2024 Climate Risk Stress Test (CRST): Technical report

South African Reserve Bank

Financial Stability Department
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Abstract

The South African financial system has notable vulnerabilities to climate-related risks. These reflect its exposure to carbon-intensive activities as well as the increased likelihood of climate-induced damage to physical assets. As part of its legal mandate to safeguard the stability of the financial system, the South African Reserve Bank (SARB) conducted a Climate Risk Stress Test (CRST) in 2024. This exercise subjected a set of systemic South African banks to a series of comprehensive climate-related scenarios, focusing on both physical and transition risks associated with climate change. This paper details the CRST design, top-down credit modelling framework, and scenario approaches that provide valuable insights into the potential impacts of climate change on the financial stability of the banking sector.

Table of Abbreviations

Abbreviation/term	Interpretation
BU	Bottom Up (stress test design)
CDR	Carbon Dioxide Removal
CET1	Common equity tier one regulatory ratio
CO_2	Carbon dioxide
CRST	Climate Risk Stress Test
CSST	Common Scenario Stress Test
FSRA	Financial Sector Regulation Act 9 of 2017
GDP	Gross domestic product
GHG	Greenhouse gas emissions
GT	Gigaton
IRB	Internal ratings-based approach (for credit risk exposures)
JET IP	Just Energy Transition Investment Plan
LGD	Loss given default
MtCO2-eq	Metric tons of carbon dioxide equivalent
NDC	Nationally determined contributions
NGFS	Network for Greening the Financial System
PA	Prudential Authority
PCC	Presidential Climate Commission
PD	Probability of default
Resilience	This refers to the ability of the financial system to deal with shocks effectively
SARB	South African Reserve Bank
Shock	An event that may cause disruption to, or the partial failure of, the financial system
SIFI	Systemically important financial institution
STA	The standardised approach (for credit risk exposures)
TD	Top down (stress test design)
Transmission channel or pathway	Also referred to as 'propagation' mechanisms; these are channels through which vulnerabilities may lead to the actual disruption of the financial system, should a shock occur.
VAF	Vehicle and asset finance
Vulnerability	A property of the financial system that (i) reflects the existence or accumulation of imbalances; (ii) may increase the likelihood of a shock; and (iii) when impacted by a shock, may lead to a systemic disruption of the financial system

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Executive Summary

Climate change and the transition to a low-carbon economy pose risks to financial stability. The South African financial system's vulnerability to climate-related risks is influenced by its high exposure to carbon-intensive activities and the increasing incidence of climate-induced damage to property and infrastructure. South Africa has already experienced the materialization of some of these risks, many of which are expected to escalate in the future.

The South African Reserve Bank (SARB), as part of its legal mandate to safeguard the stability of the financial system, conducted a Climate Risk Stress Test (CRST) for the first time in 2024. The SARB's CRST was an exploratory macroprudential stress test that subjected banks designated as systemically important financial institutions (SIFIs) to a set of plausible, long-term climate scenarios with the primary goal of evaluating the resilience of the banking sector to the physical and transition risks associated with climate change. The CRST also included the secondary objective of evaluating banks' data quality and coverage and methodological ability to assess climate-related risks.

A novel scenario and modelling framework were developed and implemented to achieve these objectives, with the 2024 CRST framework employing both a BU (bottom-up) and a TD (top-down) approach to ensure a comprehensive analysis of climate impacts across the banking sector. Full balance-sheet modelling was not included in the exercise given data gaps and modelling constraints in this first exercise of its kind in South Africa. Instead, SIFIs were required to estimate the impact of climate scenarios on credit risk quantitatively, while other key risks were assessed qualitatively. For the TD approach the SARB developed an in-house bespoke methodology to model both the physical and transition risks and to act as challenger model to the bank BU submissions.

The exercise indicated that while SIFIs are reasonably well positioned to assess their vulnerability to climate risks, certain challenges remain. Specifically, data gaps and modelling capabilities. However, this exercise - being the first of its kind - also helped to identify tangible and practical interventions to help address these challenges. The SARB will continue to engage with SIFIs to resolve data challenges that need to be addressed to better assess and imbed climate risk within their existing risk management frameworks and stress-testing capabilities.

1. Introduction

This technical report outlines the South African Reserve Bank's (SARB) newly developed macroprudential climate risk stress test (CRST) framework and aims to provide a foundational platform for future climate risk stress tests. The 2024 CRST exercise assessed the resilience of the banking sector's Systemically Important Financial Institutions (SIFIs[1]) to a set of plausible, long-term climate-related scenarios. These scenarios encompassed both physical[2] and transition[3] risks, enabling a quantitative forward-looking evaluation of the sector's vulnerabilities to climate risk for the first time. By understanding these risks and their implications, the SARB seeks to enhance the resilience of the financial system and help ensure its stability in the face of evolving climate-related challenges.

The CRST framework was designed to capture the multifaceted nature of climate-related risks and their potentially diverse impacts on the financial system. Drawing inspiration from established methodologies and best practices (Hosseini, et al., (2022); Wyman, et al., (2018); Bank of England, (2021)), the CRST incorporated a sectoral classification that distinguished between climate-sensitive and non-climate-sensitive sectors, enabling a more granular analysis of SIFIs' exposures to climate-related risks. This approach facilitated a detailed examination of both corporate and retail exposures. Aligned with practices adopted by other central banks and informed by the SIFI feedback during the planning phase, a static balance sheet approach was applied. Under this approach, SIFIs' credit exposures were held constant as of the reference date (31 December 2023). This method was essential for isolating the effects of the climate scenarios without the confounding influence of changes in balance sheet composition.

For the CRST, the SARB conducted both bottom-up (BU) and top-down (TD) stress tests, combining institution-specific insights with a consistent, system-wide perspective on climate-related risks. These tests were conducted using uniform assumptions, criteria, and scenarios. Three scenarios developed by the Network for Greening the Financial System (NGFS) were used in the CRST: *Current Policies*, *Delayed Transition*, and *Net Zero 2050*. To enhance the relevance and impact of these scenarios in both the TD and BU stress tests, the SARB

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1 For the purposes of this document, SIFIs were considered to be representatives of the total banking sector. These SIFIs refers to the six designated banks: Absa, Capitec, FirstRand, Investec, Nedbank, and Standard Bank.

2 Physical risks include chronic changes like rising sea levels and shifting weather patterns, alongside acute events such as floods and droughts.

3 Transition risk encompasses challenges arising from the shift to a low-carbon economy, driven by regulatory changes, market shifts, and technological advancements. It also includes behavioural changes, such as shifts in consumer preferences and investor demands towards sustainability.

provided integrated, granular climate and macro-financial variables. These inputs enabled a more detailed mapping of physical and transition risk pathways across the scenarios.

The CRST TD modelling framework was designed to capture the complex interactions between climate and credit risk, incorporating both quantitative and qualitative elements of the exercise. Adapted from methodologies by Wyman, et al., (2018) and Hosseini, et al., (2022), the model was based on the same set of assumptions given to the participants and served as a challenger model to the BU results. The primary focus was on assessing the impact of physical and transition risks on the credit portfolios of SIFIs. This involved modelling the climate-adjusted probabilities of default (PD) and the loss given defaults (LGD), which are crucial inputs for calculating the SIFIs' expected credit losses.

The results of the exercise were reported in the First Edition of the 2025 *Financial Stability Review*[4] (*FSR*). They showed varying vulnerabilities within the banking sector. The stress test also showed some shortcomings in SIFIs' data systems and capacity to analyse climate-related risks.

This report is organized as follows: Section 2 provides an overview of the CRST framework. Sections 3 and 4 present detail on the scenarios and the top-down model. Section 5 provides concluding remarks, including lessons learned.

4 https://www.resbank.co.za/content/dam/sarb/publications/reviews/finstab-review/2025/financial-stability-review/First%20Edition%202025%20Financial%20Stability%20Review_1.pdf

2. CRST framework

The CRST covered the six South African banks designated as SIFIs under section 29 of the FSR Act. Its primary goal was to test the resilience of the banking sector to physical and transition risks. Given data gaps and modelling constraints, this exercise did not include full balance sheet modelling. Instead, quantitative assessments were limited to changes in credit risk emanating from climate-related shocks.

The 2024 CRST framework employed both BU (bottom-up) and TD (top-down) approaches. The BU assessments were conducted by individual SIFI banks using internally developed stress-testing models and expert judgment. Each SIFI used the same climate scenarios, provided by the SARB, as well as certain assumptions (Section 2.1) and key data reporting specifications (Section 2.2). The TD assessment used the same assumptions, criteria, and scenarios as the BU process; however, it was limited in scope and did not produce the full range of credit risk metrics that SIFIs were able to generate through their BU process (discussed in Section 4).

Climate risks can manifest as sudden, catastrophic events or as risks that accumulate gradually over time. Their distinct features - such as extended time horizons, high uncertainty, limited historical data, and complex dynamics like feedback loops and tipping points (NGFS, 2024) - make it essential to assess both immediate and long-term impacts. To ensure a comprehensive evaluation of the potential risks to the South African economy and financial system, the 2024 CRST framework assessed climate-related risks annually in the short term (2024 - 2026) and in five-year increments for the medium to long term (until 2050).

This exploratory exercise aimed to improve both the SARB's and the participants' understanding of the potential impacts of climate-related risks on the South African banking sector and to provide a basis for future climate risk stress tests. The principal objective of the 2024 CRST was to test the resilience of the South African banking system to both physical and transition risks. Secondary objectives and desired outcomes of this exploratory exercise included:

- Gaining an understanding of SIFIs' current climate risk stress-testing frameworks and assess their level of preparedness.
- Developing climate scenario analysis capabilities across financial institutions and the SARB.

- Quantifying and developing modelling and risk management capacity, specific to climate-related risks, within the sector. This included facilitating dialogue with the industry about climate-related financial vulnerabilities.
- Understanding the mitigating actions that SIFIs might take in response to climate-related risks and consider the effects, if any, from a systemic perspective.
- Identifying data gaps and collective challenges faced by the SIFIs.

To assist with the delivery of these goals, the SARB included a qualitative survey in the exercise, to better understand the impact of climate risk beyond credit, extending into other Basel Pillar 1 risk types such as market risk and operational risk. More detail on these findings is available in the 2025 *Financial Stability Review* (*FSR*) first edition.

2.1 Assumptions

Given the exploratory nature of the CRST exercise, relatively few prescriptive assumptions were provided and SIFIs were not required to anticipate changes to accounting standards, tax regimes, or regulatory reforms effective after the reference date (31 December 2023).

CRST TD and BU key assumptions:

- Static Balance Sheet: The size and risk profile of the balance sheet remained unchanged over the forecast horizon. This enhanced risk assessment by isolating scenario impacts on the SIFIs' exposures without considering future changes in risk appetite and business models. This implied:
    - Constant Residual Maturity: The residual maturity of each exposure remained constant, ensuring no exposures would mature over the forecast horizon and removing the need to replace maturing exposures.
    - No Write-Offs: No write-offs of defaulted exposures were to be assumed.
    - Constant Asset Mix: Participants asked to maintain a constant asset mix, with no artificial shifts in balance sheet composition. However, asset quality in each portfolio was expected to evolve over the stress horizon.
    - Total Credit Exposure: Total credit exposure was to remain constant over the forecast horizon.
    - No Curing of Non-Performing Exposures: Once an exposure becomes non-performing, it must remain in that status throughout the stress test horizon. However, this assumption does not restrict the calculation of provisions, which

can still vary based on changes in loss given default (LGD) or other credit risk parameters.

- Credit Risk Adjustments: The exposure distribution among risk grades and non-performing exposures needed to be adjusted based on the SIFIs' own methodologies, consistent with the estimated default flows and migrations for impairment purposes.

- Movements Between Exposures: Movements between off-balance sheet and on-balance sheet exposures were permitted over the projection horizon.

