
144 Cf. DAV (2021), p. 15.

Therefore, a first qualitative analysis of transition risks can be done with regard to diversification e.g. for the portfolio

- by private and corporate customers,
- by business line,
- by geographical focus,
- of corporate business by industry/sector.

In corporate business, it may be useful to dovetail the company-specific asset classes with the commercial/industrial insurance operation types if, for example, data are available for the CO_2 relevance of investments. In addition, the sample lines specified above show that an analysis of the product portfolio can provide knowledge for assessing transition risks. Thus, the question is which policies in relevant types of operations are revenue-related and which premium volume is affected by this. In addition, an analysis of the excess cost issue in property insurance, including regulatory build-up restrictions, can provide indications of changes in premium and reserve risk valuations.

7. Other risks

In addition to the risks discussed in detail in the previous chapters, other risks might also arise under certain circumstances.

Operational risks

Operational risks can arise from the following aspects (the list is exemplary and not exhaustive; company-specific items would also have to be taken into account):

- insufficient availability of personnel as a result of natural catastrophes;
- impairment of the technical infrastructure (IT), e.g. in the event of power outages;
- limited usability of own business premises;
- in the event of an accumulation of loss reports as a result of natural catastrophes and/or accumulative loss events, possibly increased errors in claims processing;
- in emergency operations, possibly higher risk exposure to cyberattacks.

As is generally the case with operational risks, the development of contingency plans and technical security measures appears to be more important in many cases than maintaining a specific capital requirement in the scenario analysis carried out here.

Legal risks are also possible if liability issues are unclear (scope of insurance coverage).

Additional legal risks to which third parties are exposed may also play a role for the insurance company if the third party is the policyholder or investment object of the insurance company. In the course of the transition, new legal regulations or court rulings, for example, can have a major impact on the share price of affected companies.[145] However, such indirect legal risks are part of the insurance company's underwriting risks or capital investment risks and do not constitute operational risks or a separate risk category.

Reputational risks

Reputational risks describe risks arising from possible damage to the company's reputation as a result of negative public perception. In connection with the risks from climate change, risks are conceivable, for example, from investment decisions or products offered.

Liquidity Risks

Liquidity risk is defined as the risk of not being able to procure the funds required to settle due payment obligations, or only being able to do so at increased refinancing costs. In general, liquidity risk is addressed through sufficient fungibility and diversification of capital investments. In connection with climate change, liquidity risks from increased claim payments or cancellations are conceivable, for example. The transition risks on the capital market described in Chapter 4 should normally not be associated with liquidity risks for insurers.

[145] Cf. NGFS (2021).

8. Critical examination of results

The previous chapters presented possible approaches that insurance companies can use to examine the impacts of climate change and the transition to a low-carbon economy. The generally accepted scenarios of the NGFS form the basis for this. Possible effects on investments, personal insurance and property/casualty insurance were presented in detail. Finally, some suggestions for interpretation and critical discussion of the results will be given.

What approaches individual companies ultimately follow and what they do with the respective results is entirely up to them.

8.1 General considerations

The purpose of considering climate change scenarios in the ORSA is for insurance companies to address how they, as a company, will be affected by climate change. Both climate change itself and its potential impact on the economy and society can have consequences for a company's future risk and solvency situation. The transformation of the economy needed to mitigate climate change can also lead to significant transition risks during a transition phase.

The analyses are intended to detect vulnerabilities in order to be able to take countermeasures within the company at an early stage if necessary. "Early" in this context can mean very different points in time. Some decisions may be pending today, while other decisions may not be made until well into the future, if at all. With this gain in knowledge and any necessary measures derived from it, the resilience of companies can and should be increased.

Supervisory requirements include consideration of appropriate scenarios that project climate and economic trends over long periods of time. In the analysis of the scenarios, attention should be paid to the development of common parameters for the short-term time horizon. This includes in particular:

- own funds,
- SCR and
- overall solvency needs.

For the longer time horizon that follows, the focus is more on qualitative findings. Examples include:

- → What are the implications for strategic planning?
- → What are the implications for business strategy (availability, insurability, adaptation, avoidance, product design, affordability, distribution channels, etc.)?
- → What are the effects on the company's own business operations (impact on sites/employees)?
- → Are the resilience and robustness of the company's strategies subject to various adverse developments?
- → Is the business model sustainable in the long run?
- → Can potential adverse developments be mitigated or prevented?
- → Where does the company want to go in the future? What are the options for action?
- → What are the future and, if applicable, current relevant management decisions?
- → How adaptable is the company (duration of contracts, premium adjustment clauses, risk prevention measures, development of new business areas, etc.)?

When classifying results from individual scenarios, it must be kept in mind in any case that these are **not forecasts**, but rather pure **what-if analyses** that are only intended to identify risks. Given the high epistemic uncertainty, more is not possible.[146]

Certainly none of the NGFS scenarios will occur exactly like this. Instead, the scenarios serve to provide examples of possible developments that can be analysed in a coherent manner. In the Delayed Transition and Current Policies scenarios selected here, the focus is on transition risks and on physical risks, respectively. In a certain sense, this opens up a space in which many different developments are conceivable.

