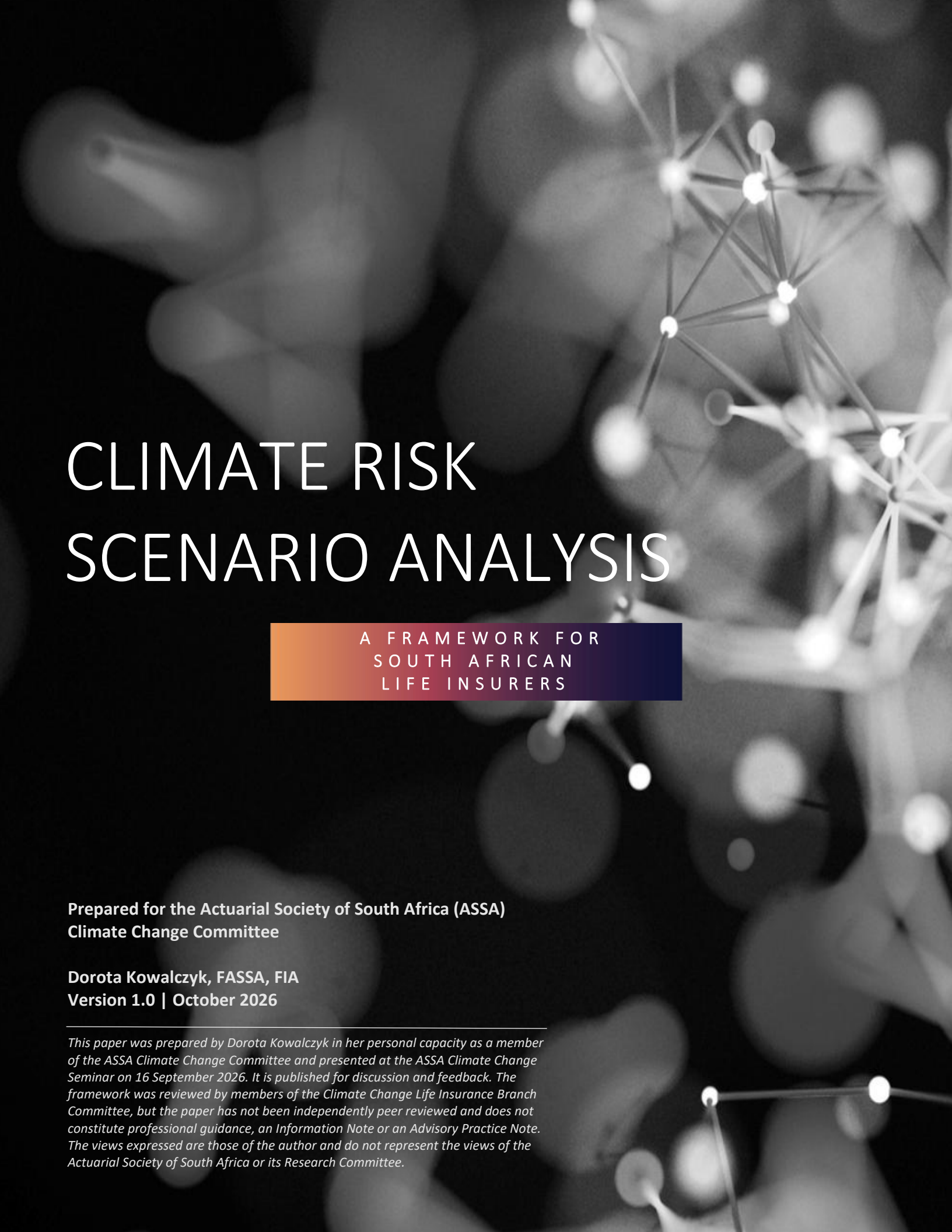


CLIMATE RISK SCENARIO ANALYSIS

A FRAMEWORK FOR SOUTH AFRICAN LIFE INSURERS

Prepared for the Actuarial Society of South Africa (ASSA)
Climate Change Committee

Dorota Kowalczyk, FASSA, FIA
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EXECUTIVE SUMMARY



Climate change is becoming increasingly important for life insurers to consider. As weather events and patterns shift due to climate change, longer-term consequences that are expected to affect life insurers are emerging. The assessment and disclosure of climate change risks are also receiving increased regulatory scrutiny in South Africa, increasing the importance of life insurers incorporating this risk into their existing risk management frameworks.