2.2 Data reporting specifications

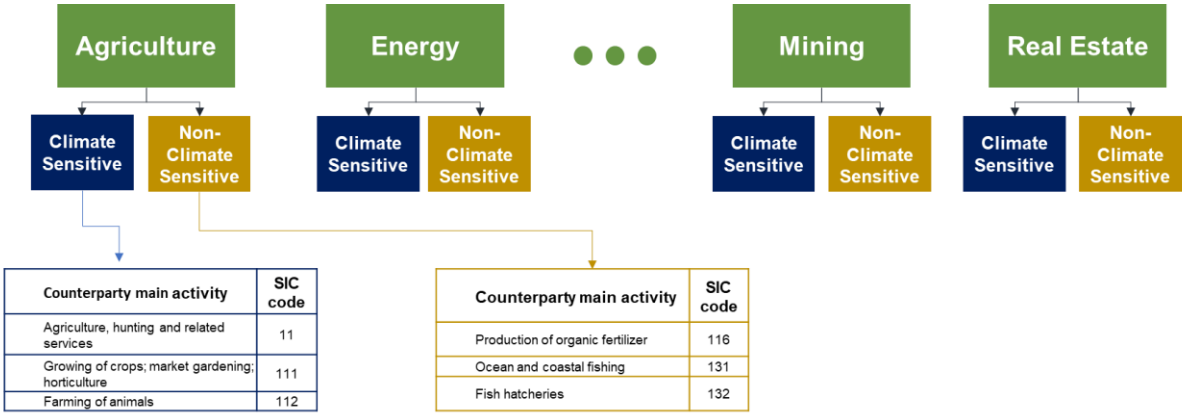
2.2.1 Climate sensitivity taxonomy

The CRST framework introduced a classification system, based on Standard Industrial Classification (SIC) codes, for SIFIs to categorize their exposures to climate-sensitive sectors. This taxonomy helped SIFIs identify their counterparties' vulnerabilities per economic sector to transition and physical risk. These economic sectors were specifically aligned to the Prudential Authority's sectoral classification that the SIFIs report on for regulatory purposes.[5]

However, each economic sector has unique activities that are exposed to varying scales and types of climate risk (Monnin, et al., 2024). To address heterogeneity within sectoral exposures, it was crucial to interrogate climate sensitivity and non-sensitivity of each sector. Drawing from existing academic literature (Monnin, et al., (2024); Battiston, et al., (2017); Herzog, et al., (2005)), the SARB divided the economic sectors (aligned with the SIFIs' regulatory sectoral submissions) into climate-sensitive and non-climate-sensitive categories using SIC codes down to the fourth level of classification tiers (See Appendix 1).

5 Access to the latest guidance on the BA210

Figure 1: Illustrative example of the CRST climate sensitivity taxonomy



Note: Each green block represents SIC level 1 economic sector that is split into climate sensitive (dark blue blocks) and non-climate sensitive (gold blocks). The blue and gold tables provide an example of SIC codes ranging from level 2 to 4 of attributed to counterparties' main activity or source of income that are respectively classified as climate sensitive or non-climate sensitive.

Source: SARB

Figure 1 provides a visual example of how these sectors were categorized. For example, within the agriculture sector, certain subsectors such as drought-resistant crops could be considered non-climate sensitive.

2.2.2 Counterparty and geographic sectoral allocation

The CRST exercise tested both the corporate and retail components of the SIFIs' credit exposures from a sectoral and geographic perspective. While the corporate segment was straightforward and consistent with regulatory reporting, climate risk assessment of the retail segment was the first of its kind, presenting several unique challenges. This novel approach, introduced by the SARB, necessitated adjustments in SIFIs' data gathering processes.

i. Retail credit risk exposure

Climate risk is assumed to impact SIFIs' retail books through the spillover effects from the negative impact on corporates, from which households derive income. Specifically, SIFIs may face increased default risk if borrowers lose their ability and capacity to repay loans as a result of lost employment.

The inclusion of the retail counterparties or private households in the CRST is relatively unique in comparison to climate scenario analysis performed in other jurisdictions. As climate risk does not discriminate between corporate entities and the public in general, the exclusion of private households from a climate scenario assessment will tend to understate the full impact. Recent global events have demonstrated that physical risks impact households as much as corporate entities (Ranger, et al., 2022). Households also typically depend on corporates for income and should those corporates' financial position be affected by both transition and physical risks, there is a spillover of the stress to households which will negatively impact their ability to honour their debt obligations. For this reason, ignoring households and focussing solely on firms will tend to understate climate risks.

To map retail risks, the CRST required SIFIs to assign SIC codes to retail exposures based on the source of income or employment of the obligor. These retail exposures are aligned with the economic activity classification used in the Quarterly Labour Force Survey (QLFS) and correspond to the Level 1 economic activities outlined in section 2.2.1. Furthermore, each exposure had to be reported per asset class, distinguishing between secured lending, such as residential mortgages and vehicle finance, and unsecured lending, such as revolving credit.

ii. Corporate counterparty credit risk exposure

Based on the CRST climate-sensitivity taxonomy, banks had to classify each corporate exposure, in each sector, as climate sensitive or non-climate sensitive. Additionally, the exercise required SIFIs to provide details regarding their largest counterparties, defined as exposures greater than 5% of the bank's Common Equity Tier 1 (CET1) capital. SIFIs were also required to report counterparties with climate-related financial disclosures, with the Task Force on Climate-related Financial Disclosures (TCFD) framework[6] (TCFD, 2017) and the Prudential Authority's Guidance note (Prudential Authority, 2024) on this matter.

Notably, 70% of the SIFI's largest counterparties were ultimately classified as climate sensitive. The interconnected[7] nature of these counterparties, where multiple SIFIs have exposures to the same entities, was also considered.

iii. Geographic credit risk exposure

Lastly, the purpose of the geographic element of the exercise was to assist with the assessment of physical risk. SIFIs were requested to report credit metrics per economic activity per province. The reporting province was selected based on where the counterparty's main operations took place, or alternatively, the location of the majority of the counterparty's physical collateral. Foreign exposures, meaning loans granted to foreign counterparties but held on South African balance sheets, were also captured in a "Rest of the world" section.

6 Recently replaced by the International Sustainability Standards Board's (ISSB) IFRS S2 Climate-related Disclosures Standard.

7 This interconnectedness means that systemic risk could arise if these counterparties adopt a 'do nothing' approach towards climate risk

In line with this regional focus, CRST exercise also considered the effect of insurance as a mitigant to potential credit losses. Since it has been noted that the insurance sector often lacks sufficient coverage for natural catastrophes, as evidenced by the recent Los Angeles wildfires in January 2025, which left many without adequate protection against significant losses (Johansmeyer, 2025), SIFIs were asked to provide LGDs excluding potential loss mitigation resulting from insurance coverage. Additionally, SIFIs provided data that included exposures collateralized by movable property and immovable property respectively.

3. Scenarios

3.1 Climate Risks

There is broad consensus in the literature that climate change poses risks to the financial system through two primary channels, namely physical and transition risks (see Figure 2).[8] The extent to which these risks threaten financial stability depends on various factors. These include the nature of the climate shock, the financial system's exposure to the shock, its interaction with existing financial vulnerabilities, and how effectively the shock is managed. Once a climate shock interacts with existing vulnerabilities in the real economy or financial sector, it is transmitted through the traditional risk channels used in financial stability assessments under the Basel framework, namely in the form of increased credit, market, operational, liquidity and underwriting risk (see Figure 2 for the transmission channels from climate to financial risks).

The NGFS further distinguishes two categories of physical risks: acute physical risks (those that arising from the rising intensity and frequency of extreme weather event such as droughts or heat waves, storms, and floods) and chronic physical risks (due to increased intensity and frequency of weather events as a result of persistent changes in climate patterns, changes in precipitation and increasing temperatures).

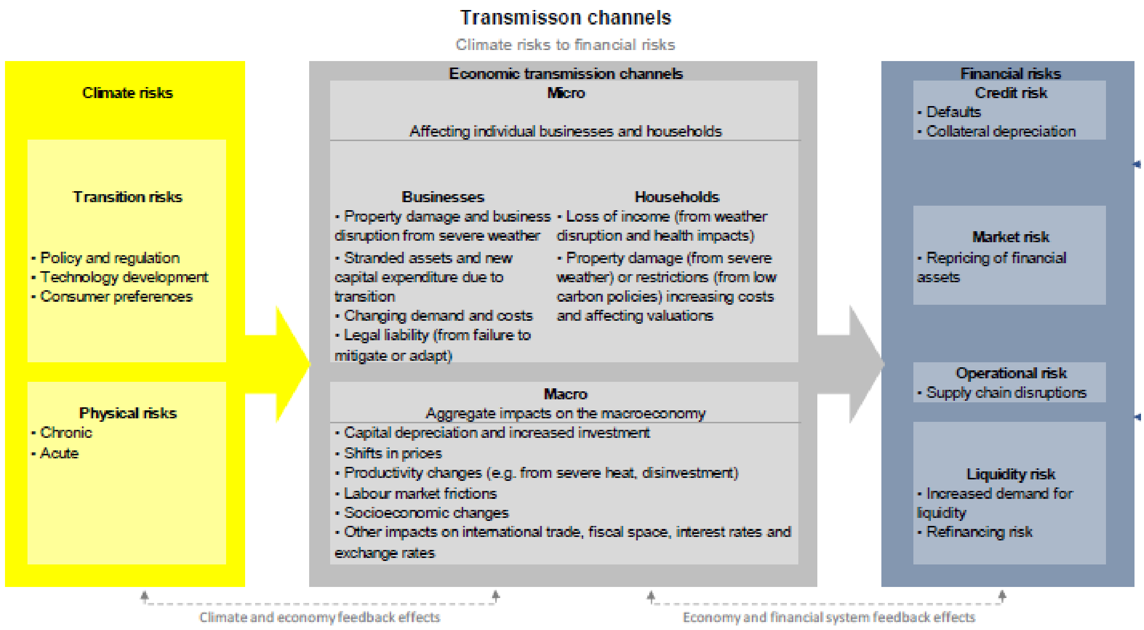
Physical risks may result in damages to property, land and infrastructure, and increase probabilities of default (PDs) and losses given default (LGDs). For South Africa, the most common climate-related physical risks are drought, floods and wildfires, with the sectors responsible for water supply, agriculture, health and tourism being the most vulnerable (World Bank, 2021).

8 From an emerging market perspective, and specifically relevant to South Africa, social risks are elevated since both physical and transition risks affect vulnerable communities. However, the exercise will not explicitly incorporate the effects of social risks in the calibration.

The second channel, transition risks, arise from changes in climate policy, technology, and consumer and market sentiment along the adjustment path to a low-carbon economy (which may lead to growing financial pressures as well as stranded assets). Policy interventions may cause a shift in economic balance by incentivising the uptake of lower carbon technologies and influencing changes in investment flows between lower and higher carbon industries. The banking sector could experience higher credit losses from exposure to carbon intensive counterparties, which in turn could lead to increasing PDs and declining collateral values. From a liquidity perspective, the South African banking sector is highly dependent on wholesale funding. Higher credit losses (or the prospect thereof) could increase refinancing risk.

Physical and transition risks are also interrelated, where an accelerated decarbonisation[9] may increase transition risk but result in lower long-run physical risk. Alternatively, a slower transition would result in lower transition costs but higher future losses from global warming.

