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Frankfurt School

RESEARCH REPORT

Climate scenarios in banks a case study

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October 2023

Climate scenarios in banks – a case study

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October 20, 2023

The report is based on a Master thesis, which was supervised and refined by Ulf Moslener and Sebastian Rink. Part of SATISFY under the research project Sustainable Finance and Climate Protection by the German Federal Ministry of Education and Research (grant number: 01LA2210A)

We thank Alix Auzepy, Fernanda Ballesteros, and Alexandra Hüttel for their helpful comments.

Abstract

In this report, we develop and apply a typology that helps banks differentiate climate scenarios based on their characteristics and discuss four use cases. With the increasing importance of climate scenarios for assessing the risks and opportunities of climate change in the financial system, banks face the question of which climate scenarios to select for different use cases. We review academic and grey literature to develop a typology that helps banks differentiate climate scenarios using a heuristics approach. We differentiate commonly used scenarios based on the typology. We then apply the typology through a case study in a large German promotional bank. Being the first case study with a bank in this field, the paper adds to the literature by providing a characterisation of climate scenarios for banks and by supporting the selection of a climate scenario amongst banks.

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1 Introduction

- The use of climate scenarios is recommended to better understand how the risks and opportunities of climate change could affect a company's business model.
- According to the ECB (2021), especially banks experience difficulties in using scenario analysis on climate- and environmental-related risks.
- To get a better understanding of what makes a climate scenario usable for banks, we develop a model to identify characteristics of climate scenarios which are relevant for different use cases.

About 190 countries signed the Paris Agreement in 2015 with the aim of limiting global warming to well below 2°C, preferably 1.5°C (Nations, 2015). To reach this goal, countries define nationally determined contributions (NDC), that is, how they plan to contribute to achieving the temperature target. The European Union (EU) aims to reduce emissions by 55% by 2030 compared to 1990 levels and reach climate neutrality by 2050 (European Commission, n.d.-b, n.d.-c). The achievement of these goals requires support from individuals and companies, which entails different actors becoming Paris-aligned. The European Commission aims to foster this process by increasing regulation to assess and report their exposure to climate-related risks (European Commission, 2019).

The Task Force on Climate-Related Financial Disclosures (TCFD), consisting of 31 members from across the G20 countries, released recommendations on climate-related financial disclosure for companies in 2017 (on Climate Related Financial Disclosures (TCFD), 2022). These recommendations are a basis for developing mandatory regulations on climate-related disclosures in various countries (Huiskamp, Brinke, & Kramer, 2022). An essential part of the TCFD's recommendations is using climate scenarios to better understand how the risks and opportunities of climate change might affect a company's business (Huiskamp et al., 2022; on Climate Related Financial Disclosures (TCFD), 2017c). Progress in their implementation differs greatly depending on, for example, the kind of company (Green and Sustainable Finance Cluster Germany (GSFC Germany) (2019).

Banks can mainly use climate scenarios in two ways: First, as part of risk management (i.e., how the climate affects the bank) and second, impact management, that is, assess the impact of a bank on the climate. The appropriate implementation requires the expansion of existing strategies and risk management processes. Especially banks experience difficulties, with only 11% of the 113 banks surveyed already using scenario analysis on climate- and environmental-related risks, according to a recent study by the European Central Bank (ECB) (n.d.-a). For example, one reason is the perception of climate scenario analysis as a "complex and daunting task" (Huiskamp et al., 2022, p. 2).

Existing research has developed an implementation process for climate scenarios (Huiskamp et al., 2022), providing an overview of environmental scenario studies (van Vuuren, Kok, Girod, Lucas, & de Vries, 2012) or analysing climate scenarios from the Intergovernmental Panel on Climate Change (IPCC) in detail (Bauer et al., 2017; O'Neill et al., 2017; Riahi et al., 2017; Ritchie & Dowlatabadi, 2018). So far, no study focusses on bridging the gap between the original scientific and policy-oriented intent of climate scenarios and its use in the banking sector. Given the low adaptation rates in this sector, as well as the fact that the Global Compact Network Germany (GCNG) "identified basic challenges in the selection of suitable scenarios" (Global Compact Network Germany (GCNG), 2019, p. 9), this report aims to provide a better understanding of what makes a climate scenario usable from the perspective of a bank. Thus, this report seeks to answer the following question:

Which characteristics of climate scenarios are relevant to the practical use of climate scenarios in banks?

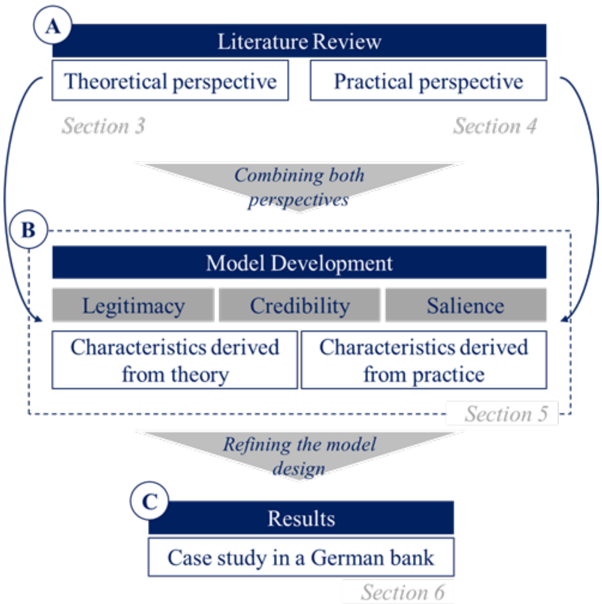
To answer the research question, a model is developed that combines characteristics of scenarios outlined in the literature with the reasons given by banks for selecting a particular climate scenario. The model is refined through a case study in a German promotional bank. This report extends previous research in two ways. Firstly, we provide a characterisation of climate scenarios in the context of the banking sector. Secondly, the framework developed in the report supports banks in selecting appropriate climate scenarios.

The remainder of this report is structured as follows: Beginning with the general methodology applied in this report in Section 2, Section 3 provides an overview of the climate scenario literature and the characteristics of climate scenarios. This perspective is extended with the practical use of climate scenarios in Section 4. Subsequently, a more detailed explanation of the definition of the underlying problem, the objectives of the model, and the design of the model is given in Section 5. Section 6 discusses the model in the context of a large German promotional bank. Section 7 concludes.

2 Methodology

The analysis of climate scenarios and the corresponding alignment of business activities with climate goals have gained increasing relevance for banks over the last years. This report aims to determine the relevant characteristics of climate scenarios for their practical application in banks. Based on a review of existing literature in this field and an extensive analysis of TCFD reports of 52 banks in the following sections, we develop a model which combines scenario characteristics from both theoretical and practical perspectives. Afterward, this model is refined through a case study in a German bank to identify which characteristics are essential in practise. A graphical illustration of the methodology is provided in Figure 1.

Figure 1: Illustration of the applied methodology.



The subsequent sections, Sections 3 and 4, create a basis for developing the model by reviewing the existing literature (point A in Figure 1). Precisely, Section 3 focusses on climate scenarios from a theoretical perspective. Initially, the literature on scenarios and their properties is reviewed, in general. Then, a scenario typology developed by van Notten et al. (2003) is applied to climate scenarios from four different institutions to gain insights into their characteristics from a theoretical point of view. As previous research recognises scenario typologies as a valuable tool to guide the selection of an appropriate climate scenario (Huiskamp et al., 2022), it is expected that the application of the models will reveal relevant information on climate scenarios for the subsequent model development. While Section 3 aims to create a common understanding of climate scenarios, Section 4 provides information on their practical use. We analyse the use of climate scenarios in the banking sector (Section 4.3) by examining the TCFD reports of 52 banks participating in the UNEP FI TCFD Banking Pilots (called "pilot banks" in the following). Therefore, each bank's TCFD report, or, if no TCFD report is available, the bank's annual report is examined by keyword search. With the information extracted, banks' use of climate scenarios along the three items perspective covered, risk type addressed, and sectors is analysed. These insights support the development of the model and ensure its practical relevance.

To answer the research question, a model is developed on the characteristics of climate scenarios relevant to banks, bringing together theoretical and practical perspectives. This generates more insightful results than building a model from a theoretical or practical perspective (Ven & Johnson, 2006).

To build the model, we apply an heuristics approach, a method that helps to quickly find a solution to an existing problem (Hertwig, 2006). Precisely, this means that we start from an existing set of criteria to derive more detailed characteristics of climate scenarios. Cognitive heuristics "offer possibilities to inspire collective intelligence, creativity, and the immersion into diverse futures" (Schirrmeister, Göhring, & Warnke, 2020, p.15). Combining them with scenarios fits well as they "seek to go beyond trends and extrapolations". Thus, for example, Schoemaker (1991) already analyses a heuristic approach to scenario planning. In this report, heuristics support the identification of characteristics of climate scenarios. Therefore, a common heuristic from climate science is used, consisting of the criteria 'legitimacy', 'credibility', and 'salience' (see point B in Figure 1) (Cradock-Henry & Frame, 2021).

After the model has been developed, we refine it and derive characteristics particularly relevant for banks through a case study in a German bank (see point C in Figure 1). This approach is suitable since case studies allow in-depth investigation of a real-life setting (Ridder, 2017). Specifically, it provides a better understanding of which and why specific characteristics are essential to make climate scenarios useable for banks. The case study helps to differentiate four use cases of climate scenarios for banks. Each use case represents a combination of 'risk type - risk perspective' and implies a different set of relevant characteristics. As part of the case study, we conduct interviews with six employees from different departments in one German promotional bank to gather various perspectives on the use of climate scenarios.

3 Theoretical Perspective on Climate Scenarios

- The literature review shows that climate scenarios can be applied in many different contexts. A characterisation could help to differentiate and apply them appropriately.
- Climate scenarios have become increasingly relevant for conducting climate scenario analysis in companies.
- e show how climate scenarios are structured by categorising 17 climate scenarios from the IEA, IPCC, NGFS and Agora according to a model developed by van Notten et al. (2003).
- Although there are several similarities among the climate scenarios (e.g., as they are using qualitative and quantitative data), differences occur between and within climate scenario providers (e.g., whether they are outlining peripheral or trend dynamics).

The following Section 3.1 explains the broad applicability of scenarios and a possible way of differentiating them. Next, we describe the role of scenarios in assessing climate-related risks and opportunities (Section 3.2). Lastly, 17 climate scenarios from four different institutions are examined in more detail (Section 3.3).

3.1 Definition of Scenarios

Scenarios play an important role in the research field of future studies (Bishop, Hines, & Collins, 2007): They outline possible future states and potential development paths leading to a future situation. Thus, scenarios are a valuable tool to understand what the future might look like based on a particular set of factors (Kosow & Gaßner, 2008). These factors are usually the result of making assumptions about the underlying drivers. Therefore, scenarios should not be considered as exact predictions or forecasts, but instead aim to illustrate hypothetical future pathways (Kosow & Gaßner, 2008). Evaluating "alternative futures" (Amer, Daim, & Jetter, 2013, p. 23) allows organisations to be prepared even for uncertain times, enhancing their ability to cope with difficult circumstances. Kosow and Gaßner (2008) stress the usefulness of scenarios by deriving four functions:

- the explorative and/or knowledge function,
- the communication function,
- the goal-setting function, and
- the decision-making and strategy formation function.

The exploratory function refers to the fact that scenarios can extend the scope of thinking beyond conventional alternatives and challenge existing views by considering a wide range of options (Greeuw et al., 2000; Kosow & Gaßner, 2008). Therefore, they support the identification of opportunities and the generation of new insights (Amer et al., 2013).

Scenarios can be used either as part of the communication or to foster communication. In the former, scenarios promote a commonly understood problem and the exchange of ideas to direct the focus on communication processes and potential improvements. Regarding the latter aspect, scenarios help to convey information on a topic, and thus increase understanding and stimulate discussions on this topic.

When setting goals, scenarios are a valuable method for developing an idea of what the future should look like. Additionally, decision-making processes and strategic planning are facilitated based on scenarios as various options can be tested (Kosow & Gaßner, 2008).