The assessment of climate change risk remains challenging. Significant uncertainty is inherent in climate change, while limitations in available data and technical expertise, and complex relationships between climate events and their resulting insurance impacts, make the risk difficult to quantify.

This paper proposes a practical climate scenario analysis framework developed specifically for South African life insurers. The framework consists of qualitative and quantitative components and is designed to provide life insurers with a structured approach for translating climate change into relevant insurance risks and assessing their financial resilience to these risks.

The qualitative component refers to the principles underlying the Network for Greening the Financial System (NGFS) climate scenarios. Three increases in global average temperature are considered: a Low Increase scenario of 1.5°C, a Medium Increase scenario of 2.5°C and a High Increase scenario of 4.5°C. These temperature pathways are translated into the corresponding physical and transition risks, the climate and transition events relevant to the South African context, their resulting outcomes, and the insurance risks to which they may give rise. This results in a High Transition Risk scenario under the Low Increase pathway, a Medium Physical Risk, Medium Transition Risk scenario under the Medium Increase pathway, and a High Physical Risk scenario under the High Increase pathway. The framework also recognises the uncertainty associated with climate tipping points by incorporating increasing margins for prudence as the temperature pathway becomes more severe.

The extent to which the resulting insurance risks affect an individual life insurer will depend on the specific risk profile of its portfolio. Factors such as policyholder age, geographic location, income, and affordability may influence the insurer's exposure to climate-related insurance risks. The qualitative scenarios should therefore be adapted to reflect the individual insurer's portfolio rather than applied uniformly across the industry.

The quantitative component applies reverse stress testing within the existing Own Risk and Solvency Assessment (ORSA) process. Rather than attempting to estimate the precise stresses that climate change will place on individual assumptions, the methodology identifies the stresses required for relevant insurance risks to reach a life insurer's defined risk appetite threshold and assesses whether these stresses are plausible under the relevant climate scenario.

The proposed quantitative methodology is intentionally simplified and is subject to limitations. In particular, the approach does not explicitly model the underlying dependencies between insurance risks, while limited historical data and uncertainty regarding tipping points introduce further uncertainty into the assessment. The framework is therefore intended to provide a starting point rather than a static methodology. The scenarios and assumptions applied should be adapted to reflect the specific risk profile of an individual life insurer's portfolio and periodically recalibrated as climate change and policy interventions develop.

Life insurers can take immediate steps to improve their ability to assess and manage climate change risk by developing the necessary technical expertise, improving data collection and retention processes, remaining aware of regulatory developments, and incorporating climate change risk into their existing risk management frameworks. Advancements in technology may further improve climate change risk assessment and the understanding of relationships between climate events and insurance risks.

The proposed framework provides South African life insurers with a practical starting point for incorporating climate change risk into their existing risk management frameworks, allowing the approach to be progressively refined as further information and expertise become available.



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1. INTRODUCTION

Climate change is becoming increasingly important for life insurers to consider. Traditionally, short-term insurers were primarily affected by climate change due to the direct impacts of climate-related events on short-term insurance portfolios. However, as weather events and patterns shift due to climate change, longer-term consequences are emerging that are expected to affect life insurers.

The assessment and disclosure of climate change risks by South African life insurers is also receiving increased regulatory scrutiny. In recent years, the Prudential Authority (PA) has published guidance relating to climate change risk. Although this guidance is voluntary, the PA has indicated that it intends to follow a graduated approach to the management of climate change risks and will monitor the implementation of the guidance through its ongoing supervisory activities.[1] The PA has also recognised the challenges associated with climate scenario analysis and stress testing, including limitations in the availability of data and technical expertise.[1]

These challenges are particularly relevant for South African life insurers. Significant uncertainty is inherent in climate change. Long time horizons and complex relationships between climate events and their resulting financial and insurance impacts amplify this uncertainty.

This paper therefore proposes a climate scenario analysis framework for assessing climate change risk, developed specifically for South African life insurers. To provide a foundation for the proposed framework, the paper outlines climate change and the risks arising from it, as well as the relationship between different categories of climate change risk. It further identifies the climate and transition events relevant to the South African context before translating these events into specific insurance risks. These sections aim to provide life insurers with the necessary understanding to apply the proposed scenario analysis framework and adapt it to reflect the specific risk profile of their portfolios.