Figure 2: Transmission mechanisms of climate-related risks to financial risks



Source: adapted from the NGFS

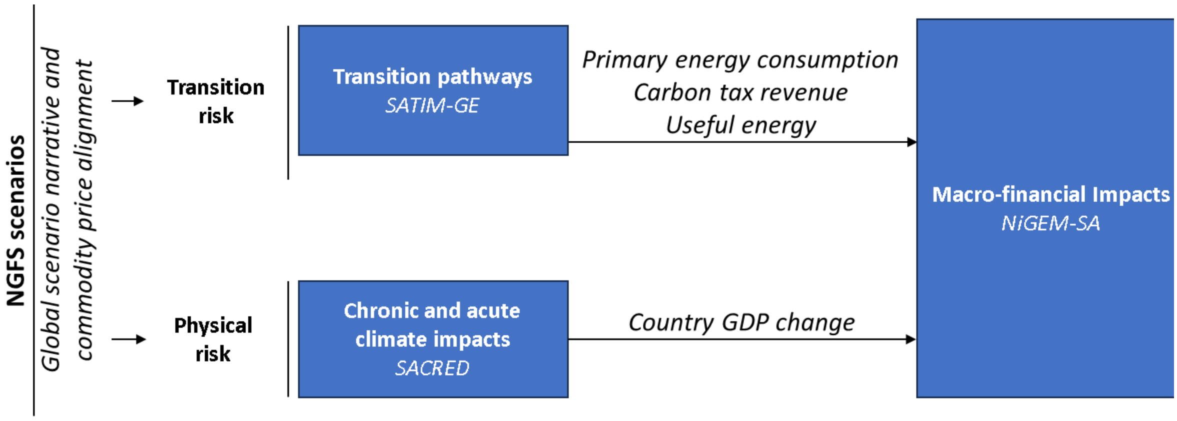
3.2 Scenario joint-modelling approach

The CRST assessed the potential climate risks facing South Africa under three long-term climate scenarios developed by the NGFS (NGFS, 2023). These scenarios were adapted for

9 Such as Carbon Dioxide Removal (CDR) that involves removing carbon from the atmosphere through increasing forest cover and soil sequestration (land use) to accelerate the decarbonisation.

South Africa through joint modelling work by the International Food Policy Research Institute (IFPRI) (Anvari, et al., 2022) and the National Institute of Economic and Social Research (NIESR) (Cornforth, et al., 2025).The CRST scenarios were developed using the multi-model framework shown in Figure 3. Each scenario started with an overarching set of assumptions from the NGFS for how climate temperatures, emissions and climate policy evolve.[10] This was then complemented with more detailed assumptions about the South African economy using local climate impact and mitigation models SATIM-GE and SACReD.[11]

Figure 3: Scenario modelling process



Source: SARB's illustration

SACReD linked climate changes to biophysical models of water, infrastructure and crops to assess the impacts of changes in temperature, precipitation and weather patterns on water availability (irrigation, bulk and industry), capital depreciation and agriculture crop yields. These impacts were assessed at the sub-national level and passed to a geographically disaggregated economy-wide model for South Africa to assess the economic impact of physical climate change across the country.

SATIM-GE assessed transition risks by incorporating climate mitigation targets into the energy model. This, along with economic projections from the economic model, was used to find the least cost path for producing energy to meet demand. No carbon tax was imposed in the linked energy-economic model. Rather, a shadow carbon price was estimated, reflecting the level of mitigation effort needed to reduce emissions and reach the respective transition goals in each scenario. This was the main policy lever driving the transition in the modelling framework.

10 The shadow carbon price is a proxy for overall climate ambition and effectiveness in the NGFS framework. See NGFS (2023). Climate Scenarios Technical Documentation V4.2 for more details.

11 The scenario's account for South Africa's emissions targets as outlined in the NDC. However, due to the timing of the exercise, the 2023 Integrated Resource Plan out for public comment was not included in the scenarios developed. The scenarios were also updated with the latest economic and climate data, model versions and policy commitments and emissions targets made up to March 2023. They also reflect the latest technology trends and energy market impacts of the war in Ukraine.

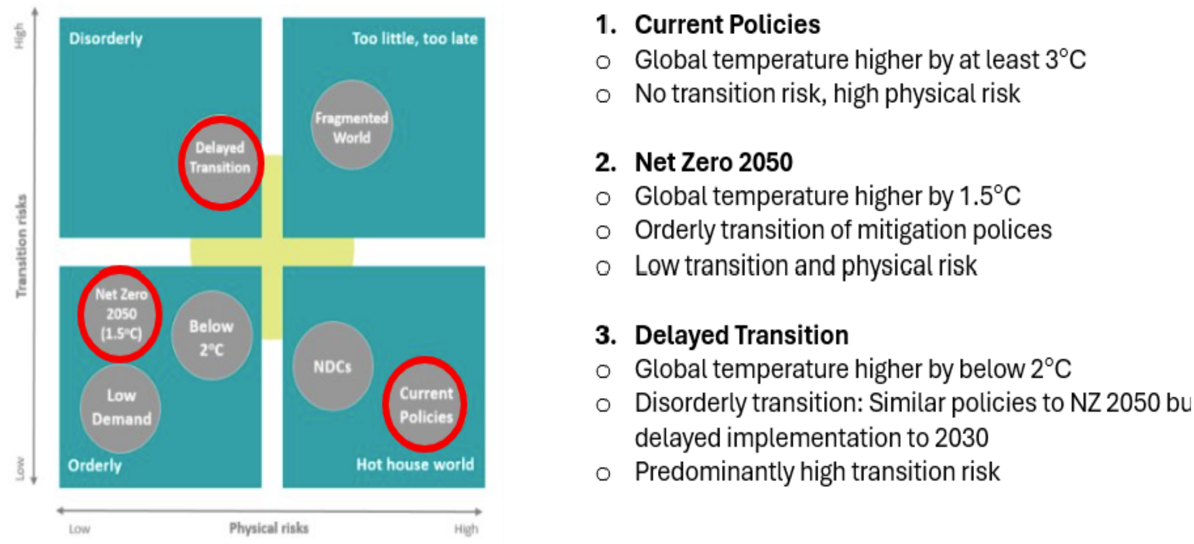
Outputs from the SACReD and SATIM-GE models were linked to the National Institute Global Econometric Model (NiGEM) model for South Africa to produce the macro-financial indicators commonly used for stress-testing. Further discussion of the methodology, including strengths and weaknesses can be found in Anvari, et al., (2022).

3.3 Scenario Narrative

The NGFS scenarios explore a range of physical and transition risks in four quadrants as shown in Figure 4. In the Orderly quadrant, the transition to a low-carbon economy is predictable and achieves climate goals, resulting in low physical and transitional risks. The Disorderly quadrant involves higher transition risks due to delayed or inconsistent policies, leading to a rapid increase in carbon prices. In the Hot House World quadrant, insufficient climate measures result in severe global warming and significant physical risks, such as an irreversible rise in sea levels. In the Too Little, Too Late quadrant, climate policies are both delayed and uncoordinated, resulting in high transition risks alongside severe physical impacts from unmitigated climate change.

The CRST used three scenarios, namely, Current Policies, Delayed Transition and Net Zero 2050. Importantly, these scenarios were not designed as, nor were they intended to be interpreted as, forecasts. Instead, they represent a range of plausible climate futures for South Africa.

Figure 4: NGFS Scenarios for the 2024 CRST

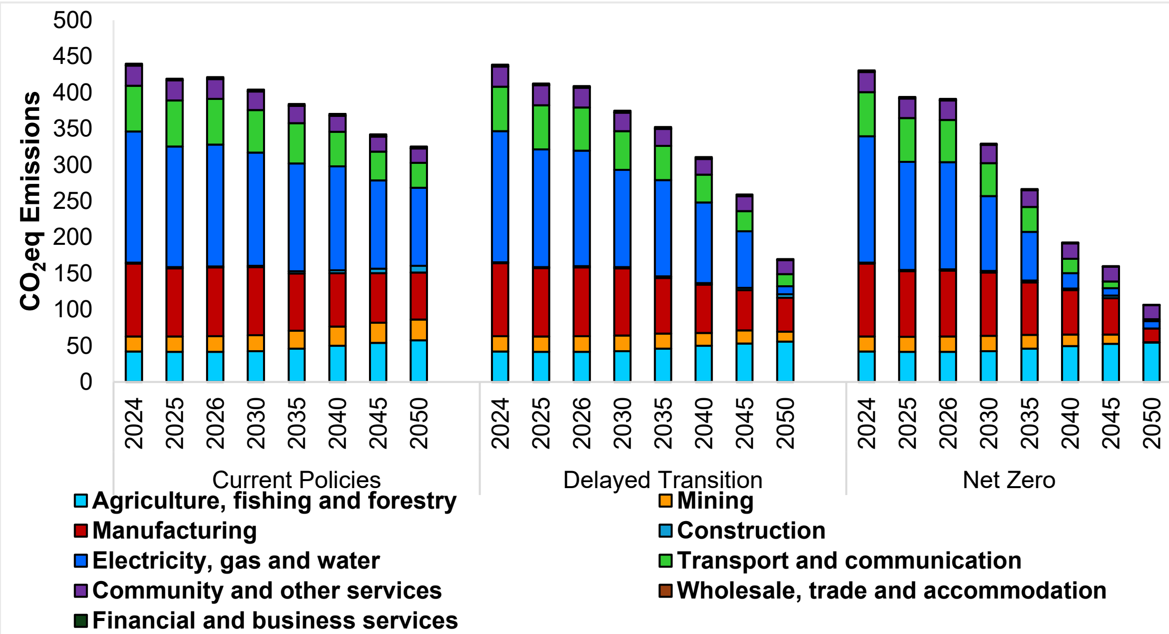


Note: Positioning of scenarios is approximate, based on assessment of physical and transition risks out to 2100.

Source: NGFS

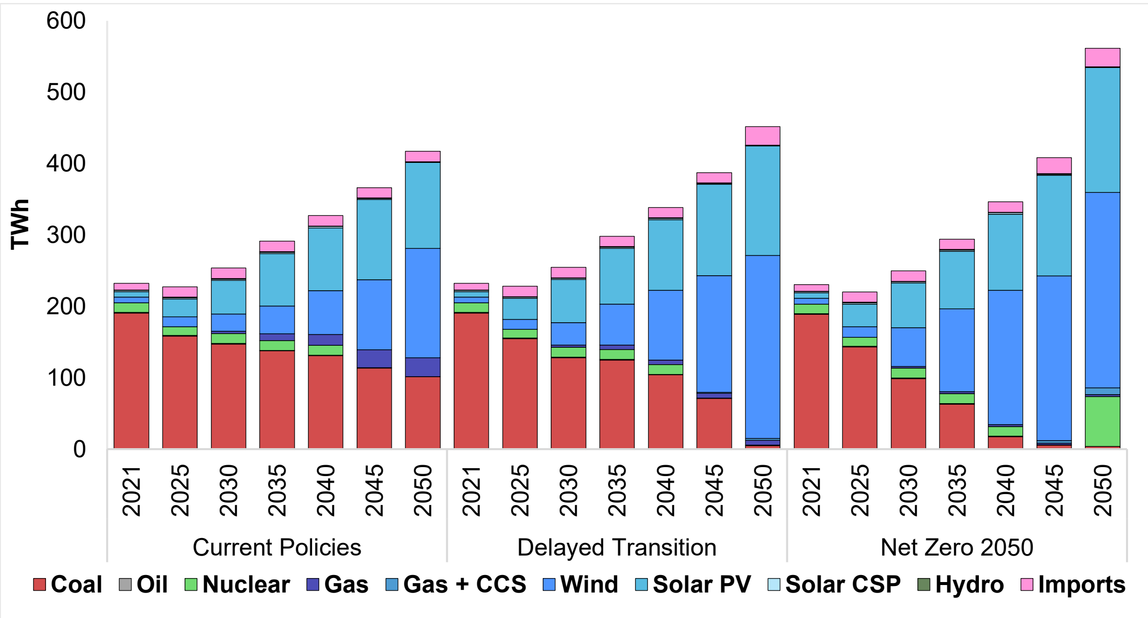
The scenarios are primarily differentiated by their level of climate ambition; the timing and distribution of policy implementation across the economic sectors and geography; and technology assumptions such as the availability and viability of carbon dioxide removal. Emissions are expected to decrease in South Africa across all three scenarios, largely driven by declines in the Electricity sector as the power generation mix shifts toward cleaner technologies (Figure 5 and Figure 6).