Given the broad applicability of scenarios, it is not surprising that they have already been used "in many industries such as energy and sustainability" (Tiberius, Siglow, & Sendra-García, 2020, p.240) and across functions such as strategy, operations, and finance. Especially in times of increased uncertainty, as occurred after the oil price shocks in 1973 and 1979, scenario planning received increasing attention from companies (Schoemaker, 1993). This phenomenon also holds more recently, with scenario research increasing considerably since 2009, partially explained by the financial crisis in 2007/2008, which affected people's attitude towards risk and uncertainty. Therefore, Tiberius et al. (2020) expect an increasing use of scenarios in various industries.

Research on scenarios can be differentiated between applied and methodological research (Tiberius et al., 2020). As an example of the former, Liu et al. (2015) examined the withdrawal and consumption of water for electricity generation in the United States by applying seven scenarios to explore the impact of growing electricity demands and socioeconomic developments. Unlike this applied scenario research, Ramirez et al. (2015) focused on the methodological aspect of scenario research. The scenario methodology allows producing 'interesting research', that is, 'research that develops theory, is innovative and less formulaic' (Ramirez et al., 2015, p.70). Specifically, using scenarios as a scholarly method facilitates the identification of new areas of research and the understanding of complex situations.

The scenarios and their use have shortcomings. For example, making appropriate scenario assumptions is crucial. Even if the outcome of the scenario seems likely or desirable, this might not be confused with forecasts or predictions, as the scenarios only aim at showing a range of future developments (Kosow & Gaßner, 2008). Furthermore, presenting them as possibilities makes them "psychologically less threatening to those holding different worldviews" (Schoemaker, 1993, p.209).

Previous research outlines various characteristics and types of scenarios (Börjeson, Höjer, Dreborg, Ekvall, & Finnveden, 2006; Girod & Mieg, 2008; Greeuw et al., 2000; Kishita, Hara, Uwasu, & Umeda, 2016; Kosow & Gaßner, 2008; van Notten, Rotmans, van Asselt, & Rothman, 2003). Most models show some unique aspects. However, there are also several overlaps between the scenarios. Although, so far, no consensus has been reached on a core set of characteristics or scenario typologies (Little, Hester, & Carey, 2016), van Notten et al. (2003) aim to provide a 'broadly shared scenario typology' (p. 423).

While other researchers already use scenario typologies to guide the selection of an appropriate climate scenario (Huiskamp et al., 2022), they did not use the model from van Notten et al. (2003). Instead, Huiskamp et al. (2022) develop an implementation process called the climate resilience cycle to simplify and standardise the application of climate scenario analysis for companies. As part of the first step of the cycle, the selection of suitable reference scenarios, they use a scenario typology to facilitate the decision-making process. The typology is based on the user's knowledge needs and clusters scenarios in predictive, explorative, and normative scenarios (Huiskamp et al., 2022).

The comprehensibility of the van Notten et al. (2003) model stands out when comparing it to other models (Börjeson et al., 2006; Huiskamp et al., 2022). Additionally, their work is appreciated by other researchers (Amer et al., 2013; Bishop et al., 2007; Börjeson et al., 2006). Thus, their typology is applied in this report to analyse the characteristics of climate scenarios in more detail (see Section 3.3).

To build their model, van Notten et al. (2003) reviewed and analysed about 70 scenario studies and, afterwards, derive a typology consisting of three overarching themes, the "project goal", the "process design", and the "scenario content". First, the "project goal" might vary from exploration, which is supposed to raise awareness and foster creative thinking, to decision support, which means the possibility of analysing future pathways regarding their desirability. Second, the "process design" focusses on differentiating between an intuitive or a formal approach. The former refers to qualitative knowledge used to develop scenario storylines; the latter describes scenario development as a "rational and analytical exercise" (van Notten et al., 2003, p. 427). The last theme, the "scenario content", takes a closer look at the composition of a scenario, for example, the variable types included, to distinguish between complex and simple scenarios. These three themes are broken down into 14 scenario characteristics. These characteristics, including more detailed explanations, can be found in Table 1.

Table 1: Scenario characteristics

Overarching theme	Scenario characteristics	Explanation
Project goal: exploration vs decision support	Inclusion of norms: descriptive vs normative	Influence of norms and values in scenario development
	Vantage point: forecasting vs backcasting	Starting point which is used to develop a scenario
	Subject: issue-based, area-based, institution-based	Focus of the scenario
	Time scale: long-term vs short-term	Time horizon of the scenario
	Spatial scale: global/supranational vs national/local	Geographical areas covered by a scenario
Process design: intuitive vs formal	Data: qualitative vs quantitative	Data conveyed in the scenario
	Method of data collection: participatory vs desk research	Process for deriving information when developing the scenario
	Resources: extensive vs limited	Financial/research resources, invested time in scenario project
	Institutional conditions: open vs constrained	Leeway available during scenario development
Scenario content: complex vs simple	Temporal nature: claim vs snapshot	Data availability during covered time horizon
	Variables: heterogeneous vs homogeneous	Types and numbers of variables in a scenario
	Dynamics: peripheral vs trend	Type of future pathways described by scenario
	Level of deviation: alternative vs conventional	Variety of possible futures considered in scenario
	Level of integration: high vs low	Degree to which study components are united

Note. Adapted from “An updated scenario typology”, by van Notten et al., 2003

3.2 The Role of Climate Scenarios

Currently, the world moves at a critical junction from which various climate developments are possible. In light of these uncertainties associated with climate change and the responses of societies to it, scenarios are a valuable tool for assessing different future outcomes. Especially when considering the multiple challenges and possibilities of climate change, scenarios help to examine them thoroughly. When applying scenarios, organisations need information to comprehensively evaluate “climate-related risks and opportunities on strategy, business model and financial planning” (Global Compact Network Germany (GCNG), 2019, p. 2). To help overcome this challenge, the TCFD, initiated by the Financial Stability Board (FSB) in 2015, provides guidelines on the use of climate scenarios (on Climate Related Financial Disclosures (TCFD), 2017b).

Unlike traditional risk management, where the underlying models are based on historical data, climate scenarios must deal with uncertainty, as they cannot rely on past sources, as climate change-related risks have rarely been observed (Allen et al., 2020; Chenet, Ryan-Collins, & van Lerven, 2021). Each 'what if' scenario represents a possible future state of the world, but does not provide accurate forecasts (Eis & Schafer, 2019; Institutional Investors Group on Climate Change (IIGCC), 2019). To be precise, climate scenarios describe various pathways of CO2e emissions leading to different temperature increases based on assumed probabilities of occurrence. To determine how a CO2e emission path develops, factors such as economic and population growth, cost of technology, and sectoral-/country-specific CO2e emissions, are relevant (GSFC Germany, 2019). TCFD defines an appropriate climate scenario as plausible, distinctive, consistent, relevant, and challenging (TCFD, n.d.). Climate scenarios refer to the two interdependent categories of climate-related risks, physical and transition risks (TCFD, 2017b). As both risk categories are likely to impact organisations in the future, we provide a short definition of both (GCNG, 2019).

Physical risks arise from climate variability, individual severe weather events, and long-term climate changes and can be defined as their hazardous effect on human and natural systems (Batten, Sowerbutts, & Tanaka, 2017; Eis & Schafer, 2019). They can be divided into categories of acute and chronic physical risks. Acute physical risks result from increased exposure to extreme weather events that cause immediate and localised effects such as floods or hurricanes. Chronic physical risks are related to long-term climate changes and changes in environmental conditions that might lead to chronic heat waves or rising sea levels (Bundesanstalt für Finanzdienstleistungsaufsicht (BaFin), 2020; Eis & Schafer, 2019; Global Compact Network Germany (GCNG), 2019; on Climate Related Financial Disclosures (TCFD), 2017b). In addition to direct effects, supply chains, operations and employees of organisations can be impacted by indirect consequences of physical risks such as extreme changes in temperature and water availability (BaFin, 2020; GCNG, 2019; TCFD, 2017b). These impacts might affect the financial performance of organisations (TCFD, 2017b). The exposure of a company to physical risks depends on various factors, including the geographic location of the value chains and sites, internationalisation, and reliance on infrastructure (GCNG, 2019). Although the insurance industry has already shifted the emphasis to possible implications of physical risks, the banking sector has not yet extensively analysed its consequences on its credit and lending portfolios (Eis & Schafer, 2019).

Currently, the world moves at a critical junction from which various climate developments are possible. In light of these uncertainties associated with climate change and the responses of societies to it, scenarios are a valuable tool for assessing different future outcomes. Especially when considering the multiple challenges and possibilities of climate change, scenarios help to examine them thoroughly. When applying scenarios, organisations need the information to comprehensively evaluate "climate-related risks and opportunities on strategy, business model and financial planning" (GCNG, 2019, p. 2). To help overcome this challenge, TCFD, initiated by the Financial Stability Board (FSB) in 2015, provides guidelines on using climate scenarios (TCFD, 2017b).

Besides the differentiation in physical and transition risks, the risk perspective needs to be considered, describing the risk's direction of impact. 2 types of impact are differentiated in the following: First, the outside-in perspective considers risks arising from climate change that may impact a company. Second, the inside-out perspective covers a company's (negative) impacts on the climate like the use of climate scenarios for aligning a bank's portfolio (Green and Sustainable Finance Cluster Germany (GSFC Germany), 2019; Hahnkamper-Vandenbulcke, 2021). Differentiating between both, the risk type and the risk perspective, is crucial as different combinations of both lead to other relevant characteristics of climate scenarios.

Primarily, climate scenarios have been designed to provide policymakers and scientists with information on potential climate-related impacts from macroeconomic analyses. Now that TCFD proposed the high relevance of climate scenarios for climate scenario analysis in businesses, the application of this tool has changed, and the usability of climate scenarios needs to be assessed form this angle.

Transition risks are associated with the change transition to a lower-carbon economy and can materialise in financial losses or economic dislocation (Batten et al., 2017; John, Khaykin, Pyanet, & Westheim, 2018). The financial and reputational risks that organisations face depend on the velocity and focus of the transformation process (TCFD, 2017b). Transition risks are related to changes in policy, legal, technology, market (price) and reputation to meet climate-related adaptation and mitigation needs (GCNG, 2019; TCFD, 2017b). Risks related to policy actions that promote the transition to a low-carbon society are referred to as political risks. In contrast, legal risks include the risks of litigation related to climate change. Technology risks arise from the development of low-emission technologies with the potential to disrupt existing systems and products. During the transition to a lower carbon economy, changing markets and social expectations can materialise in market and reputation risks, respectively (GCNG, 2019; TCFD, 2017b).

3.3 Classification of Climate Scenarios

As recommended by TCFD, most organisations use existing climate scenarios published by various (inter)national institutions. These are often referred to as reference scenarios since they "describe plausible future states of physical climate conditions and transition pathways" (Huiskamp et al., 2022, p. 4).

To better understand the characteristics of climate scenarios, we apply the van Notten et al. (2003) typology to climate scenarios which are relevant for the German banking sector. This includes international climate scenarios provided by the International Energy Agency (IEA), IPCC, and NGFS, as well as German climate scenarios from Agora Energiewende / Verkehrswende, together with the Stiftung Klimaneutralität (Agora).

To carry out the classification, we analyse the most recently published climate scenarios for each institution. This means the IEA scenarios used for the World Energy Outlook 2021, the IPCC scenarios from the Sixth Assessment Report, the NGFS scenarios published in June 2021, and the Agora scenarios from 2021. Each climate scenario is examined separately to illustrate individual differences among them. We review the literature on publicly available primary and secondary data from the agencies' websites and previous researchers. In Table 2, the detailed results of the classification are shown. Appendix A provides a more detailed introduction to each scenario and explains why each scenario is categorised in this way.

In general, the typology of van Notten et al. (2003) reveals several similarities among the climate scenarios. For example, all climate scenarios can be classified as issue-based as they deal with climate change, a phenomenon that affects society. Besides using a variety of resources, including qualitative and quantitative data, it is also striking that all climate scenarios show the development of different variables like temperature, GDP etc. over time. The largest differences become visible when comparing the different climate scenarios of each institution. While some scenarios rather reflect existing trends and illustrate how the future might look like when following these trends, other climate scenarios rather take a specific future outcome as a starting point and outline a pathway on how to achieve this state.