The proposed scenario analysis framework consists of qualitative and quantitative components. The qualitative component develops climate scenarios and identifies the insurance risks relevant to the life insurer, while the quantitative component provides a method for life insurers to quantify the risk that climate change poses to their portfolios. The quantitative methodology applies reverse stress testing within the Own Risk and Solvency Assessment (ORSA) process to assess a life insurer's financial resilience to climate change risk. The framework is intended to provide a practical approach that can be adapted to reflect the specific risk profile of an individual life insurer's portfolio.

Finally, the paper considers actions that life insurers can take to improve their ability to assess and manage climate change risk, as well as technological advancements that may influence climate and actuarial modelling in the future.

This paper aims to provide South African life insurers with a practical foundation for incorporating climate change risk into their existing risk management frameworks, while recognising that climate change risk, available data, modelling capabilities and the regulatory environment will continue to evolve, and that the proposed framework should evolve accordingly.

2. OVERVIEW OF CLIMATE CHANGE AND CLIMATE CHANGE RISK

The climate is changing, giving rise to climate change risk, with the potential to materially affect life insurers in the future. It is therefore important for life insurers to have a good understanding of climate change and its associated risks to adequately assess and incorporate them into their risk management frameworks. This section aims to provide that foundational understanding by outlining climate change and the risks arising from it. It further considers the different categories of climate change risk and the interdependent relationship between them.

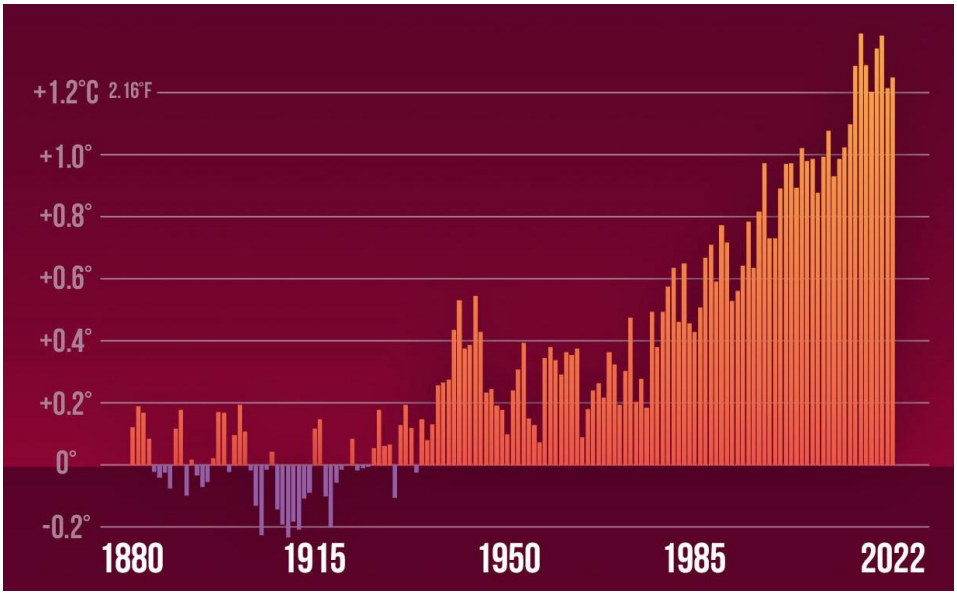
The section also discusses climate tipping points and their importance when assessing climate change risk.

2.1. FROM CLIMATE CHANGE TO CLIMATE CHANGE RISK

Climate change refers to the long-term shifts in global temperatures and the associated changes in weather patterns over time. It is primarily measured through changes in the global annual average temperature, which has shown an increasing trend since the early twentieth century.[2]

Figure 1 illustrates how much higher or lower the global annual average temperature has been relative to the average calculated over the 1881 to 1910 period. From around 1950, the global average temperature has shown a persistently increasing trend, contrasting with the annual fluctuations observed between 1880 and 1950. The figure further demonstrates that the rate of warming has accelerated over recent decades, particularly since around 1985.[2]

Figure 1: Global annual average temperature relative to the 1881 to 1910 average over the 1880 to 2022 period.[2]



Source: World Bank Group (2026). Climate Change Knowledge Portal. Included in accordance with the World Bank Terms of Use for non-commercial educational distribution.