Figure 5: Sectoral CO_2 Emissions



Source: SARB

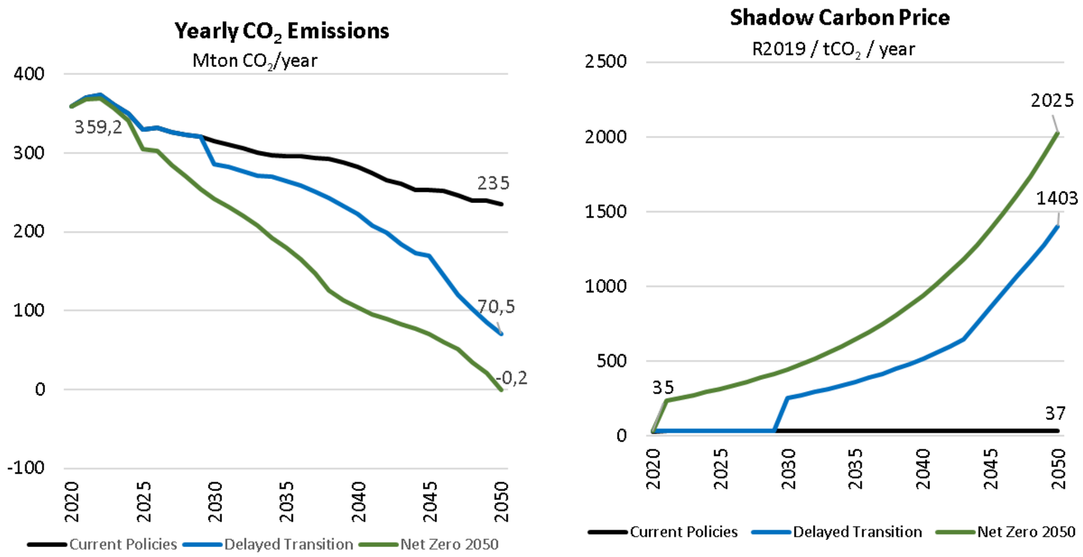
Figure 6: Power Generation Mix



Source: SARB

The main policy lever to drive the transition towards the emission targets is a "shadow carbon price". This carbon price serves as a proxy for overall climate policy ambition and effectiveness. A higher carbon price reflects a more stringent overall climate policy, over several policy instruments. These can include carbon taxes, but also other instruments such as green subsidies, energy efficiency requirements and fossil fuel bans. Figure 6 displays the transition to cleaner energy in each scenario, driven by the varying ambition in each scenario (as reflected by the shadow carbon price, see Figure 7) and encouraged by the shift towards greater climate policy certainty domestically and globally.

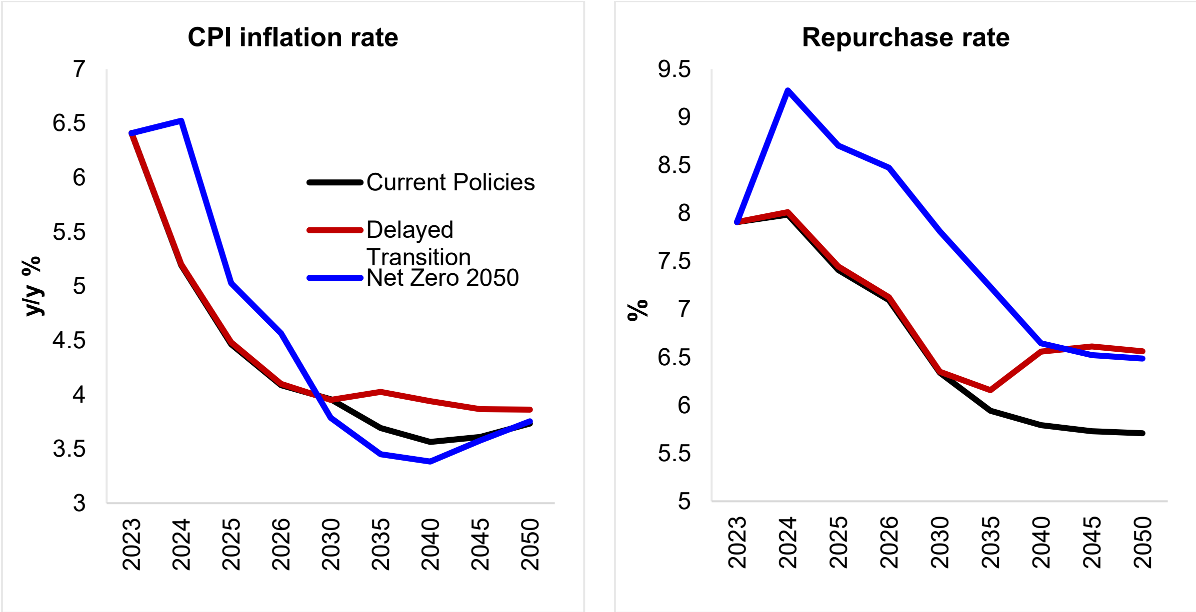
Figure 7: Main assumptions underpinning each scenario



Source: SARB

The interconnected nature of climate shocks flow into other macroeconomic channels. Inflation rates are expected to increase as the shadow carbon prices add upward inflationary pressure to the consumer goods basket. All three scenarios incorporate an internally consistent monetary policy response which acts accordingly to mitigate against price instability.

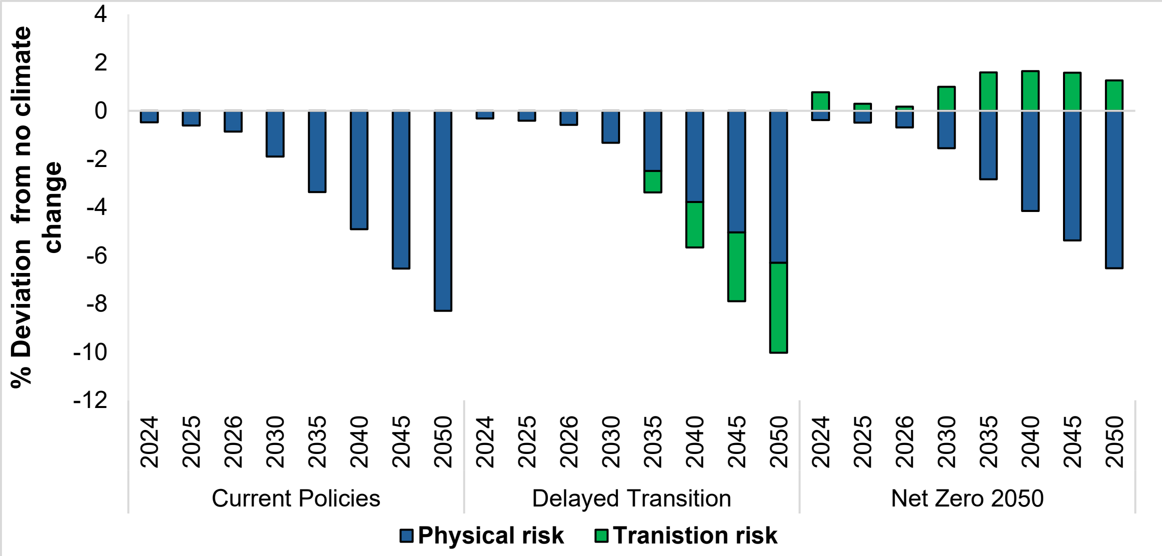
Figure 8: Summary of selected macro-economic projections



Source: SARB

These climate ambitions and transmission channels ultimately lead to different GDP growth paths. Figure 9 shows how GDP is likely to be impacted compared with a hypothetical (and implausible) baseline scenario in which no transition or physical risks occur. The results show that climate change is likely to have a negative impact on GDP across all scenarios with the physical risks from climate change likely to outweigh those from the transition. However, transition risks, which are largely driven by higher carbon prices and the implementation of related policies, can be minimized through an orderly and early transition (Monnin, et al., 2024). These effects are discussed in detail in the following scenario sub-sections.

Figure 9: Decomposition of Combined GDP



Source: SARB

Current Policies Scenario

The *Current Policies* scenario assumes existing climate policies remain in place, with no increase in climate ambition. Technology change is slow, and there is little usage of carbon dioxide removal technologies. As a result, the transition to a carbon-neutral economy never takes place. There are no transition impacts in this scenario, but the failure to halt significant global warming leads to severe physical risks as critical temperature thresholds are exceeded.

Total CO2-equivalent emissions decrease by 39% from 2023 to 2050 (see Figure 5), driven by declines in the energy sector due to committed power builds with a technology mix similar to the 2019 integrated resource plan (IRP).[12] Despite declining emissions, minimal policy measures result in South African mean surface temperatures being 1°C higher by 2050 compared to the 2000-2019 average. These higher temperatures lead to severe physical risks by 2050 due to more frequent extreme weather events.

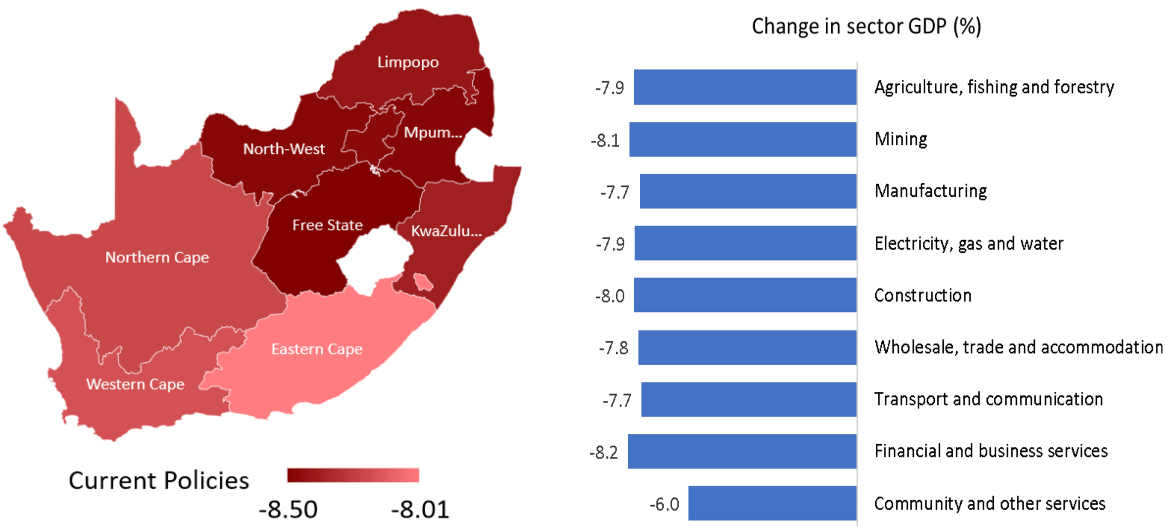
Some areas are more prone to flooding, while others face droughts. Decreased water availability at national and sub-national levels, combined with rising temperatures, negatively impacts agriculture by reducing crop yields. These physical hazards disrupt transportation,

12 The 2019 IRP is a plan for developing electricity infrastructure that aims to balance supply and demand at the lowest cost. It also considers supply security and environmental factors, aiming to minimize negative emissions and water usage.

affecting labour markets and supply chains, and cause damage to land, infrastructure, and other assets.

Real household expenditure declines less than real incomes as households adjust consumption patterns and reduce savings to supplement consumption. The climate impacts negatively affect South Africa's real GDP, which grows on average by 2.9% from 2023 to 2050. Regionally, agriculture GDP losses are largest in the North-West, Free State, Mpumalanga, and Gauteng provinces, which are key producers of oilseeds and summer cereals like maize. Climate change negatively affects these primarily rainfed crops' yields. However, higher global agriculture prices partially offset agriculture GDP losses with improved export revenues.

Figure 10: 2050 Regional and Sector GDP impact (%)



Source: SARB

Net Zero 2050 Scenario

The *Net Zero 2050* scenario assumes immediate policy action that becomes gradually more stringent. Technology change is rapid with medium to high use of innovative carbon dioxide removal technologies. This limits global warming to 1.5°C with the world reaching global net zero CO_2 emissions around 2050. This results in more subdued physical risks that are mitigated by the benefits of more orderly and timely transition efforts.

Government policies align to meet the net zero target by 2050 and the Updated NDC target of 398MT CO_2eq by 2030. A higher shadow carbon price nearing R2000/ton by 2050 incentivizes cleaner energy production, in turn also reducing energy costs in South Africa. Carbon tax revenues are partially reinvested into the economy, with 50% directed towards greener power infrastructure, stimulating private investment and overall economic growth.

Climate shocks impact other macroeconomic channels. Inflation rates are expected to increase significantly in the near term due to immediate mitigation strategies, leading to a contractionary monetary policy response. However, the early and orderly implementation of these climate policies allow subsequent inflationary pressures to ease more rapidly and remain relatively supressed in the long run.