Table 2. *Classification of the IEA, IPCC, NGFS, and Agora scenarios according to van Notten et al. (2003)*

				IEA				IPCC					NGFS						Agora	
Over-arching theme	**Character-istics**	**Form**	**Explanation**	**NZE**	**SDS**	**APS**	**STEPS**	**SSP1-1.9**	**SSP1-2.6**	**SSP2-4.5**	**SSP3-7.0**	**SSP5-8.5**	**NZ**	**B2**	**DNZP**	**DT**	**NDCs**	**CP**	**KN2045**	**KN2050**
Project goal	Inclusion of norms	descriptive	explore possible futures, non-intervention scenario			x	x			x							x	x		
		normative	describe preferable futures, intervention scenario	x	x			x	x		x	x	x	x	x	x			x	x
	Vantage point	forecasting	present as starting point			x	x	x		x	x	x					x	x		
		backcasting	explore paths required to come to a certain future state; normative	x	x				x				x	x	x	x			x	x
	Subject of scenario study	issue-based	societal issues as subject	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		area-based	explore certain geographical area																	
		institution-based	concerned with the interests of an organisation																	
	Time scale	short-term	3 to 10 years																x	x
		long-term	25 years or more	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Spatial scales	global	part of world addressed by scenario	x		x	x	x	x	x	x	x	x	x	x	x	x	x		
		supranational			x															
		national																	x	x
		regional																		
		local area																		
Process design characteristics	Nature of the data	qualitative	analysis of complex situations with high uncertainty; quantification of important information not possible	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		quantitative	often use computer models to develop forecasts	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Method of data collection	participatory approach	involvement of experts, focus groups or conducting workshops					x	x	x	x	x								
		desk research	includes analysis through computer simulations and scientific journals	x	x	x	x						x	x	x	x	x	x	x	x

Table 2. *Classification of the IEA, IPCC, NGFS, and Agora scenarios according to van Notten et al. (2003) (continued)*

				IEA				IPCC					NGFS						Agora	
Over-arching theme	**Character-istics**	**Form**	**Explanation**	**NZE**	**SDS**	**APS**	**STEPS**	**SSP1-1.9**	**SSP1-2.6**	**SSP2-4.5**	**SSP3-7.0**	**SSP5-8.5**	**NZ**	**B2**	**DNZP**	**DT**	**NDCs**	**CP**	**KN2045**	**KN2050**
Process design character-istics	Nature of the re-sources	extensive	many financial/research resources available, a lot of time invested	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		limited	few resources available, limited time																	
	Nature of institu-tional con-ditions	open	ample freedom given to project, no personal relations/political rela-tions impacting scenario	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		constrained	little independence given due to personal/political relations impact-ing scenario development																	
Scenario content character-istics	Temporal nature	chain	show development until an end-state is reached	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		snapshot	focus on end-state, only implicitly address the development behind it																	
	Nature of the varia-bles	heterogeneous	many types and large numbers of variables in a scenario	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
		homogeneous	few types and numbers of varia-bles in a scenario																x	x
	Nature of the dynam-ics	peripheral	discontinuous path, includes un-likely events	x	x			x	x		x	x	x	x	x	x			x	x
		trend	based on existing trends			x	x			x							x	x		
	Level of deviation	alternative	significant difference across vari-ous futures; often aim at raising awareness about a new issue	x	x			x	x		x	x	x	x	x	x			x	x
		conventional	business-as-usual, adherence to status quo; projecting today into the future			x	x			x							x	x		
	Level of in-tegration	high	unification of relevant variables across different times and spatial scales and various domains	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
		low	components of study are rarely formed together as a whole																x	x

4 Practical Perspective on Climate Scenarios

- Although scenarios have already played an essential role for banks, e.g., as part of stress tests, they are now becoming increasingly relevant to assessing climate-related impacts.
- Despite existing guidelines on using climate scenarios, the practical application differs among banks: Given the variety of climate scenarios available, banks not only choose different climate scenario providers, but may also select various climate scenarios from each provider, depending on the analysis.

The following section aims to understand how climate scenarios are used in practise by banks. Section 4.1 sets the stage for the general use of scenarios by banks. Section 4.2 provides information on the regulatory context for using climate scenarios. Afterwards, we examine the current status of their implementation in banks in Section 4.3.

4.1 Scenario Use in the Banking Sector

Although climate scenarios are a tool relevant for different industries, a cross-sector analysis shows that the banking sector is behind other sectors in its implementation (TCFD, 2021b). As opposed to companies operating in specific industries, banks can be exposed to many different industries and numerous customers through their portfolios.

Although traditional risk analyses in banks, such as decision trees and Bayesian models, are valuable tools for assessing risks in stable environments, they are rather inappropriate for fundamental risks (e.g., political risks or uncertainties regarding the economy/industry structure). Under these circumstances, scenario planning is more suitable for "overcoming corporate blindspots and myopic thinking frames" (Schoemaker, 1993, p. 209). In the banking industry, scenarios are widely used as part of stress tests (Cortés, Demyanyk, Li, Loutskina, & Strahan, 2020; Fernandes, Igan, & Pinheiro, 2020; Sahin, de Haan, & Neretina, 2020). They illustrate what a bank "might lose during a forward-looking, hypothetical severe economic downturn which then gets translated into a forecast of regulatory capital ratios conditional on various stress scenarios" (Cortés et al., 2020, p. 261). Generally, an adverse range of scenarios is included to ensure consideration of tail risks. Additionally, the application of common scenarios across banks leads to consistency in the supervisory standards used across banks. Finally, publishing the results of the bank stress tests restores trust and decreases market uncertainty (Sahin et al., 2020). Therefore, it seems reasonable that the disclosure of the results of stress tests moves the stock and credit markets and reduces the systematic risks of banks in the years following publication (Sahin et al., 2020).

These findings are also supported by Fernandes et al. (2020), who find evidence that stress tests contain relevant new information, especially during crises. A recent example of such a crisis is the COVID-19 pandemic. In particular at the beginning of the pandemic, scenarios were used to determine, for example, the impact of the virus on the liquidity insurance function of banks (Acharya & Steffen, 2020) or to estimate the size of the capital shortfall of European banks and to derive appropriate countermeasures (Schularick, Steffen, & Tröger, 2020).

After the 2008 financial crisis, the banking sector faced increased regulation (Cortés et al., 2020). As part of this, stress testing has also gained importance in detecting potential risks to the banking sector and defining preventive measures (Hernández, García, Suárez, & Tarancón, 2022). Thus, in the EU, the ECB conducts stress tests with its supervised banks at least once a year, which is a requirement by EU law (European Central Bank (ECB), 2022c). In 2022, the ECB conducted a climate risk stress test for the first time to analyse how well banks manage climate-related risks and to derive best practises on handling climate-related risks. Although, for now, this exercise does not affect banks' capital levels, banks and supervisors are expected to learn from it and become aware of climate-related vulnerabilities. The climate stress test has shown that the use of a variety of climate scenarios reveals that a bank's exposure to physical risks could vary depending on the respective portfolio of the bank. For example, banks with a large real estate portfolio could be more severely hit by a flooding scenario than banks with a smaller real estate portfolio (European Central Bank (ECB), 2022b).

Note. Adapted from "UNEP FI TCFD Banking Pilot Projects", by UNEP FI, n.d.

Figure 2: Overview of banks that have participated in the UNEP FI TCFD programme.

4.2 Climate Scenario Analysis

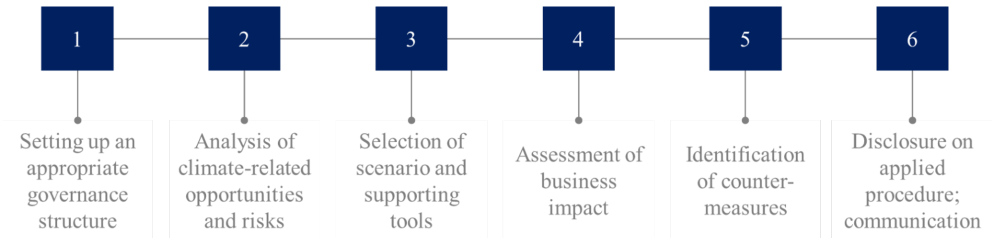
Understanding the effects of climate change on the business of a bank is key to enhancing its resilience (TCFD, 2017c). Appropriate disclosure of the impact for climate change gains importance to “enable stakeholders to better understand the concentrations of carbon-related assets in the financial sector and the financial system’s exposures to climate-related risks” (Financial Stability Board (FSB), 2015, November 9, p. 4). Therefore, the TCFD provides guidelines on reporting climate-related issues. Standardised procedures for disclosing climate-related information are crucial to enhance transparency and comparability among organisations. In particular, climate scenario analysis is a useful “tool for forward-looking assessment of financial climate-related risks and opportunities” (Institutional Investors Group on Climate Change (IIGCC), 2019, p. 9) in organisations. Its adoption helps to understand the dynamics of climate change and allows companies to analyse future potential impacts to support better decision making (Eis & Schafer, 2019; Huiskamp et al., 2022; John et al., 2018).

Scenario analysis is often mistakenly used in connection with projections and sensitivity analysis. Technically, these two are not scenario analyses because they update an existing parameter and not an entire set of variables (GSFC Germany, 2019). To support organisations in applying climate-related scenario analysis, the TCFD (2017) provides an implementation framework with six steps (Figure 2):

1. Governance structure: assess which stakeholders should be part of the approach to identify the organisation's climate-related opportunities and risks. In addition, evaluate the participation of an organisation's management. The TCFD recommends direct and active management participation in the implementation process of climate scenario analysis (Global Compact Network Germany (GCNG), 2019; on Climate Related Financial Disclosures (TCFD), 2017c).

2. Analysis of climate-related opportunities and risks: determine significant climate-related opportunities and risks. Both physical and transition risks might affect organisations in the future. Thus, it is recommended to analyse the company's exposure to physical and transition risks.

Figure 3: Process for conducting a climate scenario analysis



Note. Adapted from "A Process for Applying Scenario Analysis to Climate-Related Risks and Opportunities", by TCFD, 2017c

3. Selection of scenario and supporting tools: select climate scenarios and supporting tools (GCNG, 2019). The TCFD recommends the use of different climate scenarios since "the selection of a set of scenarios (not just one) that covers a reasonable variety of future outcomes" (TCFD, 2017b, p. 27) is a crucial aspect of climate scenario analysis. Two or three scenarios related to physical climate-related scenarios or NDCs can be added to account for the organisation's current circumstances (TCFD, 2017b). It is highlighted that the chosen scenarios should cover both favourable and unfavourable future outcomes (TCFD, 2017b). According to the TCFD banks should describe the resilience of their strategy in different climate scenarios, including a transition to a "2°C or lower scenario" (on Climate Related Financial Disclosures (TCFD), 2017a, p. 25). Scenarios must be tailored to the organisation's business environment (Huiskamp et al., 2022; TCFD, 2017b). Tools can be used to examine physical and transition risks and thus facilitate applying climate scenario analysis (GCNG, 2019).

4. Assessment of business impact: identify the main climate-related risks and opportunities of the organisation and their financial impacts (GCNG, 2019; TCFD, 2017c). Implications on "revenue, expenditures, assets and liabilities or capital and financing" (GCNG, 2019, p. 3) can be drawn from the results of the climate scenario analysis.

5. Identification of countermeasures: consider possible actions to be taken in response to the results (GCNG, 2019; TCFD, 2017b). Here, the double materiality perspective, outlined by the European Commission in its Non-Financial Reporting Directive, has to be taken into account, referring to two different perspectives for reporting of climate-related information (2019), the outside-in and inside-out perspective. Institutions should incorporate the respective findings in two ways: First, in risk management and second, in strategic planning. The former aims at better understanding to what extent climate-related changes impact, for example, market, credit, and operational risks (outside-in). The latter refers to identifying the changes required in a company's business model to transition to a low carbon economy (inside out) (Koberle, Ganguly, & Ostrovnaya, 2021). Changes in business strategy can be implemented to reduce identified risks and exploit detected opportunities (GCNG, 2019).

6. Disclosure: disclose and document critical information about the climate scenario analysis. As the choice of climate scenarios is crucial to scenario analysis, the selection process is particularly relevant for external stakeholders and other financial institutions. Comprehensive external reporting with a high level of transparency is recommended (Global Compact Network Germany (GCNG), 2019; on Climate Related Financial Disclosures (TCFD), 2017b).