The main cause of this increase is greenhouse gas emissions released into the Earth's atmosphere. Although the global average temperature has consistently increased, the extent of future warming remains uncertain. One of the factors determining the rate of future warming is the level of greenhouse gas emissions released into the atmosphere. If emissions continue to rise, the global average temperature will continue to increase. Conversely, reducing emissions will reduce the rate at which greenhouse gases accumulate in the atmosphere, thereby limiting the extent of future warming.[3]

A further source of uncertainty stems from the relationship between greenhouse gas emissions and the resulting increase in the global average temperature. Although the relationship between emissions and warming is well established, uncertainty remains regarding the magnitude of the temperature increase associated with the different levels of emissions.[2]

These two sources of uncertainty result in a range of possible estimates for the future increase in global average temperature. Lower levels of greenhouse gas emissions are associated with a lower degree of future warming, whereas higher emissions are expected to result in greater increases in global average temperature.[2]

Net zero refers to a state of equilibrium in which the amount of greenhouse gas emissions released into the atmosphere is equal to the amount removed.[3] This can be achieved through reductions in greenhouse gas emissions, or through the removal of greenhouse gases from the atmosphere. Achieving net zero carbon dioxide emissions around 2050 is considered necessary to limit the increase in global average temperature to approximately 1.5°C above pre-industrial levels.[3] Conversely, without significant reductions in emissions, an increase in global average temperature of 5°C or more is plausible by the end of the century.[2]

An increase in the global annual average temperature can have various impacts on the climate, including increases in both air and ocean temperatures. These changes can result in rising sea levels, decreasing ice cover, and changes in oceanic circulation. Additional heat within the climate system can also affect long-term weather patterns and seasonal rainfall, leading to various risks.

These risks stem from both natural climate events and human policy interventions. An example of a policy intervention is the Paris Agreement, which was introduced with the aim of limiting the increase in the global average temperature through reductions in greenhouse gas emissions.[2] The risks arising from these natural climate events and human policy interventions are collectively referred to as climate change risk, or climate risk. Both terms are used interchangeably throughout this paper.

2.2. CATEGORIES OF CLIMATE CHANGE RISK

The sources of climate change risk identified in Section 2.1 can be categorised into the following three risk components:

1. Physical Risk
2. Transition Risk
3. Liability Risk

Collectively, these components contribute to total climate risk. It is important for life insurers to understand each category of risk to adequately assess how climate change risk may affect their overall operations.

Physical Risk

Physical risks are defined as the risks arising from the direct physical impacts of climate change.[4] As the global average temperature continues to increase, physical risks are expected to become more significant. A hotter climate is anticipated to lead to more frequent and severe climate-related events.[5]

Physical risks can be further categorised as follows:

- Acute Physical Risks: These risks stem from climate events and include increases in the severity of shorter-term weather-related events. Examples include heatwaves, floods, and wildfires.
- Chronic Physical Risks: These risks arise from longer-term shifts in climate. Examples include an increase in the global average temperature and rising sea levels.[4]

Transition Risk

Transition risks are defined as the risks arising from the transition to a low carbon economy, including those arising from the introduction of policy interventions aimed at achieving net zero targets. Examples include policy, technology, and legal risks.[4] Transition risks can have a significant impact on economies, Gross Domestic Product (GDP), and other macroeconomic variables. This is because policy interventions can alter business practices and economic conditions. These changing economic conditions can materially impact life insurers.

Liability Risk

Liability risks are the risks arising from policyholders or third parties making claims due to climate-related reasons. Limited claims and litigation linked to climate change have occurred to date, and liability risk therefore remains less developed than physical and transition risk.[5] Liability risk is also more applicable to short-term insurance than to life insurance, given the short-term nature of general insurance contracts and associated third-party liabilities. For these reasons, liability risk falls outside the scope of this paper.

2.3. THE RELATIONSHIP BETWEEN PHYSICAL AND TRANSITION RISK

Physical and transition risk are interdependent. An increase in the global average temperature is associated with more frequent and severe climate-related events, giving rise to greater physical risk. This subsequently creates a need for more aggressive policy interventions to reduce greenhouse gas emissions and limit the associated climate impacts.[6] This interdependent relationship can be visualised as a balance scale, with physical risk on one side and transition risk on the other. The rate at which policies aimed at achieving net zero targets are introduced acts as the fulcrum of this scale, influencing which risk outweighs the other.