Real household incomes and expenditures decrease compared to Current Policies, with variability by income decile. Households adjust by changing consumption patterns and reducing savings, with price declines in consumption baskets mitigating spending impacts. House prices decline relative to Current Policies due to increased policy rates and user cost of capital, signalling increased competition for domestic funds given significant transition-related investments.

Figure 5 shows CO2 emissions across high-emitting sectors like transport and energy, which play key roles in reducing emissions. Total power generation increases relative to Current Policies as energy demand shifts to electricity as an alternative fuel. Electric vehicle adoption accelerates, with all new-vehicle sales being electric by 2039. Petroleum demand eases, contributing to a stronger exchange rate.

Improved water availability, smaller crop yield losses, and reduced capital losses help mitigate the negative impacts of climate change compared to Current Policies. Unlike Current Policies, non-agriculture GDP is less affected than the agricultural output. GDP declines are broad-based across the economy relative to a no climate change world, as higher investments in the power sector constrain expansion in other sectors. In the Net-Zero 2050 scenario, physical risks from climate change are partially offset by growth effects from carbon revenue recycling (van Heerden, et al., 2016).

In the mining sector, coal demand declines relative to Current Policies by 2050. This reduction affects refineries as coal-to-liquid production decreases from 2030, while in industry and commerce, coal use is partially substituted with electricity and heavy fuel oil (HFO).

Export-oriented sectors are negatively affected by the strengthening exchange rate. Imports decrease relative to Current Policies due to reduced crude oil and petroleum product imports as transport demand shifts to electric vehicles. Within manufacturing, non-energy sector-related machinery, vehicles, and metal products are most affected.

Delayed Transition Scenario

The *Delayed Transition* scenario explores higher transition risk due to delays in the implementation of policies and adoption of new technologies. Annual emissions do not decrease until 2030, after which strong policies are implemented to compensate for lost time and limit global warming to below 2°C. Implementation is disorderly with high variation across countries and sectors. This leads to more severe transition risks and as a result, by 2050, real GDP is 2% lower than in Current Policies, affecting most sectors due to increased capital costs for mitigation and crowding out of finance for non-energy sectors.

Consumer prices and interest rates follow Current Policies until 2030. Increased global carbon taxes then raise oil prices, adding inflationary pressure and prompting monetary policy responses.

Emissions decline is driven by the power sector, reaching near zero by 2050. Most of the decrease occurs after 2040 as coal power generation is replaced by solar PV and wind. Less gas is used towards the end of the period.

By 2050, coal demand decreases relative to Current Policies, primarily due to lower domestic power sector demand. The mining sector declines due to reduced coal mining and export demand. Total imports are also driven lower due to reduced petroleum product demand. The manufacturing sector, particularly machinery, non-metallic minerals, and vehicles, is most impacted.

Despite lower economic growth, total power generation is higher by 2050, driven by increased electrification. Transport shifts to hybrid and electric vehicles, which become cheaper to operate than traditional ICE vehicles by 2030. The local motor vehicle industry transitions in line with global demand, maintaining export demand. By 2050, petroleum-based fuel demand decreases, with electricity making up the difference.

4. Top-Down CRST modelling approach

The CRST TD modelling framework was designed to capture the complex interactions between climate and credit risk, incorporating both quantitative and qualitative elements of the exercise. The model was an adaptation of the papers by Wyman, et al., (2018) and Hosseini, et al., (2022). It was based on the same set of assumptions given to the participating SIFIs and was mainly used as a ‘challenger’ model to validate participants’ BU results.

The primary focus was on assessing the impact of physical and transition risks on SIFIs' credit portfolios. This involved modelling the climate-adjusted probabilities of default (PD) and the loss given defaults (LGD), which are crucial inputs for calculating expected credit losses.

4.1 Climate-Adjusted Probabilities of Default

The PDs reflect the likelihood of a counterparty or borrower defaulting and depend on counterparty specific fundamentals as well as general macroeconomic factors. Two different estimates were used: Through-the-Cycle (TTC) PDs and Point-in-Time (PIT) PDs. TTC PDs are largely insensitive to the prevailing macroeconomic conditions while the PIT PDs vary with the economic cycle.

Since the objective of any credit risk stress test is to quantify the impact of macro shocks on key metrics (i.e. credit losses, non-performing exposures etc.), the estimation of PIT PDs is vital and has inspired a comprehensive literature. For example, Hallblad (2014) discussed the relationship between the TTC and PIT PDs in a Vasicek framework and used the Hodrick-Prescott filter to estimate the economic cycle, whilst Sebolai (2014) used historical default frequencies to estimate the cycle index.

The transformation of TTC PDs into PIT PDs using the Vasicek asymptotic multi and single factor framework was employed for the CRST exercise. Two models were developed for the TD stress test of climate-related risks on the credit portfolios of SIFIs. The first model was a 2-factor Vasicek model used for climate-sensitive sectors, incorporating transition and physical risk factors. The second model was the traditional Vasicek ASRF model, used for non-climate-sensitive sectors, based on a simulation baseline Economic Conditions Index (ECI) that represented no climate risk.

The climate-adjusted PDs were informed by the climate-sensitive metrics, specifically the physical and transition risk factors. Adapting Pykhtin & Dev (2002) multi factor approach, the calculations were performed at the sector level, with multiple factors included to separately capture the impacts of transition risk and physical risk. It was assumed that the log asset values (X) at time t of obligor (sector) i could be modelled as:

$$X_{i,t} = a_i . Y_t + \sqrt{1 - a_i^2}\, \epsilon_{i,t} \qquad where, \tag{1}$$

$$i = agriculture, mining \ldots , \qquad t = 2024{,}2025 \ldots 2050 ,$$

$$Y_t = \begin{Bmatrix} Physical\_factor_t \\ Transition\_factor_{i,t} \end{Bmatrix}, \qquad a_{i,t} = \begin{Bmatrix} Physical\ factor\ loadings \\ Transition\ factor\ loadings \end{Bmatrix}$$

where Y_t is a multivariate standard normally distributed random vector composed of the systematic risk factors (physical and transition factors). For simplicity our model assumed the systematic risk factors are uncorrelated, independent and identically distributed (i.i.d.). The a_i are the factor loadings measuring the sensitivities of the asset values to the systematic risk factors for borrower i while the ϵ_t are i.i.d. standard normally distributed random variables independent of Y_t and measure the idiosyncratic risk.

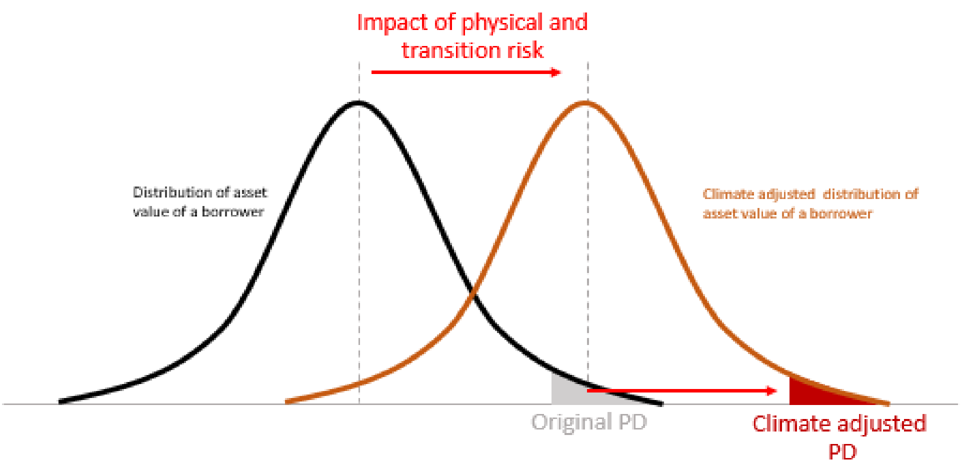
An obligor is assumed to default if the asset value of the obligor falls below the default threshold ($\Phi^{-1}(\mathrm{PD_{TTC}})$). In the multi-factor Vasicek model, the credit quality of the obligor is influenced by multiple systematic factors. Thus, the climate-adjusted PDs are given as:

$$\mathrm{PD_{climate}} = \Phi\left(\frac{\Phi^{-1}(\mathrm{PD_{TTC}}) - a_i . Y_t}{\sqrt{1 - a_i^2}}\right) \qquad (2)$$

$where\ \phi\ is\ the\ cumulative\ standard\ normal\ distribution\ function$

The transition and physical risk factors were assumed to introduce additional systematic risk to asset values which result in the shift the distribution of asset values. As illustrated in Figure 11, a climate related shock to the obligor asset values shifts the credit loss distribution to the right indicating higher PDs.

Figure 11: Climate risk impact on obligors' distribution of asset value



Source: SARB's adaptation of Wyman, Mercer, & UNEP Finance Intiative, (2018)

Transition risk factor

Drawing from the framework provided by (Wyman, et al., 2018) , Table 2 describes the four Risk Factor Pathways (RFPs) as well as the CRST TD empirical approximations.

Table 2: Transition Risk Factor pathways

Factor Pathways	Definition	Calculation
Direct Emissions	Assessed the sector's exposure to regulatory changes, carbon pricing mechanisms, and technological advancements aimed at reducing CO2 and other greenhouse gas emissions.	Product of the country's shadow carbon tax and the sectoral emissions
Indirect Emissions	Considered the sector's vulnerability to increases in fuel prices and the pass-through of direct emissions costs, impacting production costs and profitability.	Product of sectoral energy demand and coal price
Capital Expenditure	Evaluated the sector's readiness to invest in renewable energy sources, energy efficiency measures, and other sustainable technologies to mitigate climate-related risks.	Product of total new energy investment and the sectoral GDP weights.
Revenues	Analysed potential changes in revenues due to shifts in consumer preferences, price adjustments, and demand fluctuations influenced by climate-related factors.	Not used in the TD model.

Due to the complexity of this two-factor model, the number of factors had to be limited; however, future research could explore how the individual RFPs can infuence the PD calculation in equations 1 and 2. The average of the normalized factor pathways of the three cost-related RFPs was taken to produce one indicator representing the transition risk factor. Normalisation ensured that the different RFPs, which had varying scales and units, were brought to a common scale, allowing for fair comparison and combination without any single factor disproportionately influencing the result. Averaging the normalized factor pathways consolidated the multiple dimensions of transition risk into a single, comprehensive indicator, simplifying the analysis and providing a balanced measure of the sector's overall transition risk.

Following the approach employed by the BoC, banks were requested to report sectoral transition risks based on the four RFPs outlined in Table 2, ranked as low, low-mderate, moderate, and high risk (1-4 respectively). Table 3 displays the average SIFI RFP ratings that provided insights into the initial sensitivities $(a_{i,t})$ of macroeconomic sectors to various channels of climate-related transition risk that could impact the SIFIs' total credit portfolios.

Table 3: Average SIFI sectoral sensitivity to risk factor pathways

Economic Sectoral Activity	Direct Emissions	Indirect Emissions	Capital Expenditure	Revenue
Agriculture, hunting, forestry and fishing	3	3	2	3
Mining and quarrying	4	3	3	3
Manufacturing	4	3	3	3
Electricity, gas and water supply	4	3	4	4
Construction	3	3	3	2
Wholesale and retail trade, repair of specified items, hotels and restaurants	2	2	2	2
Transport, storage and communication	3	3	3	2
Financial intermediation and insurance	1	2	1	2
Real estate	2	3	3	2
Business services	2	2	1	2
Community, social and personal services	1	2	1	1
Private households	1	2	2	2

To ensure that the sectoral transition risks were evaluated in a manner that reflected the true risk exposures, it was necessary to convert the rankings into asset sensitivities, $a_{i,t}$, aligned with the Basel-prescribed asset correlation. The asset sensitivities were calibrated to fall within a range of 10% to 30%. By aligning the sensitivities of the macroeconomic sectors to these regulatory asset correlations, the analysis helped mitigate the potential for underestimating or overestimating the risk.