4.3 Practical Usage of Climate Scenarios in the Banking Sector

Based on the reports of banks, we assess the current use of climate scenarios in the banking sector. In particular, this includes examining the TCFD reports of 52 pilot banks that have participated in Phase I, II or III of the UNEP FI TCFD programme (Figure 3). We will use this analysis to build our model.

Since 2018, the TCFD has published annual status reports describing the "progress on climate-related disclosure and TCFD implementation efforts, insights, and challenges" (on Climate Related Financial Disclosures (TCFD), 2021a). The TCFD provides information on the use of climate scenarios in "more than 1,600 companies" (on Climate Related Financial Disclosures (TCFD), 2021b, p. 1), of which more than 280 can be allocated to the banking industry as of 2021 (on Climate Related Financial Disclosures (TCFD), 2021b).

The pilot banks' most recent TCFD reports available in English or German as of 31 May 2022 are downloaded and examined to obtain sufficient information on these aspects. If no TCFD report was published, we derived the corresponding information from the bank's annual report. As only specific sections of the reports are important for the analysis of practical usage of climate scenarios, the reports are investigated by keyword search ("climate scenario", "scenario", "scenario analysis", "portfolio alignment", "physical", "transition", "risk", "TCFD", "sector") to collect relevant information. The analysis focusses on the use of the chosen scenarios with respect to the perspective of the three items covered, the type of risk addressed, and the sectors analysed. Initially, we inspect the distribution of the scenarios and the scenario providers among the 52 pilot banks. Afterwards, we analyse the scenarios regarding the three items to visualise the different usages of climate scenarios in banks. In both steps, the quantitative data are complemented by qualitative reasonings extracted from the reports. Some pilot banks use scenarios by more than one provider and cover more than one perspective, risk type, or sector. Banks that do not provide information on any of the items are marked as "NA".

First, we analyse which climate scenario providers the pilot banks select (Figure 4). For a better overview, the providers selected by less than five banks are labelled 'Other'. In general, international climate scenarios, such as the IEA, IPCC and NGFS scenarios, are used most frequently (by more than 20 pilot banks each). Local climate scenarios such as the Agora scenario (n.d.) are rarely used. A breakdown of the respective scenarios of the three most commonly used scenario providers is shown in Figure 5, Figure 6, and Figure 7. For analysing the use of the NGFS scenarios, a different level of granularity is applied as many banks only provide information on the scenario cluster (orderly, disorderly, hot house world) and not on the specific scenario used.

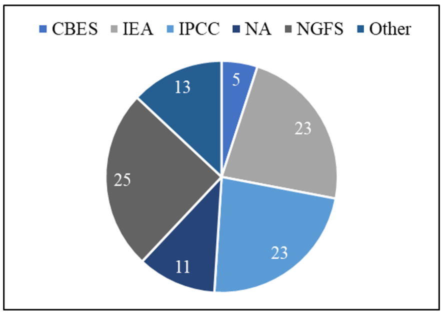


Figure 4: Use of different Scenario Providers among banks

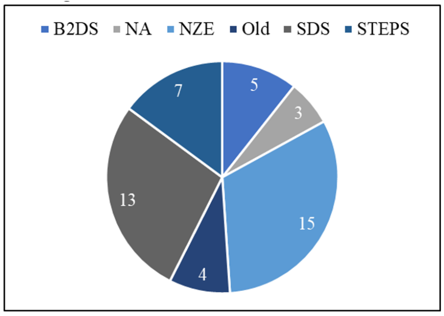


Figure 5: Use of different IEA Scenarios among banks

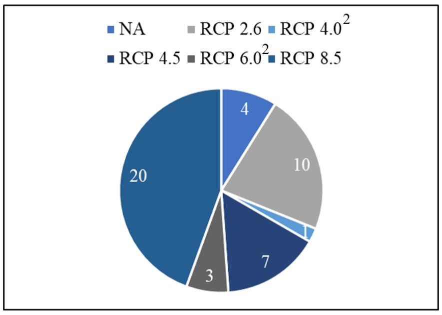


Figure 6: Use of different IPCC Scenarios among banks

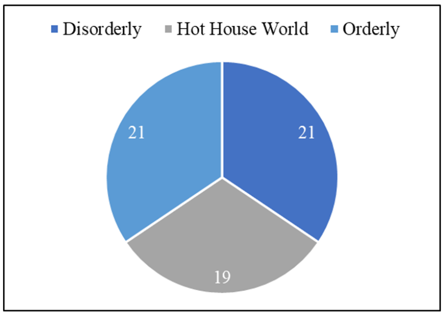


Figure 7: Use of different NGFS Scenarios among banks

The frequent use of climate scenarios by the IEA, IPCC and NGFS is explained by the perception of the banks of them as "reliable and established climate scenario provider[s]" (K. Group, 2022, p. 88). As the reasons why banks select a specific climate scenario provider vary, we assume that the choice of a climate scenario provider depends on the purpose pursued. Although the scenarios provided by the IEA are chosen due to their "sectoral and regional coverage, as well as recognition amongst policy makers and financial institutions" (Commerce International Merchant Bankers Group Holdings Berhad (CIMB Group), 2022, p. 86), IPCC scenarios are selected as they "provided best scientific consensus at the time of the report" (Bank of America, 2019, p. 6). Sovcombank selected the NGFS scenarios because they "provide a common starting point for analysing climate risks to the economy and financial system" (Sovcombank, 2022, p. 8). Another advantage of them is that they are "widely used by industry regulators" (ING Groep (ING), 2021, p. 42) and "allow stakeholders to explore transition risks, as well as physical risks" (Santander, 2021, p. 14). Apart from these favourable characteristics, Citi criticises that "NGFS scenario[s] do [. . .] not have a sector-specific CO2 emissions pathway for oil and gas" (Citi, 2021, p. 57) which would have been necessary since Citi's energy portfolio includes oil and gas companies.

In addition to these three widely used climate scenario providers, mainly British banks (Barclays PLC, 2022; N. Group, 2022) and, due to their involvement in the UK, Swiss banks (Credit Suisse, 2021; UBS, 2022) used the Climate Biennial Exploratory Scenarios (CBES) developed by the Bank of England. Therefore, these scenarios are applied by five of the banks included in the analysis (Figure 4). Since these scenarios are "built upon a subset of the Network for Greening the Financial System (NGFS) climate scenarios and expanded on the NGFS scenarios in certain aspects" (Barclays PLC, 2022, p. 23), they are consistent with NGFS (UBS, 2022). Furthermore, it can be derived that some banks based their climate scenario analysis on scenarios developed by consulting firms for bank purposes (Canadian Imperial Bank of Commerce (CIBC), 2019; L. B. Group, 2022). Although they are specially tailored for the bank, they are based on existing climate scenarios. In the case of Lloyds Banking Group, new climate scenarios were designed "to reflect that the Group is a UK focused institution that serves global clients" (2022, p. 66).

As climate scenarios from the IEA, IPCC, and NGFS are the most frequently used among banks, we examine their application in more detail. Precisely, the scenario by different providers seem to be deployed for different purposes. To understand the underlying reasons for this and to derive relevant characteristics for the selection of specific climate scenarios, the analysis focusses on perspective, risk type, and sector.

Perspective: The perspective can be either inside-out or outside-in for a given scenario (reflecting double materiality). In the data from this study, 47 banks include the outside-in perspective, while only 27 include the inside-out perspective (Figure 8). Thus, pilot banks focus more on assessing how climate change affects the bank than on how the bank affects the climate. When comparing the three scenario providers regarding the perspective, both IPCC and NGFS cover outside-in risks predominantly, while more than half of the analysed banks using IEA scenarios adopt an inside-out perspective (Figure 9, Figure 10, and Figure 11). This is not surprising as "IEA scenarios describ[e] the efforts needed to reduce carbon dioxide emissions" (BNP Paribas, 2020, p. 43). Therefore, these were selected by the Paris Agreement Capital Transition Assessment (PACTA) as applicable scenarios for the alignment of financial portfolios, which is part of the inside-out perspective ((2DII), 2021). PACTA, developed by 2º Investing Initiative together with several partners, including Frankfurt School, is a methodology that helps banks align their portfolios with the goals of the Paris Agreement.

Banks applying scenarios with a focus on the inside-out perspective usually aim to fulfil similar purposes. Wells Fargo states that the use of climate scenarios "helps [...] [to] determine how best to optimize [their] financing activities to meet particular targets, which can be business- or science-based" (2021, p. 28). Especially the alignment of a bank's portfolio with the goals of the Paris Agreement or the impact assessment of climate change in specific sectors is crucial (ING, 2021; Itaú Unibanco Holding S.A., 2021). Therefore, climate scenarios that have an inside-out perspective help to "translate the Paris Agreement into carbon budgets and sector-specific transition pathways, or 'technology roadmaps'" (Generale, 2022, p. 35).

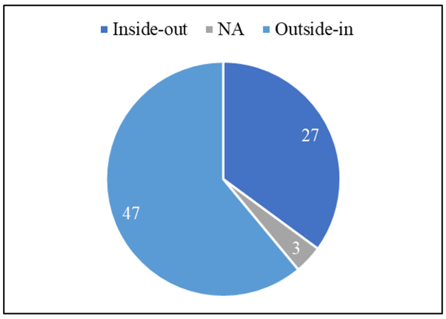


Figure 8: Split of adopted Perspective

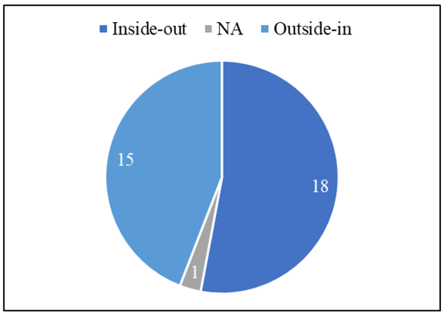


Figure 9: IEA split by Perspective

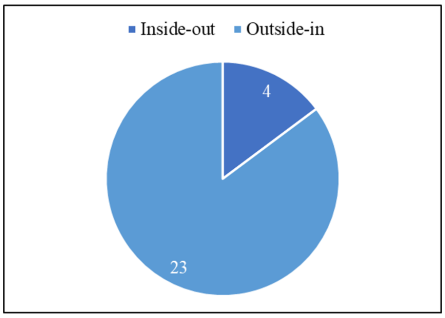


Figure 10: IPCC split by Perspective

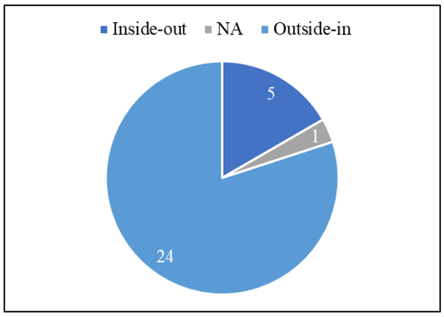


Figure 11: NGFS split by Perspective

For the outside-in perspective, climate scenarios help to "gain a better overview of the climate risk associated with the portfolio" (Den norske Bank (DNB), 2022, p. 80) and to identify the segments most affected by climate-related risks (CaixaBank, 2021). Additionally, these scenarios are a "credible basis to explore possible impacts on the economy and financial systems" (FirstRand, 2021, p. 38) and to "develop a set of overarching climate principles, to guide climate-related decisions and support the group strategy" (S. B. Group, 2022, p. 12). TSKB highlights that from the outside-in perspective, "climate scenario analysis aim[s] to develop and expand the level of awareness as well as resilience, foresight and financial planning on how climate-related physical and transition risks and opportunities could affect institutions over time" (2021, p. 21). Additionally, DNB underlines that this "method enables projections of probability of default adjusted for climate risk" (2022, p. 79).

Risk type: The impacts of climate change on banks can be distinguished into transition and physical risks (outside-in perspective). However, this differentiation is not applicable to the impact of banks on the climate (inside-out perspective) (Gourdel, Monasterolo, Dunz, Mazzocchetti, & Parisi, 2022). Thus, the risk type can only be analysed from an outside-in perspective. In general, the analysis of the data shows that transition risks are addressed slightly more frequently by pilot banks using climate scenarios than physical risks (Figure 12). With 21 banks using them, physical risks constitute the majority of risk types addressed by IPCC scenarios (Figure 14). On the contrary, IEA and NGFS, with 15 and 24 pilot banks, respectively, cover transition risks in practise (Figure 13, Figure 15).