The introduction of aggressive policy measures can result in transition risk outweighing physical risk. Stringent regulations aimed at reducing greenhouse gas emissions can limit the rate of increase in the global average temperature, thereby reducing physical risk. However, the scale and pace of these interventions can significantly affect macroeconomic variables, tilting the balance towards transition risk in this scenario.

A delay in the introduction of policy interventions can lead to failure to meet net zero targets. In this scenario, economic conditions are less materially affected by new regulations, resulting in lower transition risk. However, physical risk becomes increasingly significant as greenhouse gas emissions continue to rise, increasing the risk of severe climate-related events and tilting the scale towards physical risk.

If policy interventions are introduced at a gradual rate, the scale remains relatively balanced. The steady introduction of policy interventions allows the economy to adjust, avoiding material shocks associated with more aggressive measures. Physical risk remains present as the global average temperature continues to increase but is less material than in the scenario where policy interventions are delayed. Transition risk is similarly lower than in the scenario where policy interventions are more aggressive.

Within this conceptual framework, the scale can initially be viewed as being in a state of relative equilibrium, with all three scenarios outlined above remaining plausible pathways. However, the scale should be viewed as a state-dependent system. The policy decisions made today influence how material physical and transition risks may become in the future and which scenarios remain plausible going forward.

To further illustrate this, each policy intervention can be thought of as adding a counterweight to the transition risk side of the scale, while each period of policy delay adds a counterweight to the physical risk side. As weights accumulate on either side, they influence the future balance between physical and transition risk. Rebalancing the scale therefore requires counterweights to be added to the other side, with the scale becoming progressively more difficult to rebalance as weights accumulate.

This creates a form of path dependency in the relationship between physical and transition risk.[6] If policy interventions are consistently delayed, physical climate impacts may become progressively more severe, potentially reaching a point where gradual policy interventions are no longer sufficient. More aggressive policy interventions may consequently be required, resulting in greater transition risk. Although this scenario may appear less likely at present, decisions made today regarding policy interventions will influence how likely it becomes in the future.

This path dependency is an important consideration for life insurers when qualitatively deriving climate scenarios and developing climate risk management frameworks. It is therefore also important for life insurers to consider how the interdependent relationship between physical and transition risk may recalibrate the balance at future points in time.

The relationship is illustrated in Figure 2 below.

Figure 2: A visual representation of the balance between physical and transition risk, illustrating the interdependent nature of these sources of climate change risk and the recalibration of this balance over time.[7]



Source: Generated by the author using ChatGPT (OpenAI), May 2026.

2.4. CLIMATE TIPPING POINTS

An important consideration for life insurers when developing their climate risk management frameworks is the concept of climate tipping points. Tipping points are thresholds within the climate system which, if crossed, can result in substantial and potentially irreversible changes to the climate.[6] Two primary examples of tipping points are the destruction of the Amazon rainforest and the substantial melting of the polar ice sheets. These tipping points can be triggered when an increase in the global average temperature exceeds certain thresholds. However, the precise magnitude of temperature increase required to trigger individual tipping points remains uncertain.[6]

Tipping points are important when assessing climate change risk because once these points are triggered, there is considerable uncertainty as to whether the associated changes to the climate can be prevented, halted, or reversed. The triggering of tipping points could therefore permanently alter parts of the climate system. The climate could also become highly unpredictable following this alteration. This potential irreversibility combined with the unpredictability gives rise to greater climate change risk.[6]

Current research indicates that limiting the increase in global average temperature to 1.5°C reduces the likelihood of triggering climate tipping points, with warming beyond this level associated with greater uncertainty and risk.[6] When considering scenarios where temperature increases exceed 1.5°C, this increased uncertainty should therefore be reflected through greater margins in assumption stresses.