Physical risk factor

The impact from physical risk was incorporated into the evolution of the macroeconomic variables. These were translated into a physical risk factor, commonly known as an economic conditions index (ECI), that gives an indication of whether the economy is performing well or badly. The ECI acts as the latent systematic variable in equations 1 and 2.

The methodology employed to produce the ECI is similar to the one used by Gaglianone & Areosa, (2016) in calculating the Financial Conditions Index (FCI). The study shows that the PIT PDs are highly sensitive to the methodology used in the calculation of the systematic risk factor, which has practical implications for how regulators and SIFIs approach their stress testing frameworks.

The weights that used to calculate the FCI were estimated using a Vector Autoregression (VAR) model, based on an economic activity proxy. Thereafter impulse-response functions (IRF) were constructed, and the weights are given by the twelve-month accumulated response of the economic activity proxy, resulting from shocks in the remaining explanatory variables.

The ECI is calculated by taking the weighted average of the indicators and creating a single index as follows:

$$ECI_t = \sum_{k=1}^{4} \omega_k X_{k,t} \qquad where\ t = 1,2,3, \dots T \tag{3}$$

where ω_k are the weights for each indicator. These weights are calculated by first estimating a VAR model based on real GDP and each indicator (variable groups representing macro-economic sector, credit sector, wealth and finance sectors shown as $X_{k,t}$). Then, IRFs are constructed, and the weights are then calculated by averaging the twelve-period ahead impulse response of the RGDP variable to shocks from all indicators (including the response of RGDP to a RGDP shock).

4.2 Loss given default

The modelling of the LGDs followed the Frye Jacobs relationship as suggested in the referenced papers. This ensures that the stressed LGDs are sensitive to the same factors that drive the PDs. Under this framework, the stressed LGDs are given as follows:

$$\mathrm{LGD_{climate}} = \frac{\Phi(\Phi^{-1}(\mathrm{PD_{climate}}) - \frac{[\Phi^{-1}(\mathrm{PD_{climate}}) - \Phi^{-1}(\mathrm{PD_{TTC}} * \mathrm{LGD_{TTC}})]}{\sqrt{1-\rho}})}{\mathrm{PD_{climate}}} \tag{4}$$

where $PD_{climate}$ is the climate-adjusted PD, ρ is the asset correlation, and PD_{TTC} and LGD_{TTC} are the through-the-cycle PDs and LGDs respectively.

4.3 Expected Credit Losses

The key output of the climate model was the expected credit losses which are given as the product of the exposure (EAD), the climate-adjusted PDs and the LGDs:

$$ECL = \sum_{i=1}^{n} EAD_i * PD_{climate,i} * LGD_{climate,i} \tag{5}$$

where the sum is taken over all sectors i.

4.4 Illustrating the credit risk methodology

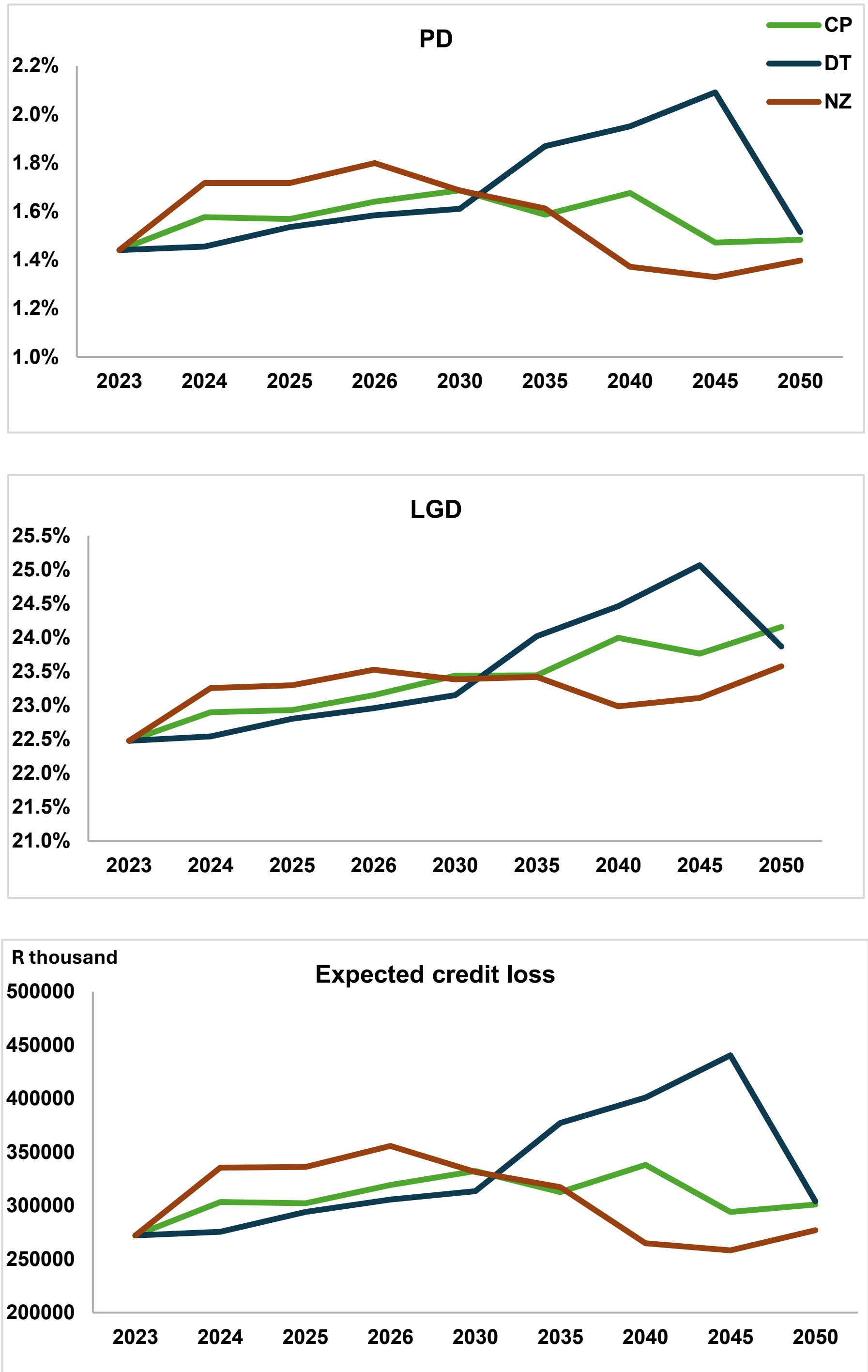
Figure 12 illustrates an overall negative relationship between the magnitude of the financial impacts for the energy sector and the scale of the change in credit risk generated from the borrower-level assessments.

In the short run (2024-2030), the Net Zero (NZ) scenario exhibits the highest credit risks, with PDs, LGDs, and ECLs surpassing those of Current Policies (CP) and Delayed Transition (DT). This is primarily due to the orderly implementation of aggressive shadow carbon taxes that could significantly impact the energy sector, driving a rapid shift in demand towards renewable energy sources. These stringent measures increase costs and uncertainties for energy-intensive companies, as they must invest heavily in new technologies and infrastructure, leading to higher PDs, LGDs, and ECLs. The substantial capital expenditure required for this transition, coupled with the financial strain of high carbon taxes, creates significant financial pressure and increases the likelihood of defaults.

Conversely, from 2030 onwards, the DT scenario experiences the highest financial risks. The delayed implementation of stringent policies necessitates drastic measures, leading to increased PDs, LGDs, and ECLs as carbon taxes intensify suddenly. This sudden shift creates significant financial strain on companies that have not gradually adapted to shift to greener technologies. Meanwhile, the NZ scenario shows the lowest financial risks in the long term, benefiting from early and consistent policy implementation that stabilizes the transition.

The CP scenario remains in between, with moderate financial risks throughout, reflecting a balanced but less ambitious approach to carbon pricing and regulatory changes. Additionally, the switch in the power generation mix plays a crucial role, with the NZ scenario rapidly shifting towards renewables, the CP scenario maintaining a gradual transition, and the DT scenario initially relying heavily on fossil fuels before a sudden shift. Finally, it is important to bear in mind that the whilst the CP scenario doesn't exhibit extreme outcomes over the forecast horizon, the unmitigated and irreversible climate change in this scenario will almost certainly lead to sharply heightened financial risks post 2050.

Figure 12: SIFI climate sensitive energy sectoral TD credit risk metrics



Source: SARB calculations

5. Challenges and insights for future CRST exercises

Given that this was the first exercise of its kind in South Africa, it is unsurprising that certain challenges were encountered by both the SARB and SIFIs. Furthermore, whilst this exercise has laid a strong foundation, there is significant room for improvement as future exercises are developed globally, and more challenger models enter the market. More specifically:

i. Static balance sheet assumption

The use of a static balance sheet in the CRST provided a practical and consistent starting point for assessing climate-related risks, enabling comparability across institutions and sectors. However, it limited the ability to reflect how SIFIs and borrowers might adapt over time to evolving climate conditions. While a fully dynamic balance sheet would offer a more realistic view of risk evolution, applying it across SIFIs introduces complexity in aligning assumptions and behavioural responses for macroprudential purposes. As a potential middle ground, future exercises could consider a constrained dynamic approach, similar to the approach used in the SARB's Common Scenario Stress Test (CSST), which allows for limited, rule-based adjustments while maintaining consistency and comparability across entities.

ii. Climate sensitivity taxonomy

The climate sensitivity classification offered a structured entry point for assessing sectoral exposure to climate risk, using SIC codes aligned with the Prudential Authority's regulatory reporting framework. To enhance this, the CRST drew on NACE-based classifications from Battiston et al. (2017) to distinguish between climate-sensitive and non-climate-sensitive activities within these broader economic sectors. This approach helped address some of the heterogeneity within sectors, but limitations remained. Unlike the IPCC's thematic focus on emissions-intensive sectors or Battiston, et al., (2017) original use of Climate Policy Relevant Sectors (CPRS) for transition risk analysis, the CRST's alignment with standard economic sectors constrained the granularity of classification. The lack of detailed, activity-level data further limited the ability to fully capture the spectrum of climate exposure.

iii. Geographic granularity

While the geographic breakdown supported the assessment of physical risk, its reliance on provincial-level data limited the ability to capture more localized climate hazards. The absence of finer geospatial detail may have obscured exposure to region-specific risks such as flooding or drought, suggesting a need for more granular location data in future exercises.

iv. Data gaps

Data limitations within financial institutions are often cited as a key limitation to quantitative efforts to assess climate change risk in the financial sector and the CRST was no different. Whilst no single data gap was ubiquitous across all SIFIs, all participants identified areas where their data was at least incomplete. For example, most SIFIs were able to report exposure data from a geolocation perspective, but many encountered challenges in identifying the location of collateral assets. Sectoral mapping of credit exposures was another area where experience varied widely, with reporting on the retail sector a particularly new perspective for many SIFIs. Importantly, the CRST served to highlight these data limitations and most SIFIs have implemented reforms that should move towards closing these gaps for future exercises.

v. Scenario modelling

Although the NiGEM macroeconomic model was tailored to reflect South Africa's economic structure (Cornforth, et al., 2025), its integration for the CRST with domestic climate models like SATIM-GE and SACReD presented challenges. The underlying modelling frameworks differ significantly; NiGEM being a global macroeconomic model with top-down dynamics, while SACReD and SATIM-GE are bottom-up, sector-specific models that focused on energy and emissions pathways as well as frequencies of acute physical events. These differences in model architecture, assumptions, and time horizons made it difficult to ensure complete coherence across macro and micro-outputs.

vi. Climate-financial risk modelling

The current multifactor Vasicek model, incorporating physical and transition climate risks, is limited by data scarcity and reliance on assumptions. Asset correlations are treated simplistically, lacking climate sensitivity, which may understate systemic risk. LGD dynamics are modelled using the Frye-Jacobs framework, originally designed for economic downturns, not climate-specific stress. This introduces complexity without strong empirical grounding, as recovery behaviours under climate shocks may differ significantly. Moreover, LGD trends often mirror PDs because both are driven by the same macroeconomic variables in the model. While this co-movement is convenient for calibration, it risks oversimplifying the relationship and may lead to overstated losses or missed sectoral nuances. A more robust approach would decouple these dynamics and model recovery rates directly, allowing for differentiated responses to climate risk.