Physical risks are mainly analysed for "estimating the potential financial impact of extreme weather events in the future" (Australia and New Zealand Banking Group (ANZ), 2021, p. 7). Additionally, scenarios that include physical risks are selected to "evaluate the resilience of sectors which have weight in the Bank's loan portfolio being vulnerable to climate change" ((TSKB), 2021, p. 21). Transition risks are essential to assess how the counterparty's financials could be affected by transitioning to a low carbon economy (Credit Suisse, 2021).

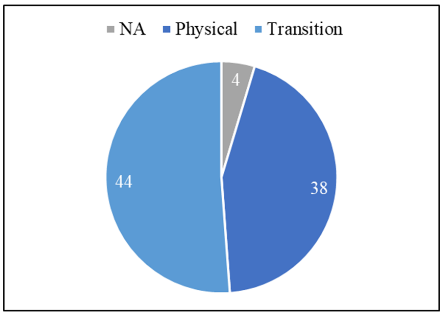


Figure 12: Risk Types

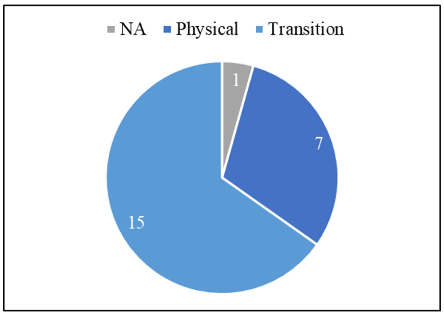


Figure 13: IEA split by Risk Type

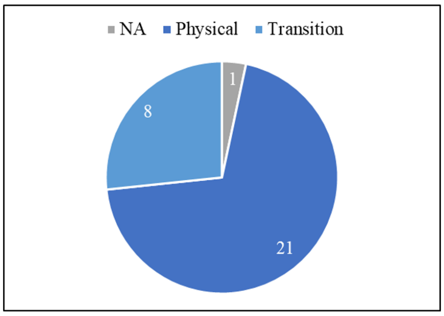


Figure 14: IPCC split by Risk Type

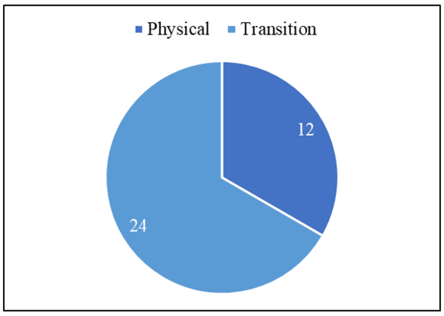


Figure 15: NGFS split by Risk Type

Sectoral coverage: even though banks can decide whether they prefer using a climate scenario analysis on, for example, a portfolio, sector, or asset level, analysing a bank's portfolio along its sectoral split is recognised as a best practise in the market. This is because banks' portfolios usually cover a variety of sectors whose exposure to climate risks differs (European Central Bank (ECB), 2022a; Green and Sustainable Finance Cluster Germany (GSFC Germany), 2019). Based on this, so-called heatmaps can be derived, illustrating the vulnerability of the bank in various sectors. Therefore, it is worthwhile to examine whether specific scenarios are especially useful for assessing one sector.

To obtain a consistent breakdown, the sectors are extracted from the TCFD reports in the first step and manually categorised according to the Global Industry

Classification Standard (GICS) in the second step. GICS is a renowned standard for classifying industries and, due to the wide variety of sectoral breakdowns, helps to aggregate the sectors appropriately to enhance the comparability of the sectors covered by the scenarios (Phillips & Ormsby, 2016). Some pilot banks mention within their reports that they cover several sectors with climate scenarios, but do not provide detailed information on which sectors. In this case, the covered sectors are classified as 'Other'.

The analysis of the complete data set shows that energy (34 banks), real estate (25 banks), and utilities (24 banks) are the three sectors most often covered by the pi-lot banks. Compared to the general distribution, banks using the IEA scenarios include consumer discretionary (10 banks), energy (17 banks), and utilities (15 banks) disproportionately often, while the sectors real estate (7 banks) and financials (2 banks) are covered relatively less frequently. In contrast, banks using the IPCC scenarios mainly focus on the two sectors real estate (9 banks) and financials (5 banks), while the sectors energy (6 banks) and utilities (1 bank) are less covered compared to the overall sector breakdown. Banks using the NGFS scenario have a sectoral coverage very similar to the overall sector distribution, but with relatively higher coverage of the sector energy (15 banks) and slightly less containment of real estate (7 banks) and utilities (6 banks).

Two relevant factors for choosing a specific sector can be identified. First, several banks state that the vulnerability of a sector to climate-related risks was critical in the selection process (outside-in) (Absa Group Limited, 2022; Carbon Disclosure Project (CDP), 2022; Canadian Imperial Bank of Commerce (CIBC), 2019; Danske Bank, 2021). Second, the pilot banks (inside out) chose the sectors with the highest impact on climate change (inside-out) (Bank of Montreal (BMO), 2021; Sanpaolo, 2021; K. F. Group, 2021; K. Group, 2022). Shinhan Bank even goes one step further, explaining that "among high-emitting industries [...] industries with the highest priority – power generation and Oil and Gas – [were chosen] for analysis" (S. F. Group, 2021, p. 68). KBC Group also highlights the need to choose sectors "wherein KBC's financial leverage is largest to support the transition to a low-carbon economy" (K. Group, 2022, p. 96). This is similar to the Standard Bank Group report stating that the "client sectors in [...] [the] portfolio which present the greatest potential for climate-related opportunities" were chosen (S. B. Group, 2022, p. 12). Santander outlines that besides "climate relevant sectors [...] [also] individuals, SCF [Santander Consumer

Finance] and corporates customers" (2021, p. 20) were focused on the climate scenario analysis.

The analysis of the practical application of climate scenarios in the banking industry shows that the three most frequently used climate scenario providers, IEA, IPCC and NGFS, are all relevant in practise (Figure 4). Many banks even use climate scenarios by several institutions. However, national climate scenarios like the on from Agora seem rarely important in practise. When evaluating the results of the analyses focussing on the covered perspective, risk types, and sectors in Section 4.3, different reasons for using climate scenarios of one of the three leading providers are identified. IEA scenarios are used primarily to align the bank portfolio to a defined temperature goal; therefore, they are applied mainly to adopt an inside-out perspective (Figure 9). Consistent with the perspective taken, carbon-intensive sectors are selected to bring bank activities with the highest carbon-saving potential in line with the chosen emission pathway (ABN AMRO, 2022; Danske Bank, 2021; ING Groep (ING), 2020). Unlike IEA, IPCC and NGFS focus on an outside-in perspective (Figure 10 and Figure 11). IPCC scenarios focus on examining physical risks (Figure 14) and include sectors such as real estate, which are especially vulnerable to these risks (Chatain, Ghosh, Preudhomme, & Mazzacurati, 2021). NGFS scenarios, on the contrary, primarily cover transition risks and sectors most affected by this risk type, such as energy (NGFS, 2021). Concludingly, while analysing the practical use of climate scenarios shows their broad applicability, certain tendencies are discernible as to which climate scenario appears to be best suited in practise for which perspective or risk type.

5 Model Development

- We extend the model of van Notten et al. (2003) to integrate characteristics relevant for practical applications of climate scenarios in the banking context.
- is should help banks in the climate scenario selection process by highlighting particularly relevant characteristics.
- The model on the characteristics of climate scenarios relevant for banks is based on the common climate science heuristic of the three criteria: 'legitimacy', 'credibility' and'salience'.

In this chapter, we build on the literature review and practical perspective and develop a model of characteristics for climate scenarios that combines theory and practise. Section 5.1 compares the results of both analyses. Section 5.2 presents the model.

5.1 Problem Definition

Section 3.3 shows that the model of van Notten et al. (2003) can be applied to analyse the climate scenarios by IEA, IPCC, NGFS, and Agora. However, the typology allows only for differentiating three types of climate scenarios. These scenario types are primarily derived from four characteristics that vary across climate scenarios: normative / descriptive, forecasting / forecasting, trend / peripheral and conventional / alternative scenario. Looking at the three types of climate scenarios identified (Table 3), it is striking that the classification of a scenario as normative or descriptive seems to impact the latter characteristics, as normative climate scenarios are also peripheral and alternative scenarios, whereas descriptive scenarios are trend and conventional scenarios. Table 2 shows further differences for the Agora scenarios, which can be explained by the fact that it is a national climate scenario.

In general, most of the scenario characteristics are the same among the scenarios analysed. Therefore, although the typology helps to better understand climate scenarios and how they are constructed, the concept of the model by van Notten et al.

Table 3: Types of climate scenarios identified among the IEA, IPCC, NGFS, and Agora scenarios

	Scenario characteristics				Scenarios			
Type	Inclusion of norms	Vantage point	Nature of the dynamics	Level of deviation	NGFS	IEA	IPCC	AGORA
1	normative	backcasting	peripheral	alternative	NZ; B2; DNZ; DT (Orderly & Disorderly)	NZE; SDS	SSP1-2.6	KN2045; KN2050
2	descriptive	forecasting	trend	conventional	NDCs; CP (Hot House World)	APS; STEPS	SSP2-4.5	-
3	normative	forecasting	peripheral	alternative	-	-	SSP1-1.9; SSP3-7.0; SSP5-8.5	-

Note. The scenario characteristics are adopted from “An updated scenario typology” by van Notten et al., 2003

(2003) does not allow us to draw any conclusions about unique characteristics since several climate scenarios (also between different providers), leading to challenges when differentiated on the model as seen in the practical analysis where the model is of limited use. The model does not seem to sufficiently differentiate the characteristics of climate scenarios and can be extended to fully capture their variety.

5.2 Model Design

Legitimacy, Credibility, and Salience. To develop a new model on the characteristics of climate scenarios relevant for banks, a common heuristic of climate science is applied. This refers to the three criteria 'legitimacy', 'credibility' and 'salience'. Other researchers have already used these attributes as, for example, a framework for “co-producing knowledge for action [...] for many different sustainability issues” (Cash & Belloy, 2020, p. 9) or to examine the evolution of IPCC scenarios against these criteria (Girod, Wiek, Mieg, & Hulme, 2009). Specifically, 'legitimacy' refers to the transparency and fairness involved in the scenario construction process (Girod et al., 2009), which is required to ensure trust in the knowledge provided by the scenario (Cash & Belloy, 2020). Furthermore, 'credibility' focusses on whether the information inherent in a climate scenario is “meeting standards of scientific plausibility and technical adequacy” (Cash et al., 2002, p. 4). The last criterion, 'salience', sometimes called relevance, refers to the relevance of information for decision making. High salience is given when information addresses, for example, problems relevant to the decision-maker (Cash et al., 2002).

Using the three criteria from climate science as a starting point allows us to identify various characteristics of climate scenarios. “Their cohering function for assessments of climate change impacts and adaptation options” (Hulme & Dessai, 2008, p. 66) ensures the completeness of the model. Starting from these criteria, characteristics specific to climate scenarios are identified. In the first step, the 14 characteristics of van Notten et al. (2003) are assigned to a respective criterion, since the validity of the van Notten et al. (2003) model has been recognised by various researchers (Amer et al., 2013; Bishop et al., 2007; Börjeson et al., 2006). Afterwards, 12 criteria derived from the practical analysis are added based on the insights gained from analysing the TCFD reports (see Section 4.3). This ensures that the reasons considered by banks during the selection of a climate scenario are included in the model. The complete model can be found in Table 4.

Characteristics derived from theory. Van Notten et al. (2003)'s “project goal”-theme aims at answering the question “why” a scenario is developed. Having this question answered provides the fundamental basis for constructing a scenario and ensures transparency on the objectives pursued with the scenario. Thus, the five characteristics outlined under this overarching theme by van Notten et al. (2003) are included under 'legitimacy' (inclusion of norms (L1), vantage point (L2), subject (L3), time scale (L4), spatial scale (L5)).