Likewise, it is not to be expected that companies will suffer exactly the fate played out in the analyses – especially since, in most cases, the analysis probably does not take reactive behaviour into account. In fact, companies have the opportunity to counteract at any time. Supposedly poor results in the scenarios should therefore not be viewed negatively per se, but on the contrary are valuable for the company, as they indicate a need for action in a forward-looking manner. The learning effect from dealing with unfavourable scenarios is precisely to prevent comparable outcomes from actually occurring by taking timely action.

8.2 Capital investment

As the largest institutional investor, the German insurance industry can make a significant contribution to supporting and financing the transformation of the real economy. At the same time, however, insurers, in their role as investors, are highly exposed to the capital market risks associated with the transition to a climate-friendly economy. Economic transformation influences the future performance of equities, bonds and property. There will be more or less affected, and there will certainly be winners and losers.

Even if the on average expected changes are already fully priced into today's market prices – which is partly doubted – future development is subject to major uncertainties. In the capital market, paths that do not correspond to today's mean expectations can realise as well. Whether this may result in significant losses for certain capital investments depends in particular on the timing and the specific measures used to drive the transition forward. In general, the longer the transition is delayed, the more severe the disruptions are likely to be. These risks must be taken into account in today's capital investment decisions.

If the analysis of transition risk is accordingly based on the Delayed Transition scenario, in which the transformation suddenly begins only in 2030, quite different effects arise at different levels. With regard to energy supply and use, a long-lasting and far-reaching transformation of the global economy is to be expected. By contrast, economic growth in Germany is expected to decline only slightly at the very beginning, before the economy resumes growing at its usual pace. The stock market is also projected to experience an initial decline, which on the one hand will be smaller than in past crises, but on the other hand will only be fully recovered after many years. However, this general decline in equity prices conceals disparate developments for individual sectors and companies. Analyses at the level of macroeconomic sectors reveal significantly higher risks in some areas, but are accompanied by great model uncertainty.

In order to be able to assess the transition risk of individual capital investments, even more granular studies would be necessary, for which, however, the data situation is lacking so far. The NGFS scenarios themselves only provide results at an aggregate level. Moreover, in the economic aspects of the NGFS scenarios, model uncertainty is enormous in general. Depending on which of the three Integrated Assessment Models (IAMs) of the NGFS is used, the results differ very significantly. The differences from one NGFS model vintage to the next are also considerable. Which model is supposedly "more correct" cannot be said. The GDV project group therefore opted for an agnostic approach and averaged over the models. With a special selection of models, even higher effects could be generated, but ultimately it is true for every type of stress test that something could always be added to obtain even more extreme results. This does not necessarily make sense. Robust results are more likely from averaging over different models that seem suitable.

In summary, the picture that emerges from the analyses presented is that transition risk should not pose an extraordinary threat to today's capital investments as a whole. However, a closer look should be taken at individual assets for which a particular exposure to transition risks seems plausible. Limited data availability and high model uncertainty pose significant problems.

[146] Cf. BaFin (2023).

8.3 Personal insurance

Climate change, especially through heat waves and other extreme weather events, can affect people's health. Therefore, it is useful to also examine and understand the potential impact of climate change on the underwriting of personal lines insurers. Although the biometric risks of this insurance line initially appear to be relatively unaffected, developments that will take effect only in many years may, due to the long terms of many contracts, also affect contracts concluded today. Future trends and risks must therefore be anticipated as well as possible. In Germany, unlike many health insurance policies, life insurance policies do not offer the option of reacting to new developments by adjusting premiums at a later date.

It is possible that other factors not directly related to climate change will have a much greater influence on the future development of life expectancy and health in central Europe. On the one hand, recent experience with the Covid 19 pandemic raises fears of new pandemics. On the other, the successful development of novel vaccines also raises hopes for progress in the fight against diseases such as cancer. Lifestyle and dietary habits that change for the better or worse, regardless of the climate, can also have a notable impact.

Nevertheless, as climate change is accompanied by predictable and potentially relevant long-term changes, life and health insurers should address the extent to which their decade-long business model is subject to climate change-related risks. It is inevitable that the climate will change notably during the term of many contracts; the extent to which this may have material consequences for the company has to be assessed. This is a general requirement, even if little quantitative analysis should be possible in this area. Depending on the outcome of the assessment, more in-depth analyses may then prove either necessary or unnecessary. In many cases, the assessment of the results should give the all-clear, so that no in-depth analyses will then be required. It is possible, however, that findings on long-term risks might already have consequences for today's product policy.

8.4 Property/casualty insurance

Insurers want and need to provide financial protection for people and businesses against natural hazards that are foreseeably becoming more severe and frequent. This means that property/casualty insurers in particular must keep an eye on climate change and be able to assess its consequences. Although much research has been done on the effects of climate change on natural hazards for many years, data on specific changes in hazards are subject to great uncertainty. This means that, just as in the case of capital investors and the consideration of the underwriting risks of personal insurance, the analyses largely correspond to a what-if analysis. Consequently, the assessment of impacts should not be viewed as a probable or expected outcome.

In addition, changes in other general conditions may occur apart from the changes in the actual natural hazards. Loss prevention through reformed building laws, climate-smart construction, and climate-adapted infrastructure plays a key role in minimising the damage of climate change. It should also not be ignored that property/casualty insurers have many short-term adjustment options such as with premiums, the scope of coverage and their underwriting strategy.

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