6. Concluding remarks

This technical document has detailed the CRST framework, scenario analysis, and the top-down credit risk modelling approach for the assessment of climate-related risks impacts on the South African banking sector. The SARB's TD modelling framework aimed at capturing the complex interactions between climate and credit risk and served as a challenger model to validate the BU results. Adapted from methodologies by UNEP FI and the Bank of Canada, the model followed a multi factor approach that included both physical and transition risk factor pathways to estimate the SIFIs climate-adjusted PDs and LGDs, which are crucial inputs for calculating expected credit losses

The framework also establishes a robust methodology to evaluate the resilience of the banking sector under various scenarios, each of which was refined to capture local dynamics. It also introduced novel design elements, such as the detailed analysis of the retail book and the application of a climate-sensitive sectoral lens, enhancing the granularity and relevance of risk assessments. As the first of its kind in South Africa, this effort lays the groundwork for future climate risk assessments in the region, and it intends to contribute towards the knowledge base of quantitative climate scenario assessments of the financial sector.

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Appendix

SIC climate sensitivity

On a sectoral level, mapping of industrial sectors to standard industrial classification (SIC 5th edition) codes were used in respect of the CRST. The SIC codes highlighted below are classified as climate sensitive for the purposes of the CRST:

Table 1: Climate sensitive SIC codes

Standard Industrial Classification System for Economic Activities code (5th edition)	SIC code	Climate sensitive category[13]
Agriculture, hunting, forestry and fishing	1	Participants to determine[B]
AGRICULTURE, HUNTING AND RELATED SERVICES	11	Agricultural Production|Non-Energy
GROWING OF CROPS; MARKET GARDENING; HORTICULTURE	111	Agricultural Production|Non-Energy|Crops
FARMING OF ANIMALS	112	Agricultural Production|Non-Energy|Livestock
FORESTRY, LOGGING AND RELATED SERVICES	12	Land Cover|Forest|Managed
FORESTRY AND RELATED SERVICES	121	Land Cover|Forest|Managed
FORESTRY AND RELATED SERVICES	1210	Land Cover|Forest|Managed
Mining and quarrying	2	Participants to determine[B]
MINING OF COAL AND LIGNITE	21	Primary Energy|Coal
MINING OF COAL AND LIGNITE	210	Primary Energy|Coal
MINING OF COAL AND LIGNITE	2100	Primary Energy|Coal
EXTRACTION OF CRUDE PETROLEUM AND NATURAL GAS; SERVICE ACTIVITIES INCIDENTAL TO OIL AND GAS EXTRACTION, EXCLUDING SURVEYING	22	Primary Energy|Oil and/or Primary Energy|Gas[A]
EXTRACTION OF CRUDE PETROLEUM AND NATURAL GAS; SERVICE ACTIVITIES INCIDENTAL TO OIL AND GAS EXTRACTION, EXCLUDING SURVEYING	221	Primary Energy|Oil and/or Primary Energy|Gas[A]
Extraction of crude petroleum and natural gas	2211	Primary Energy|Oil and/or Primary Energy|Gas[A]
MINING OF GOLD AND URANIUM ORE	23	Primary Energy|Nuclear
MINING OF GOLD AND URANIUM ORE	230	Primary Energy|Nuclear
MINING OF GOLD AND URANIUM ORE	2300	Primary Energy|Nuclear
MINING OF METAL ORES, EXCEPT GOLD AND URANIUM	24	Production|Steel
Mining of metal ores	241	Production|Steel
Mining of iron ores	2410	Production|Steel

[13] Source: Battiston, Stefano, et al. "A climate stress-test of the financial system." Nature Climate Change 7.4 (2017): 283-288 and Battiston, Monasterolo, van Ruijven, Krey. “The NACE – CPRS – IAM mapping: a tool to support climate risk analysis of financial portfolio using NGFS scenarios.” 19 September 2022.

Standard Industrial Classification System for Economic Activities code (5th edition)	SIC code	Climate sensitive category[13]
OTHER MINING AND QUARRYING	25	Energy intensive
MINING AND QUARRYING N.E.C.	253	Energy intensive
Mining of chemical and fertilizer minerals	2531	Energy intensive
Extraction and evaporation of salt	2532	Energy intensive
Other mining and quarrying n.e.c.	2539	Energy intensive
SERVICE ACTIVITIES INCIDENTAL TO MINING OF MINERALS	29	Primary Energy|Fossil
SERVICE ACTIVITIES INCIDENTAL TO MINING OF MINERALS	290	Primary Energy|Fossil
SERVICE ACTIVITIES INCIDENTAL TO MINING OF MINERALS	2900	Primary Energy|Fossil
Manufacturing	3	Participants to determine[B]
MANUFACTURE OF FOOD PRODUCTS, BEVERAGES AND TOBACCO PRODUCTS	30	Energy intensive
PRODUCTION, PROCESSING AND PRESERVATION OF MEAT, FISH, FRUIT, VEGETABLES, OILS AND FATS	301	Energy intensive
Processing and preserving of fish and fish products	3012	Energy intensive
MANUFACTURE OF GRAIN MILL PRODUCTS, STARCHES AND STARCH PRODUCTS AND PREPARED ANIMAL FEEDS	303	Energy intensive
Manufacture of starches and starch products	3032	Energy intensive
MANUFACTURE OF OTHER FOOD PRODUCTS	304	Energy intensive
Manufacture of sugar, including golden syrup and castor sugar	3042	Energy intensive
MANUFACTURE OF BEVERAGES	305	Energy intensive
Distilling, rectifying and blending of spirits; ethyl alcohol production from fermented materials; manufacture of wine	3051	Energy intensive
MANUFACTURE OF TEXTILES, CLOTHING AND LEATHER GOODS	31	Energy intensive
Manufacture of textiles	311	Energy intensive
MANUFACTURE OF WEARING APPAREL; DRESSING AND DYEING OF FUR	314	Energy intensive
MANUFACTURE OF WEARING APPAREL, EXCEPT FUR APPAREL	3140	Energy intensive
MANUFACTURE OF LEATHER, LEATHER PRODUCTS AND FOOTWEAR	316	Energy intensive
MANUFACTURE OF WOOD AND OF PRODUCTS OF WOOD AND CORK, EXCEPT FURNITURE; MANUFACTURE OF ARTICLES OF STRAW AND PLAITING MATERIALS; MANUFACTURE OF PAPER AND PAPER PRODUCTS; PUBLISHING, PRINTING AND REPRODUCTION OF RECORDED MEDIA	32	Energy intensive
MANUFACTURE OF WOOD AND PRODUCTS OF WOOD, EXCEPT FURNITURE; MANUFACTURE OF ARTICLES OF STRAW AND PLAITING MATERIALS	322	Energy intensive
Manufacture of other products of wood; manufacture of articles of cork, straw and plaiting materials	3229	Energy intensive
MANUFACTURE OF PAPER AND PAPER PRODUCTS	323	Energy intensive
Manufacture of pulp, paper and paperboard	3231	Energy intensive

Standard Industrial Classification System for Economic Activities code (5th edition)	SIC code	Climate sensitive category[13]
MANUFACTURE OF COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL; MANUFACTURE OF CHEMICALS AND CHEMICAL PRODUCTS; MANUFACTURE OF RUBBER AND PLASTIC PRODUCTS	33	Secondary Energy|Gases|Coal and/or Secondary Energy|Liquids|Oil&Energy intensive and/or Secondary Energy|Hydrogen|All and/or Final Energy|Industry|Chemicals[1]
Manufacture of coke, refined petoleum products and nuclear fuel	331	Secondary Energy|Gases|Coal
Manufacture of coke oven products	3310	Secondary Energy|Gases|Coal
PETROLEUM REFINERIES/SYNTHESISERS	332	Secondary Energy|Liquids|Oil
PROCESSING OF NUCLEAR FUEL	333	Energy intensive
PROCESSING OF NUCLEAR FUEL	3330	Energy intensive
Manufacture of basic chemicals and chemical products	334	Secondary Energy|Hydrogen|All
Manufacture of basic chemicals, except fertilizers and nitrogen compounds	3341	Secondary Energy|Hydrogen|All
Green (hydrogen electricity)	No code	Secondary Energy|Hydrogen|Electricity
Non green (hydrogen fossil)	No code	Secondary Energy|Hydrogen|Fossil
Manufacture of fertilizers and nitrogen compounds	3342	Fertilizer Use|Nitrogen
Manufacture of plastics in primary form and of synthetic rubber	3343	Primary Energy|Oil
MANUFACTURE OF OTHER CHEMICAL PRODUCTS	335	Final Energy|Industry|Chemicals
Manufacture of pesticides and other agro-chemical products	3351	Final Energy|Industry|Chemicals
Manufacture of pharmaceuticals, medicinal chemicals and botanical products	3353	Final Energy|Industry|Chemicals
Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	3354	Energy intensive
MANUFACTURE OF RUBBER PRODUCTS	337	Final Energy|Industry|Chemicals
Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres	3371	Final Energy|Industry|Chemicals
Manufacture of other rubber products	3379	Final Energy|Industry|Chemicals
MANUFACTURE OF OTHER NON-METALLIC MINERAL PRODUCTS	34	Production|Cement
MANUFACTURE OF GLASS AND GLASS PRODUCTS	341	Energy intensive
MANUFACTURE OF NON-METALLIC MINERAL PRODUCTS N.E.C	342	Production|Cement
Manufacture of cement, lime and plaster	3425	Production|Cement
Manufacture of articles of concrete, cement and plaster	3425	Production|Cement
Manufacture of basic metals, fabricated metal products, machinery and equipment and of office, accounting and computing machinery	35	Production|Steel
MANUFACTURE OF BASIC IRON AND STEEL	351	Production|Steel
MANUFACTURE OF BASIC IRON AND STEEL	3510	Production|Steel
MANUFACTURE OF BASIC PRECIOUS AND NON-FERROUS METALS	352	Production|Non-ferrous metals
MANUFACTURE OF BASIC PRECIOUS AND NON-FERROUS METALS	3520	Production|Non-ferrous metals
CASTING OF METALS	353	Production|Steel

Standard Industrial Classification System for Economic Activities code (5th edition)	SIC code	Climate sensitive category[13]
Casting of iron and steel	3531	Production|Steel
Casting of non-ferrous metals	3532	Energy intensive
MANUFACTURE OF OTHER FABRICATED METAL PRODUCTS; METALWORK SERVICE ACTIVITIES	355	Energy intensive
Manufacture of cutlery, hand tools and general hardware	3553	Energy intensive
Manufacture of other fabricated metal products n.e.c.	3559	Energy intensive
MANUFACTURE OF GENERAL PURPOSE MACHINERY	356	Energy intensive
Manufacture of engines and turbines, except aircraft, vehicle and motorcycle engines	3561	Energy intensive
Manufacture of pumps, compressors, taps and valves	3562	Energy intensive
Manufacture of bearings, gears, gearing and driving elements	3563	Energy intensive
Manufacture of ovens, furnaces and furnace burners	3564	Energy intensive
Manufacture of lifting and handling equipment	3565	Energy intensive
Manufacture of other general purpose machinery	3569	Energy intensive
MANUFACTURE OF SPECIAL PURPOSE MACHINERY	357	Energy intensive
Manufacture of agricultural and forestry machinery	3571	Energy intensive
Manufacture of machine tools	3572	Energy intensive
Manufacture of machinery for metallurgy	3573	Energy intensive
Manufacture of machinery for mining, quarrying and construction	3574	Energy intensive
Manufacture of machinery for food, beverage and tobacco processing	3575	Energy intensive
Manufacture of machinery for textile, apparel and leather production	3576	Energy intensive
Manufacture of weapons and ammunition.	3577	Energy intensive
Manufacture of other special purpose machinery	3579	Energy intensive
MANUFACTURE OF HOUSEHOLD APPLIANCES N.E.C.	358	Energy intensive
MANUFACTURE OF OFFICE, ACCOUNTING AND COMPUTING MACHINERY	359	Energy intensive
MANUFACTURE OF ELECTRICAL MACHINERY AND APPARATUS N.E.C.	36	Energy intensive
MANUFACTURE OF ELECTRIC MOTORS, GENERATORS AND TRANSFORMERS	361	Energy intensive
MANUFACTURE OF ELECTRICITY DISTRIBUTION AND CONTROL APPARATUS	362	Energy intensive
MANUFACTURE OF INSULATED WIRE AND CABLE	363	Energy intensive
MANUFACTURE OF ACCUMULATORS, PRIMARY CELLS AND PRIMARY BATTERIES	364	Energy intensive
MANUFACTURE OF ELECTRIC LAMPS AND LIGHTING EQUIPMENT	365	Energy intensive
MANUFACTURE OF OTHER ELECTRICAL EQUIPMENT N.E.C.	366	Energy intensive