The theme 'process design' contains two characteristics, the nature of the data and the data collection method, which also belong to 'legitimacy' (L6 and L7, respectively). The last two, nature of the resources and institutional conditions, are assigned to the second criterion, 'credibility' (C1 and C2, respectively). This is because open institutional conditions mean that more freedom is given to the scenario project, i.e., developing the scenario is not impacted by external interventions such as political or personal relations. Being independent is a “key ingredient [. . .] of scientific credibility” (Ruggiero, 2007, p. 1) and, thus, the institutional conditions impact whether a scenario is perceived as credible. In addition, the development of a scenario can be considered more reliable through the extensive use of resources, since investing a great deal of time or resources in scenario development allows to include various aspects relevant to the scenario (Cradock-Henry & Frame, 2021). Hence, scenario users are expected to perceive it as more credible.

All characteristics of the theme 'scenario content' by van Notten et al. (2003) are assigned to 'legitimacy' (temporal nature (L8), nature of variables (L9), nature of dynamics (L10), level of deviation (L11), and level of integration (L12)) as they provide information on the general construction of the scenario and thereby increase transparency.

Table 4: Model on the characteristics of climate scenarios

Criterion	No.	Scenario characteristics	Form of characteristic	Source
Legitimacy	L1	inclusion of norms	descriptive/normative	van Notten et al. (2003), Greeuw et al. (2000)
	L2	vantage point	forecasting/backcasting	van Notten et al. (2003), Greeuw et al. (2000)
	L3	subject	issue-/area-/institution-based	van Notten et al. (2003)
	L4	time scale	short-/long-term	van Notten et al. (2003), Greeuw et al. (2000)
	L5	spacial scale	global/international/ national/regional /local	van Notten et al. (2003), Greeuw et al. (2000)
	L6	nature of the data	qualitative/quantitative	van Notten et al. (2003), Greeuw et al. (2000), Kishita et al. (2015)
	L7	method of data collection	participatory approach / desk research	van Notten et al. (2003), Greeuw et al. (2000)
	L8	temporal nature	snapshop/chain	van Notten et al. (2003)
	L9	nature of the variables	homogeneous/heterogeneous	van Notten et al. (2003)
	L10	nature of the dynamics	peripheral/trend	van Notten et al. (2003), Greeuw et al. (2000)
	L11	level of deviation	alternative/conventional	van Notten et al. (2003)
	L12	level of integration	low/high	van Notten et al. (2003), Greeuw et al. (2000)
Credibility	C1	inclusion of norms	descriptive/normative	van Notten et al. (2003), Greeuw et al. (2000)
	C2	vantage point	forecasting/bastcasting	BNP (2022), CIMB Group (2022)
	C3	subject	issue-/area-/institution-based	Bank of America (2019), BMO (2021), TSKB (2021)
	C4	time scale	short-/long-term	Banorte (2022), Citi (2021), ING (2021)
	C5	spacial scale	global/international/ national/regional /local	ANZ (2021)
	C6	nature of the data	qualitative/quantitative	Deutsche Bank (2022), ING (2021)
Salience	S1	inclusion of norms	descriptive/normative	BNP (2022), Credit Suisse (2021), Sovcombank (2022)
	S2	vantage point	forecasting/bastcasting	BMO (2021), Citi (2021), DanskeBank (2021), ING (2021)
	S3	subject	issue-/area-/institution-based	Banorte (2022), Credit Suisse (2021)
	S4	time scale	short-/long-term	Nomura (2021)
	S5	spacial scale	global/international/ national/regional /local	BBVA (2020), ING (202)
	S6	nature of the data	qualitative/quantitative	Bank of Ireland (2022), ING (2020)
	S7	method of data collection	participatory approach / desk research	BMO (2021), Citi (2021), Credit Suisse (2021)
	S8	temporal nature	snapshop/chain	AIB (2022)

Note. Criteria are adopted from "Salience, Credibility, Legitimacy and Boundaries: Linking Research, Assessment and Decision Making" from Cash et al., 2002

According to the assignment of the scenario characteristics identified by van Notten et al. (2003), 12 characteristics are found under 'legitimacy', two under 'credibility', but none under 'salience'. This observation can be explained by the fact that "salience" refers to the transmission of information relevant to the users of the scenario. Although the van Notten et al. (2003) model was built to identify scenario types from various industries, it cannot include detailed criteria applicable to climate scenarios as this was not part of the researchers' objectives.

Characteristics derived from practise. We extend the model by van Notten et al. (2003) with additional characteristics relevant to climate scenarios by including findings from the practical perspective. Based on the analysis of the TCFD reports (as outlined in Section 4.3), the reasons for selecting a particular climate scenario are assessed to derive the related scenario characteristics. The practical examination also supports many of the characteristics under 'legitimacy', for example, the point of view (Citi, 2021), the time scale (Chartered, 2022) and the spatial scale (KBC Group, 2022; Lloyds Banking Group, 2022) but no other characteristics are added here; while 'credibility' and 'salience' are extended by four and eight characteristics, respectively.

Additions to "credibility": the first identified criterion is the use of a science-based approach (C3) (Bank of America, 2019; Bank of Montreal (BMO), 2021; (TSKB), 2021) that can be applied to a limited or extensive degree. This criterion aims at evaluating whether banks value the fact that a climate scenario is built based upon scientific standards to a large extent, and thus ensures credibility in the selected scenario.

The second criterion, the usage of a climate scenario by other banks (C4), examines whether banks consider the approach taken by other banks regarding climate scenario analysis. If many other banks use a particular climate scenario, this implies frequent use, while the usage of a few banks implies infrequent use. This aspect gains importance as NGFS aims to provide "a common reference framework for financial institutions" (Banorte, 2022, p. 17). Using the same climate scenario in an industry brings consistency and comparability (ING Groep (ING), 2021), which also contributes to credibility (Abernathy, Stefaniak, Wilkins, & Olson, 2017).

The following characteristic deals with the degree to which a climate scenario is based on recent data and is expected to be updated regularly (C5). Depending on the frequency of updates, this characteristic might be classified as one-time, meaning that a climate scenario is not updated after being published, or as continuous, referring to regular updates. Considering that climate scenarios illustrate possible future developments, they must use recent data so that the model has a solid foundation. If out-dated data were used, this would reduce the validity of the analysis.

When analysing the impact of climate change from a risk management perspective (outside-in), compliance with regulatory guidelines (C6) gains importance. Although the use of a particular climate scenario is not currently prescribed (TCFD, 2017a), adhering to the regulator's guidelines is essential to avoid adverse consequences. Here, climate scenarios can be distinguished based on whether they are recognised by the regulator (TCFD, 2017c) or published and used by industry regulators themselves, like the NGFS scenarios (Network for Greening the Financial System (NGFS), 2021). Given that fulfilling regulatory requirements is of highest importance for banks, it is expected that using a climate scenario that is accepted or even applied by the regulatory authorities is credible.

Additions to "salience": eight characteristics are derived that compare the content of the scenario in detail. The first scenario characteristic refers to the temperature tar-get outlined by a scenario (S1). Since the various climate scenarios show future pathways leading to different temperature outcomes in the final year, this may be a relevant decision criterion, especially to ensure Paris alignment (BNP Paribas, 2022; Sovcombank, 2022). Therefore, this could require a Paris-aligned temperature target (that is, below 2 ° C). For other purposes, for example, when assessing the impact of climate change on a bank, it might be worthwhile to include a non-Paris-aligned temperature target to assess the impact of current policies.

Secondly, the practical analysis shows that climate scenarios apply to various sectors. They may differ on the extent to which a sector is covered. For example, Danske Bank (2021) criticises NGFS scenarios for insufficient sector-specific assumptions. Thus, another characteristic of the scenario is the granularity of the sectors covered (S2), which can be low, medium or high, where low refers to providing little information on a specific sector, and high implies the availability of precise sectoral information. In addition to the varying level of detail on a sectoral level, climate scenarios can also differ regarding the degree of detail to which various regions are covered.

To precisely determine the impact of climate change on a particular country or region, banks may need data on a regionally disaggregated level (Banorte, 2022). Thus, the third characteristic focusses on the granularity of the regions covered by a climate scenario (S3). Depending on the degree of disaggregation required, this characteristic might take the form of low, medium or high, where low implies a strong aggregation level (e.g., on a global scale) and high refers to a large disaggregation (e.g., on the postcode or even the address level) (Network for Greening the Financial System (NGFS), 2020).

The next criterion (S4) focusses on the type of risk considered in a climate scenario, that is, whether physical, transition or both risks are included in the climate scenario. For example, Nomura (2021) chose the NGFS scenarios as these include both types of risk within one scenario. However, other banks use different climate scenarios to examine the impact of transition and physical risks in the same sector (Citi, 2020; Sanpaolo, 2021; K. Group, 2022). Focussing on transition risks, technological change is required for decarbonisation (Banco Bilbao Vizcaya Argentaria (BBVA), 2022; ING Research, 2020).

Scenarios illustrating the required technological changes to achieve, for example, net zero in 2050, help banks to adjust their portfolios accordingly (inside-out). Therefore, the provision of a technology guideline is another relevant characteristic of the scenario for bank decision making (S5) and can be distinguished depending on whether the scenario conveys this information in detail or at a high level. The assignment of this characteristic to 'salience' is supported by Cash et al. (2002), who recognise the availability of appropriate technology for the environmental context as a relevant aspect of 'salience'.

In addition to technological development, policy changes can be a major driver of scenario development. For example, "policies that restrict flying to reduce emissions from aviation" (ING Research, 2020, p. 9) would significantly contribute to achieving net zero. Depending on whether these policy reactions occur immediately or delayed, the impact on banks can vary (S6). Within this report, delayed means any policy reaction that occurs after 2030 while immediately covers the period until 2030. This is because the EU developed a separate Climate Target Plan for 2030, which serves as a milestone for achieving climate neutrality by 2050 (European Commission, n.d.-a).

To achieve emission reductions, climate scenarios also differ in their assumptions for carbon dioxide removal (Citi, 2021). This means that some scenarios allow offsetting, for example, by planting forests to achieve emission targets. Although net zero emissions can be achieved in this way (CO2 removals offset anthropogenic CO2 emissions), this should not be confused with absolute zero emissions, which means that no CO2 emissions are produced at all (Citi, 2021; Intergovernmental Panel on Climate Change (IPCC), 2018). Consequently, banks could include whether carbon dioxide removal is prohibited or permitted in a certain scenario in their decision-making process for a climate scenario (S7).

The last characteristic of the scenario refers to the specific variables used in a scenario (S8). For example, AIB (2022) considers precipitation, heavy rainfalls, and rise in sea level as key elements in the analysis of the physical environment. Hence, whether a climate scenario contains weather-related and/or economic variables is also relevant for deciding upon a scenario.

6 Case Study

- Based on a case study in a German promotional bank, we identify 14 characteristics of climate scenarios that are most relevant to banks.
- We identified four use cases based on different combinations of perspective (inside-out / outside-in) and risk type (physical and transition).
- Different climate scenario providers have strengths and weaknesses along those dimensions.
- Despite the general usability of climate scenarios for banks, there are still some challenges in using climate scenarios, related to insufficient data granularity, a difficult translation of a standard climate scenario to bank requirements and the variety of disclosure formats

We refine the model derived in the previous section by conducting a case study. We begin by explaining the context of the case study. Subsequently, we explain the 14 characteristics of the model that are applicable to four use cases and derive the corresponding implications for the use of climate scenarios in banks (Section 6.1). The second part differentiates challenges related to the data provided by climate scenarios, their respective implementation, and the disclosure of the results of the climate scenario application (Section 6.2).

Case study setting. To refine the model and identify which characteristics are particularly relevant to banks when selecting a climate scenario and why, we carry out a case study in a German promotional bank. For confidentiality, the name of the Bank is disguised and hereafter referred to as the "Bank". Since the adoption of the TCFD guidelines, climate scenarios from IEA, IPCC, and NGFS have been applied in the Bank. These are also the most frequently used climate scenarios among the pilot banks (Section 4.3). Thus, the Bank represents a suitable case for analysing the reasons for choosing a specific climate scenario.