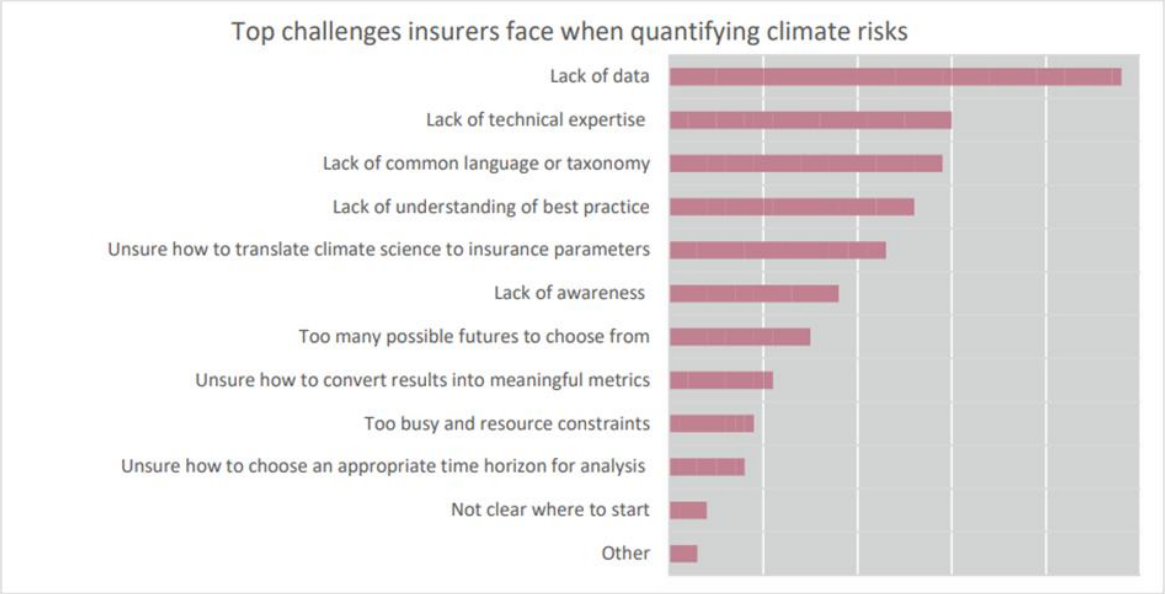
When viewing physical and transition risk as a scale, tipping points are likely to become relevant in scenarios where policy interventions have been delayed or absent. In these scenarios, counterweights accumulate on the physical risk side of the scale as temperatures and associated physical risks increase. Once the scale tilts sufficiently to cross tipping point thresholds, it becomes increasingly uncertain whether subsequent measures can recalibrate or rebalance this scale. Significant transition risk can also arise if aggressive policy interventions are subsequently introduced to stabilise the climate system.

Historically, tipping points have been considered high impact, low likelihood events. However, as global temperatures continue to increase, the likelihood of triggering climate tipping points is increasingly recognised as a significant concern.[6] Consequently, life insurers deriving qualitative climate scenarios should explicitly incorporate tipping points into their scenario analyses when assessing climate change risk.

3. CHALLENGES ASSOCIATED WITH CLIMATE CHANGE RISK MANAGEMENT

Life insurers face several challenges when incorporating climate change risk into their risk management frameworks. A survey conducted by the Financial Stability Institute (FSI) in 2019 among insurance supervisory authorities identified the most common challenges insurers encountered when quantifying climate change risks. The results of this survey are presented in Figure 3 below.[5]

Figure 3: Top challenges insurers face when quantifying climate risks.[5]



Source: Bank for International Settlements (2019). FSI Insights No 20. Reproduced for non-commercial purposes in accordance with BIS generic terms of permitted use.

The most significant challenge insurers face when quantifying climate risk is a lack of data. This includes not only insufficient data but also limited granularity and usability of existing data. Given that climate change risks are spatial in nature, meaning that their impacts vary significantly depending on geographic location, insurers may not be collecting sufficiently detailed data to appropriately quantify their climate-related exposures. Furthermore, even where historical data exists, such as data relating to past climate events, it may not be a reliable predictor of future outcomes and exposures due to changing weather patterns. There is also limited data available on the nature and timing of future policy interventions in response to climate change.[5] Consequently, relying on historical experience to predict future outcomes becomes particularly challenging when assessing climate change risk.