Standard Industrial Classification System for Economic Activities code (5th edition)	SIC code	Climate sensitive category[13]
MANUFACTURE OF RADIO, TELEVISION AND COMMUNICATION EQUIPMENT AND APPARATUS AND OF MEDICAL, PRECISION AND OPTICAL INSTRUMENTS, WATCHES AND CLOCKS	37	Final Energy|Industry
MANUFACTURE OF ELECTRONIC VALVES AND TUBES AND OTHER ELECTRONIC COMPONENTS	371	Final Energy|Industry
Manufacture of electronic components	3710	Final Energy|Industry
MANUFACTURE OF TELEVISION AND RADIO TRANSMITTERS AND APPARATUS FOR LINE TELEPHONY AND LINE TELEGRAPHY	372	Energy intensive
MANUFACTURE OF TELEVISION AND RADIO RECEIVERS, SOUND OR VIDEO RECORDING OR REPRODUCING APPARATUS AND ASSOCIATED GOODS	373	Energy intensive
MANUFACTURE OF OPTICAL INSTRUMENTS AND PHOTOGRAPHIC EQUIPMENT	375	Energy intensive
MANUFACTURE OF WATCHES AND CLOCKS	376	Energy intensive
MANUFACTURE OF TRANSPORT EQUIPMENT	38	Final Energy|Transportation|Passenger|no specific fuel and/or energy intensive and/or Energy Service|Transportation|Freight|International Shipping and/or Energy Service|Transportation|Rail and/or Energy Service|Transportation|Aviation[1]
MANUFACTURE OF MOTOR VEHICLES	381	Final Energy|Transportation|Passenger|no specific fuel
of which: combustion	No code	Final Energy|Transportation|Passenger|Liquids
Electricity	No code	Final Energy|Transportation|Passenger|Electricity
Hydrid	No code	Final Energy|Transportation|Passenger|Electricity
Hydrogen	No code	Final Energy|Transportation|Passenger|Hydrogen
MANUFACTURE OF BODIES (COACHWORK) FOR MOTOR VEHICLES; MANUFACTURE OF TRAILERS AND SEMI-TRAILERS	382	Energy intensive
MANUFACTURE OF PARTS AND ACCESSORIES FOR MOTOR VEHICLES AND THEIR ENGINES	383	Energy intensive
BUILDING AND REPAIRING OF SHIPS AND BOATS	384	Energy Service|Transportation|Freight|International Shipping
MANUFACTURE OF RAILWAY AND TRAMWAY LOCOMOTIVES AND ROLLING STOCK	385	Energy Service|Transportation|Rail
MANUFACTURE OF RAILWAY AND TRAMWAY LOCOMOTIVES AND ROLLING STOCK	3850	Energy Service|Transportation|Rail

Standard Industrial Classification System for Economic Activities code (5th edition)	SIC code	Climate sensitive category[13]
of which combustion	No code	Energy Service|Transportation|Rail
Electricity	No code	Energy Service|Transportation|Rail
MANUFACTURE OF AIRCRAFT AND SPACECRAFT	386	Energy Service|Transportation|Aviation
MANUFACTURE OF AIRCRAFT AND SPACECRAFT	3860	Energy Service|Transportation|Aviation
MANUFACTURE OF FURNITURE; MANUFACTURING N.E.C.; RECYCLING	39	Energy intensive
MANUFACTURE OF FURNITURE	391	Energy intensive
MANUFACTURE OF FURNITURE	3910	Energy intensive
Electricity, gas and water supply	4	Participants to determine[B]
ELECTRICITY, GAS, STEAM AND HOT WATER SUPPLY	41	Secondary Energy|Electricity|any fuel
Production, collection and distribution of electricity	411	Secondary Energy|Electricity|any fuel
Production, collection and distribution of electricity	4111	Secondary Energy|Electricity|any fuel
Of which from: batteries	No code	Utilities
Coal	No code	Secondary Energy|Electricity|Coal
Gas	No code	Secondary Energy|Electricity|Gas
Hydro	No code	Secondary Energy|Electricity|Hydro
Nuclear	No code	Secondary Energy|Electricity|Nuclear
Wind	No code	Secondary Energy|Electricity|Wind
Solar/PV	No code	Secondary Energy|Electricity|Solar|PV
Ocean	No code	Secondary Energy|Electricity|Ocean
Biomass	No code	Secondary Energy|Electricity|Biomass
Manufacture of gas; distribution of gaseous fuels through mains	412	
Manufacture of gas; distribution of gaseous fuels through mains	4120	Secondary Energy|Gases|Biomass and/or Secondary Energy|Gases|Natural Gas[A]
Construction	5	Participants to determine[B]
CONSTRUCTION	50	Housing and/or Energy Service|Residential and Commercial|Floor Space and/or Energy Service|Transportation|Road
SITE PREPARATION	501	Housing
BUILDING OF COMPLETE CONSTRUCTIONS OR PARTS THEREOF; CIVIL ENGINEERING	502	Energy Service|Transportation|Road
Construction of buildings	5021	Energy Service|Residential and Commercial|Floor Space
Construction of civil engineering structures	5022	Energy Service|Transportation|Road
Construction of other structures	5023	Housing
Construction by specialist trade contractors	5024	Housing

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BUILDING INSTALLATION	503	Housing
Plumbing	5031	Housing
Electrical contracting	5032	Housing
Shopfitting	5033	Housing
Other building installation n.e.c.	5039	Housing
BUILDING COMPLETION	504	Housing
Painting and decorating	5041	Housing
Other building completion n.e.c.	5049	Housing
RENTING OF CONSTRUCTION OR DEMOLITION EQUIPMENT WITH OPERATORS	505	Housing
Wholesale and retail trade, repair of specified items, hotels and restaurants	6	Participants to determine[B]
WHOLESALE AND COMMISSION TRADE, EXCEPT OF MOTOR VEHICLES AND MOTOR CYCLES	61	Primary Energy|Fossil
WHOLESALE TRADE IN NON-AGRICULTURAL INTERMEDIATE PRODUCTS, WASTE AND SCRAP	614	Primary Energy|Fossil
Wholesale trade in solid, liquid and gaseous fuels and related products	6141	Primary Energy|Fossil
HOTELS AND RESTAURANTS	64	Energy Service|Residential and Commercial|Floor Space
HOTELS, CAMPING SITES AND OTHER PROVISION OF SHORT-STAY ACCOMMODATION	641	Energy Service|Residential and Commercial|Floor Space
HOTELS, CAMPING SITES AND OTHER PROVISION OF SHORT-STAY ACCOMMODATION	6410	Energy Service|Residential and Commercial|Floor Space
Transport, storage and communication	7	Participants to determine[B]
LAND TRANSPORT; TRANSPORT VIA PIPELINES	71	Final Energy|Transportation|No specific fuel
RAILWAY TRANSPORT	711	Final Energy|Transportation|No specific fuel
RAILWAY TRANSPORT	7111	Final Energy|Transportation|No specific fuel
Electricity vehicles	No code	Transport
Oil diesel vehicles	No code	Final energy|Transportation|Electricity
Oil gas vehicles	No code	Final Energy|Transportation|Liquids
Hydrogen vehicles	No code	Transport
OTHER LAND TRANSPORT	712	Transport
Other scheduled passenger land transport	7121	Transport
Electricity vehicles	No code	Transport
Oil diesel vehicles	No code	Transport
Oil gas vehicles	No code	Transport

Standard Industrial Classification System for Economic Activities code (5th edition)	SIC code	Climate sensitive category[13]
Hydrogen vehicles	No code	Transport
Other non-scheduled passenger land transport	7122	Transport
Electricity vehicles	No code	Transport
Oil diesel vehicles	No code	Transport
Oil gas vehicles	No code	Transport
Hydrogen vehicles	No code	Transport
Freight transport by road	7123	Transport
Electricity vehicles	No code	Transport
Oil diesel vehicles	No code	Transport
Oil gas vehicles	No code	Transport
Hydrogen vehicles	No code	Transport
TRANSPORT VIA PIPELINES	713	Primary Energy|Gas
TRANSPORT VIA PIPELINES	7130	Primary Energy|Gas
WATER TRANSPORT	72	Primary Energy|Gas
SEA AND COASTAL WATER TRANSPORT	721	Primary Energy|Gas
SEA AND COASTAL WATER TRANSPORT	7211	Primary Energy|Gas
Electricity vehicles	No code	Transport
Oil diesel vehicles	No code	Transport
Oil gas vehicles	No code	Transport
Hydrogen vehicles	No code	Transport
INLAND WATER TRANSPORT	722	Transport
Electricity vehicles	No code	Transport
Oil diesel vehicles	No code	Transport
Oil gas vehicles	No code	Transport
Hydrogen vehicles	No code	Transport
AIR TRANSPORT	73	Energy Service|Transportation|Aviation
AIR TRANSPORT	730	Energy Service|Transportation|Aviation
AIR TRANSPORT	7300	Energy Service|Transportation|Aviation
Electricity vehicles	No code	Transport
Oil diesel vehicles	No code	Transport
Oil gas vehicles	No code	Transport
Hydrogen vehicles	No code	Transport
SUPPORTING AND AUXILIARY TRANSPORT ACTIVITIES; ACTIVITIES OF TRAVEL AGENCIES	74	Transport

Standard Industrial Classification System for Economic Activities code (5th edition)	SIC code	Climate sensitive category[13]
SUPPORTING AND AUXILIARY TRANSPORT ACTIVITIES; ACTIVITIES OF TRAVEL AGENCIES	741	Transport
Cargo handling	7411	Transport
Storage and warehousing	7412	Transport
Other supporting transport activities	7413	Transport
Activities of other transport agencies	7419	Transport
Financial intermediation and insurance, real estate and business services	8	Participants to determine[B]
FINANCIAL INTERMEDIATION, EXCEPT INSURANCE AND PENSION FUNDING	81	Finance
MONETARY INTERMEDIATION	811	Finance
Other monetary intermediation	8112	Finance
OTHER FINANCIAL INTERMEDIATION N.E.C	819	Finance
Lease financing	8191	Finance
Other credit granting	8192	Finance
Other financial intermediation n.e.c.	8199	Finance
INSURANCE AND PENSION FUNDING, EXCEPT COMPULSORY SOCIAL SECURITY	82	Finance
INSURANCE AND PENSION FUNDING, EXCEPT COMPULSORY SOCIAL SECURITY	821	Finance
Life insurance	8211	Finance
Pension funding	8212	Finance
Medical aid funding	8213	Finance
Other insurance n.e.c.	8219	Finance
Real estate	84	Housing
REAL ESTATE ACTIVITIES WITH OWN OR LEASED PROPERTY	841	Housing
Property owning and letting	8411	Housing
Developing real estate, subdividing real estate into lots and residential development on own account	8412	Housing
Owning and/or sale of own fixed property	8413	Housing
REAL ESTATE ACTIVITIES ON A FEE OR CONTRACT BASIS	842	Housing
Activities of estate agencies, rent collectors, appraisers and valuers	8421	Housing
Subletting of fixed property	8422	Housing

Notes

[A] Participants to classify the economic activities based on the underlying data (for example, in the case of biomass gas or natural gas, participants to determine based on their data if the activities relate to extracting gas from biomass or natural gas extraction or both)

[B] For the highest level SIC code, participants should use climate sensitive activities identified for SIC 2, 3 and 4 digits to guide how to classify the granular data used to report the SIC one digit code.