We choose semi-structured interviews to reveal the relevant characteristics of climate scenarios as they give the opportunity to slightly adapt the questions asked according to the specific knowledge and organisational context of the interviewee. At the same time, they leave enough space to explain the derived characteristics in more detail (Saunders, Lewis, & Thornhill, 2016). Having flexibility for follow-up questions allows diving into the details of relevant characteristics, which is an essential base for understanding why specific scenario characteristics are suitable for banks (Adams, 2018).

Since the selection of appropriate interviewees constitutes an 'iterative process' (Bogner & Menz, 2009, p. 55), we conducted four preliminary talks to gain an understanding of where the knowledge on climate scenarios is distributed among the Bank. Subsequently, we selected six interviewees, as they have worked with climate scenarios for at least one year. For case studies, the applicable experts must be identified "in relation to the concrete field of operation in which the expert acts" (Bogner & Menz, 2009, p. 54). An overview of the interviewees can be seen in Table 5, where the last two experts have only been interviewed as part of preliminary talks (due to a lack of technical expertise on the matter).

In the interview, we discuss all the characteristics of the scenarios as presented in Table 4. Each interviewee discusses the relevant characteristics during the climate scenario selection process. Criteria are randomly selected, that is, the order of characteristics is varied across all interviews, to avoid bias (Baehring, Thommes, Hauff, &

Sossdorf, 2008).

Table 5: Overview of experts interviewed

Name	Division	Responsibility	Persepective	Risk Type
Expert 1	Risk controlling	Climate-related stress testing	Outside-in	Transition
Expert 2	Risk controlling	Climate-related stress testing	Outside-in	Transition
Expert 3	Risk management	Climate impact on sovereign ratings	Outside-in	Transition/Physical
Expert 4	Risk management	ESG-risks (TCFD-reporting, climate scenario analysis)	Outside-in	Transition/Physical
Expert 5	Strategy	Paris-compatible alignment of portfolio	Inside-out	NA
Expert 6	Strategy	Country-specific Climate-Factsheets	Outside-in	Physical
Expert 7	Risk controlling	Climate-related stress testing	Outside-in	Transition
Expert 8	Bank's subsidiary	Impact management	Inside-out	NA

6.1 Refined Model

Relevant characteristics. To derive a list of relevant characteristics for banks, we decided to differentiate them according to four combinations of the 'perspective risk type' (see Table 6 for more details). Section 4.3 already shows that not only the outside-in and inside-out perspective may lead to choosing different climate scenario providers but also the risk type examined under the outside-in perspective. This observation is confirmed by the case study in which the interviewees perceived different characteristics as relevant. Table 6 shows the characteristics of the relevant climate scenario and their respective criteria ("legitimacy", "credibility", and "salience"), as well as a split by four combinations of 'perspective risk type'. The former differentiates between the outside-in and inside-out perspectives. The latter applies only to the outside-in perspective and distinguishes physical, transition, or both risks. The expression 'both risks' is included since banks may want to assess physical and transition risks simultaneously and do not want to examine them independently.

Table 6: Overview of relevant characteristics of climate scenarios for banks

<table>
<tr><td rowspan="2">Criteria</td><td rowspan="2">Characteristic</td><td colspan="4">Use Cases</td></tr>
<tr><td>Outside-in – Physical risk</td><td>Outside-in – Phys. & trans. risks</td><td>Outside-in – Transition risk</td><td>Inside out</td></tr>
<tr><td rowspan="5">Legitimacy</td><td>Spatial scale</td><td colspan="4">Global</td></tr>
<tr><td>Temporal nature</td><td colspan="4">Chain</td></tr>
<tr><td>Time scale</td><td>Long-term</td><td colspan="3">Short-/Long-term</td></tr>
<tr><td>Nature of the data</td><td>Quantitative</td><td colspan="3">Quantitative & Qualitative</td></tr>
<tr><td>Level of integration</td><td colspan="3">High</td><td>NA</td></tr>
<tr><td rowspan="5">Credibility</td><td>Science-based approach</td><td colspan="4">Extensive</td></tr>
<tr><td>Institutional conditions</td><td colspan="4">Open</td></tr>
<tr><td>Usage of scenario by banks</td><td colspan="4">Frequent</td></tr>
<tr><td>Up-to-dateness</td><td>NA</td><td colspan="3">Continuous</td></tr>
<tr><td>Regulatory compliance</td><td>Acknowledged by the regulator</td><td colspan="2">Published by the regulator</td><td>Acknowledged by the regulator</td></tr>
<tr><td rowspan="4">Salience</td><td>Temperature target</td><td colspan="3">Paris-aligned/non-Paris-aligned</td><td>Paris-aligned</td></tr>
<tr><td>Granularity of regions covered</td><td>High</td><td colspan="2">Medium</td><td>NA</td></tr>
<tr><td>Granularity of sectors covered</td><td colspan="2">NA</td><td colspan="2">high</td></tr>
<tr><td>Required data</td><td>Weather-related</td><td>Weather-related and economic</td><td>Economic</td><td>Technology guidelines</td></tr>
<tr><td></td><td>Climate scenarios used in the Bank</td><td>IPCC (RCP 2.6, RCP 4.5, RCP 8.5)</td><td>NGFS (NZ, B2, CP)</td><td>NGFS (NZ, DT)</td><td>IEA (NZE, SDS)</td></tr>
</table>

Some characteristics share the same expression across all combinations of 'perspective risk type' for the Bank, while others show different expressions. The broadly shared characteristics occur mainly among the first two criteria, 'legitimacy' and 'credibility'. For 'salience', the expressions vary. Based on this, we conclude that characteristics under 'legitimacy' and 'credibility' are required to ensure general acceptance of a climate scenario. Thus, scenario providers should comply with these characteristics when building climate scenarios. On the contrary, the characteristics listed under 'salience' illustrate the different aspects depending on the combination of 'perspective - risk type'. These are particularly relevant for banks when selecting a climate scenario and help to distinguish various climate scenario providers. Subsequently, we discuss the individual characteristics.

Legitimacy

The first criterion, spatial scale, takes the same form in all combinations of 'perspective risk type': a climate scenario must have a *global* scale when bank operations are spread throughout the world. This ensures that one climate scenario covers large parts of the portfolio, which is crucial to receiving meaningful results in stress tests. Combining various local climate scenarios, such as the Agora scenarios, to increase the geographical coverage might not be possible due to systematic differences among the climate scenarios. However, local climate scenarios can complement global climate scenarios by providing more in-depth information for specific countries/regions.

Secondly, only having *chain data* (i.e., time series data) makes climate scenarios usable for all perspectives, for example, to model risk-bearing capacity under the outside-in perspective. For the inside-out perspective, aligning a portfolio with the goals of the Paris agreement is a continuous process where the changing financing restrictions must be outlined over several years.

In contrast to the previous criteria, the relevant time scale of a climate scenario varies across the use cases. When analysing the impact of physical risks, *long-term* horizons usually yield stronger effects, given that physical risks are not expected to hit the Bank soon (and thus are less relevant for stress testing as of now). Although this holds for the Bank, the exposure of other banks to physical impact may differ. Therefore, they must determine for themselves whether a short-term analysis of physical risks is required. For transition risks, the *short- and long-term* views are essential. Supervisory authorities demand a risk assessment for the next 12 months (*short-term*). However, more significant impacts can only be seen under a *long-term* risk analysis. Concerning the inside-out perspective, an appropriate portfolio steering is only possible when having a *short-term* view. However, as Paris compatibility becomes only apparent in the *long term*, the climate scenario must continue for a longer period.

Analysing the impact of physical risks requires *quantitative* data on the occurrence and intensity of extreme weather events. For transition risks, further explanations by *qualitative* statements on the underlying assumptions are necessary to understand the *quantitative* data. The same holds for the inside-out perspective, where *quantitative* data is used for calculating quotas on, for example, investments in gas-fired power plants. Still, *qualitative* data conveys information on technologies that could become relevant in the future (e.g., carbon capture and storage technologies).

The last characteristic under “legitimacy” shows that a *high* level of integration within a scenario is required for the outside-in perspective. A coherent climate scenario facilitates understanding the applied scenario and communicating its results to the management. Thus, such a scenario is more likely to be accepted. However, the level of integration has not been mentioned as relevant from the inside-out perspective.

Credibility

The first three criteria are all shared among the various combinations of 'perspective risk type': When the climate scenario uses a science-based approach *extensively*, this contributes to credibility, as it conveys durability (application of a consistent approach over the years) and is a quality feature given that scientific work has been peer-reviewed. Secondly, *open* institutional conditions ensure the independence of the scenario publishing institution and provide the basis for meeting the standards of scientific work as outlined before. Thirdly, looking at how other banks deal with the topic before or during the implementation of climate scenarios allows to derive best practises and fosters acceptance of the scenario. Therefore, the *frequent* use of the climate scenario by other banks provides a solid guideline on whether a bank is on the right track. Still, this does not imply that banks should solely follow the approach other banks take, but could also be a pioneer.

Regarding the up-to-dateness characteristics, climate scenarios should contain the most current information to obtain the correct results of their implementation. When climate scenarios are used over a longer time horizon (e.g., for portfolio alignment), *continuous* updates are required. Similarly to software updates, scenario updates ensure keeping up with recent market trends, such as technological developments. Choosing a climate scenario that is expected to be updated regularly also avoids additional costs from switching to another scenario after a few years as the selected scenario is outdated. However, updates mainly focus on the underlying economic model and not the climate pathways as these are usually not exposed to significant changes over time. Consequently, continuous updates are less relevant for analysing physical risks, which mainly depend on a specific climate pathway.

Lastly, choosing a climate scenario accepted or recognised by the regulator is essential across all perspectives. Although the use of a specific climate scenario provider is not yet prescribed, the interviewees mention the importance of choosing a climate scenario that is *acknowledged by the regulator* to avoid additional effort in switching to a new climate scenario provider. However, for the outside-in perspective combined with transition and with both risks, several interviewees also state that they selected a climate scenario as it is *published by the regulator* (that is, referring to the NGFS scenarios). Intuitively, using this scenario would be preferable for every perspective, as it leaves very limited to no room for being criticised by the regulator for using a specific climate scenario. Still, Section 4.3 and the case study show that also other climate scenarios gained recognition. Thus, we conclude that other climate scenarios contain additional information, which keeps banks from using the NGFS scenarios for all application cases.

Salience

The inside-out perspective requires *Paris-aligned* temperature targets. Steering a portfolio to Paris-compatibility is only possible when the underlying climate scenario outlines a corresponding path. On the contrary, for the outside-in perspective, the consideration of various climate scenarios, i.e., *Paris-aligned* and *non-Paris-aligned* pathways, is relevant. Despite the TCFD recommendation to assess the impacts of a 2 ° C climate scenario (on Climate Related Financial Disclosures (TCFD), 2017b), TCFD also suggests using "favorable and unfavorable [scenarios]" (TCFD, 2017b, p. 27) to cover various future outcomes.

Assessing physical risks requires a *high* regional granularity since the impact of extreme weather events might already differ at low distances. Therefore, even the address level might sometimes be needed to comprehensively examine the physical risks. On the contrary, when analysing the impact on the Bank for the remaining two outside-in perspectives, *medium* granularity of the regions is sufficient, that is, country-level data. Here, less granularity is needed as physical risks are not analysed as precisely as when examined together with transition risks. However, the level of granularity required in a bank depends on the bank's risk assessment approach and, therefore, could differ for other banks.

For the inside-out perspective, a *high* sectoral granularity is essential for the Bank as it decided to steer its portfolio along technology-based pathways. This requires a sectoral breakdown in the first step. Afterwards, the Bank can identify sector-specific technologies that are aligned with the chosen climate scenario. As the Bank's risk assessment is structured along various sectors, a high sectoral granularity is relevant for the transition risk assessment under the outside-in perspective. This should also hold for other banks according to our TCFD analysis.

A sectoral disaggregation was not required for the physical assessment nor for the combined (physical and transition) risk assessment. Still, this view largely depends on the fact that the Bank aims to determine the impact of climate change on sovereign ratings under the combined perspective and to analyse the exposure of countries to physical risks. If other banks apply climate scenarios differently, this classification may change.

The criterion *required data* captures the data requirements for each combination of "perspective risk type". After the case study, we created this criterion combining the characteristics "technology guidelines" and "variables used" shown in Table 4. The interviews show that depending on the combinations of 'perspective risk type', specific data are required to model the impacts of climate change. Technological guidelines can be seen as one form of data needed. Thus, both characteristics are merged. Assessment of physical risks requires various *weather-related* data, for example, the magnitude of change in weather events such as floods and storms. On the contrary, when examining transition risks, *economic* and social data on gross domestic product (GDP), CO2 price, or population are needed. *Weather-related and economic data* are essential for the combined perspective. However, as explained above, less granularity is sufficient, especially regarding weather-related data. Concerning the inside-out perspective, *technological guidelines* are relevant to appropriately steer the portfolio. Precisely, the scenario should show which technologies may still be financed, which may only be financed to a limited extent, and which must not be financed anymore.

Excluded characteristics. Unlike the original model shown in Table 4, several characteristics seem to be irrelevant to the Bank decision making or are (implicitly) included in other characteristics. In the following, the reasons for excluding them in the final model are briefly explained. As already outlined in the definition of the problem (Section 5.1), the characteristics *inclusion of norms* (descriptive/normative), *dynamics* (peripheral/trend), and *level of deviation* (alternative/conventional) seem to be closely linked to each other. The first interviewees observed the same dependencies among the criteria and considered none as relevant; therefore, all of them are excluded as they do not provide additional information. Further, the characteristic *vantage point* (forecasting/backcasting) is dropped in favour of the characteristic *temperature target*, which may imply a backcasting approach if, for example, a 1.5 ° C pathway is outlined. As this report focusses on the assessment of climate scenarios, the *subject* *of the scenarios* is already issued-based. With the subject being specified in advance, this characteristic involves little value-add, and hence can also be neglected.

Although the characteristic *method of data collection* also plays a minor role when selecting a climate scenario, the characteristic is replaced by the *use of a science-based approach*. A similar reasoning applies to the following characteristic, the *variables used*: The differentiation between heterogeneous / homogeneous has received little attention although the inclusion of specific variables in a climate scenario is relevant, referred to as *required data* in the model. The *number of resources* is excluded since the availability of sufficient resources is implicitly assumed when *uses a science-based approach*. The last two excluded characteristics are *carbon dioxide removal* and *policy reaction*. The interviews reveal a lack of importance of the former criterion. Instead of using carbon dioxide removal as a decision criterion, the assumptions of the climate scenario are simply used. Combined with the fact that the public and politicians in Germany rarely accept carbon capture and storage technologies (Arning et al., 2019). Hence, including the former characteristic would not be reasonable when examining a German bank. For the latter, the experts perceived this characteristic to already be included in transition risks or as irrelevant.

Despite excluding several characteristics from van Notten et al. (2003), the distribution of characteristics in the final model supports the chosen approach to combine a theoretical and practical perspective. Relevant characteristics are derived from both perspectives in equal parts: The first seven characteristics in Table 6 (from *spatial scale* to *institutional conditions*) originate from van Notten et al. (2003) and the latter seven characteristics come from the pilot banks' reports (*usage of scenario by banks* to *required data*).

Implications. While climate scenarios were not developed for banks, the derived use cases bridge the gap by helping banks select a suitable climate scenario. Increasing the adoption rates of climate scenarios is particularly relevant, as an early assessment of climate-related risks and opportunities allows banks to improve their business resilience to climate change. The interviews reveal that banks should be aware of two aspects when conducting scenario analysis. First, to maintain consistency in the climate scenario applied, and second, to allocate sufficient resources to the work with climate scenarios. Banks should use consistent climate scenarios across their teams to avoid a mismatch in the climate scenarios applied. Setting up a central unit that coordinates the use of climate scenarios in a bank increases internal alignment. Many banks hire external consultants to support them in working with climate scenarios (Barclays PLC, 2022; Fargo, 2021). Although they are a valuable interim support, banks should build up sufficient internal capacity and expert knowledge to be prepared to work with climate scenarios in the future.

6.2 Challenges of Using Climate Scenarios

During the case study, we identified challenges related to using climate scenarios within the three fields of data, implementation, and disclosure. These aspects directly feed back into the use of our model.

Data. The availability of data is highly relevant for applying climate scenarios in practise. Therefore, it is apparent that the challenge of missing data needs to be overcome. The TCFD recommendations already outline that "the availability and granularity of data can be a challenge for organizations" (TCFD, 2017b, p. 30), further highlighting its importance. The case study reveals missing granularity of information within three categories. First, the time intervals between the data points are too large. Especially the stress testing team of the Bank needs a yearly provision of the data, as shorter-term scenarios are essential for management decisions. Currently, only data are available over five years. Thus, interpolation is used to provide a workaround for this data lack. A yearly provision of data would make this additional task obsolete and facilitate the work with climate scenarios. Second, the provision of regional data by the IEA and IPCC scenarios is perceived as insufficient because it is covered within the characteristic of *granularity of the covered regions*. Regarding the application of climate scenarios for the outside-in perspective, several experts stress the need for regional-level data. We identify different approaches to deal with this problem in practise. To disaggregate data on regions, additional tools and datasets, for example, from the Climate Service Centre and local climate models, are used. Another method is to break down the data provided at the country level to a regional level by internal experts. In addition to that, assumptions about missing data are made to cope with the issue of data unavailability. Third, the *granularity of the sectors covered* provided by the NGFS and IPCC scenarios is limited (Allen et al., 2020). As the effects of climate change differ significantly across sectors, it is necessary to provide granular sector information in climate scenarios. These are crucial to, for example, identify in which sectors banks must reduce or omit their business activities to become net zero and which sectors benefit from climate change (e.g., renewable energy technologies). Thus, the supply of sector-based data by scenario providers could help banks generate more insightful results from using climate scenarios.

In addition to a lack of data granularity, at least one scenario provider does not provide three relevant variables. First, the results of the case study highlight that the NGFS scenarios, so far, do not cover acute physical risks for all countries. As NGFS scenarios do not allow banks to fully assess physical risks, additional sources of acute physical risks must be applied (e.g., International Disaster Data Base). This is related to a higher implementation effort, as they must be aligned and integrated with existing systems and processes of organisations.

Second, IEA scenarios can be improved with regard to the granularity of sectors covered: more information on the regionally disaggregated energy mix would be helpful to facilitate aligning the portfolio. As the Paris Agreement differentiates between developing, emerging, and industrialised countries, this should also be reflected in the scenario data.

Third, the case study uncovers that the translation of the climate scenarios into granular risk drivers such as oil prices (transition risk driver) or the strength of storms (physical risk driver) is missing within the provided data. Thus, a provision of these risk drivers and their intensity by the scenarios is desired for the application in the Bank.

In addition, we find that a simplified overview of the data provided for each scenario would facilitate the selection and comparison of climate scenarios. Furthermore, finding the assumptions underlying the climate scenarios, precisely the NGFS scenarios, is perceived as difficult, as they are provided in different documents. Thus, it would unburden the application of climate scenarios if scenario providers conveyed all assumptions connected to the scenarios in a bundled and aggregated form, for example, on an overview page.

Implementation. Climate scenarios are usually provided in a standardised format to make them usable for all types of organisations. Therefore, when a bank decides to apply a particular climate scenario, it must first adapt the scenario to its requirements. The experts interviewed highlight that adjusting the scenarios to company-specific systems and processes poses challenges. As little guidance is provided for translating the standardised climate scenarios into a bank-specific format, this task is perceived as very difficult. For example, banks face the difficulty of translating the identified risks in companies into economic impacts. If a bank is insured against the risk in question, its loss is reduced; however, taking the insurance into account when assessing risk increases complexity. Therefore, extensive internal and external resources are used to examine how the translation and adaptation process can be performed.

Furthermore, if the Bank uses a specific sectoral split for risk assessment, this sector mapping might be unsuitable for climate scenarios. For some industries like energy, no further breakdown is provided, which prevents a distinction between, for ex-ample, green- and non-green-energy sources. Consequently, existing industry splits must be redefined to allow a practical application of climate scenarios.

Disclosure. The TCFD guidelines for climate-related financial disclosures also include recommendations for climate scenarios (TCFD, 2017b). However, in practise, the degree and format of information provided on climate scenarios within the analysed TCFD reports vary greatly between banks. Often, the specific scenario used, or the underlying temperature goal, is not evident from the reports. Providing best practises and more detailed regulations on the use of a particular climate scenario would increase transparency and comparability between banks and thus support other banks in the selection and implementation process (Green and Sustainable Finance Cluster Germany (GSFC Germany), 2019; Jürgens et al., 2021). This also concerns the handling of scenario updates: Although two banks use climate scenarios by the same scenario provider, they might differ if one bank uses an older version of the climate scenario. Thus, we call for regulators to provide more guidance on the use of the latest climate scenarios to increase comparability among banks. To guide banks when climate scenarios are updated, scenario providers should inform about these updates in advance.

Considering that TCFD recommends running climate scenarios that examine the inside-out and outside-in perspective as well as physical and transition risks, the use of climate scenarios from various scenario providers is necessary. Although IEA, IPCC, and NGFS scenarios have several fields of application, neither of them is the most appropriate provider for all use cases. It would help banks if scenario providers disclosed the purposes for which their climate scenarios are most suitable and published concepts for integration with other scenario providers. The NGFS already started this by mapping its scenarios against the IEA scenarios (NGFS, n.d.). However, this information does not provide sufficient guidance for banks in choosing a climate scenario. Alternatively, consolidating the three most frequently used scenario providers would allow one to connect their areas of expertise and to ease the use of climate scenarios for banks. This would also increase transparency and comparability between banks.

7 Conclusions

Climate scenarios were originally designed for policymakers and scientists (Bauer et al., 2017; O'Neill et al., 2017; Riahi et al., 2017; Ritchie & Dowlatabadi, 2018). Over the last years, the use of climate scenarios has gained increasing importance for banks. However, little research has been done to analyse what makes climate scenarios usable in practise. This report aims to bridge the gap between research and practise by examining the practical use of climate scenarios and which characteristics of them are particularly relevant for banks. We review existing literature from both the theoretical and practical perspectives to develop a model using a heuristics approach. This model is subsequently refined by conducting a case study in a German bank and, ultimately, covers 14 characteristics of climate scenarios. The practical application of the model shows its usability and allows us to derive challenges related to climate scenarios.

Some limitations inherent to the selected approach remain. First, the criteria relevant from a practical point of view are derived based on analysing the TCFD reports. Although the banks analysed can be assumed to be relatively advanced in their use of climate scenarios due to their participation in the UNEP FI TCFD Banking Pilots, other banks might also apply climate scenarios extensively. Therefore, future researchers could examine whether other banks are also advanced in using climate scenarios and refine the existing model based on their perspective on climate scenarios.

Second, the most recent data are used for both the classification of climate scenarios according to the van Notten et al. (2003) model and the analysis of the TCFD reports. However, some climate scenarios classified in Section 3.3 were updated in 2021 and banks might not yet have implemented these updated versions. Although climate scenarios are only updated and not completely changed, it may be worthwhile to examine the TCFD reports in the future to determine whether different characteristics relevant to banks are mentioned.

Third, this report focusses on the selection process of climate scenarios, as this is expected to reduce barriers to entry into the work with climate scenarios. However, the challenges outlined in Section 6.2 stress the need to also address problems during the use of climate scenarios. Therefore, future researchers should aim to identify the most significant difficulties in using climate scenarios in various banks, for example, by conducting interviews with their employees.

The paper adds to the literature by providing a characterisation of climate scenarios for banks and by supporting the selection of a climate scenario amongst banks. It is the first case study with a bank in this field. Our aim is to contribute to the continuous improvement of climate scenarios by outlining concrete actions for providers and regulators. The case study shows that climate scenario providers should increase regional and sectoral data granularity to become the "one-stop" solution for banks. The analysis of TCFD reports highlights that the climate scenarios used and the level of detail in each report vary widely.

In conclusion, climate scenarios gained increasing relevance for the banking sector over the last years, despite initially being developed for scientists and policy makers. This report illustrates the versatile applicability of climate scenarios for banks and helps to differentiate their use cases accordingly. Although the use of climate scenarios involves various challenges, these can be overcome when climate scenario providers and banks work together to benefit from each other's knowledge. The successful use of climate scenarios in the banking sector not only contributes to achieve the goals of the Paris Agreement, but also to improve the resilience to climate change of the banking sector.

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