Another significant challenge associated with quantifying climate change risk is a lack of technical expertise. Skilled professionals with the knowledge required to translate temperature pathways and climate events into climate scenarios and insurance risk assumptions are scarce. Climate change risk quantification is an emerging field, and the limited availability of expertise and experience makes it difficult to translate climate scenarios into appropriate assumption stress tests. This is further compounded by limited experience within the industry in assessing how climate change impacts accumulate over the extended time horizons relevant to life insurers.[5]

This paper aims to address these challenges by providing an overview of climate change, climate risk, and the interrelationship between the risk categories. It further identifies the climate and transition events most relevant to South Africa and illustrates how these events translate into specific insurance risks for life insurers. Finally, the paper proposes a scenario analysis framework that extends existing global frameworks to the South African and insurance-specific context, while recognising the limitations of currently available data and the uncertainty inherent in long-term climate projections.

4. CLIMATE CHANGE RISK WITHIN THE SOUTH AFRICAN CONTEXT

Having reviewed the foundational concepts of climate change and climate change risk, as well as the key challenges insurers face when assessing and quantifying these risks, this section explores the climate change risks relevant to South Africa.

Both physical and transition risks are inherently spatial. This means that different regions will be affected by different climate and transition events depending on their geographic location.[8] For example, the same increase in the global average temperature may lead to droughts in regions prone to dry conditions, while causing increased flooding in coastal areas. Similarly, the severity of transition risks is influenced by a country's reliance on carbon-intensive sectors, as well as the nature and extent of policy interventions introduced to achieve net zero targets.

It is therefore essential for life insurers to understand the climate and transition risks relevant to the geographic areas within which they operate. Where a life insurer operates across multiple areas, the complexity of the risk assessment increases, as the events relevant to each region will need to be considered individually given the spatial nature of these risks.[9]

This section identifies the physical and transition risks most relevant to the South African context, focusing on locally relevant climate and transition events. It also considers the implications of triggering tipping points. This provides the foundation for Section 5, which explores how these events translate into specific insurance risks for South African life insurers. This section is not intended to provide an exhaustive assessment of all potential climate change risks in South Africa, but rather an overview of the locally relevant climate and transition events associated with physical and transition risk.

4.1. PHYSICAL RISK AND ASSOCIATED CLIMATE EVENTS IN THE SOUTH AFRICAN CONTEXT

South Africa has significant exposure to physical climate risk due to several climate events expected to affect the country as the global average temperature increases.

Although this section details the climate events and associated effects expected to arise in South Africa due to physical risk, it should be noted that the triggering of climate tipping points has not been accounted for in the research reviewed for this section. Ongoing research aims to understand how the climate system may change once these tipping points are triggered and the potential consequences thereafter. Nonetheless, the following overview provides an understanding of the climate events that could affect South Africa as the global average temperature increases.

The southern African region is characterised by warmth and aridity, with a further increase in temperature expected to intensify these conditions.[10] Climate change is expected to cause the temperatures over the South African interior to increase at approximately 1.5 to 2 times the global rate of temperature increase, resulting in the region becoming hotter and drier.[10]

Estimates of future temperature increases across South Africa vary considerably depending on the emissions pathway, time horizon, geographic region, and modelling approach considered. The CSIR projects temperature increases over South Africa relative to a 1961 to 1990 baseline, with increases towards the end of the 21st century ranging from approximately 2°C to 3°C over the southern coastal regions, to more than 4°C across much of the interior under a low mitigation scenario. [10] Under a higher mitigation scenario, considerably lower temperature increases are projected.[10] Other climate projections similarly estimate substantial differences between emissions pathways. The G20 Climate Risk Atlas projects an increase in South Africa's average temperature of approximately 1.2°C by 2050 under a low emissions pathway, compared to approximately 2.1°C under a high emissions pathway.[11]

The range of estimates considered in the research reflects the significant uncertainty inherent in climate change projections. As noted in Section 3, historical data may not be a reliable predictor of future outcomes. This is an important consideration for life insurers when assessing the impact of climate change risk on their portfolios. It suggests that assumption stresses may not be derived with a high degree of confidence and that a framework which considers this uncertainty may be more appropriate than one relying solely on quantified estimates.

The increase in regional temperatures is also expected to result in an increase in the number of warm spell days. A warm spell day is defined as a day forming part of a period of at least six consecutive days during which the maximum temperature exceeds the 90th percentile threshold for that time of year.[12] Estimates indicate that the number of warm spell days in South Africa is projected to increase from fewer than 5 days in 1990 to approximately 145 days on average by 2100 under a high emissions scenario, or approximately 25 days if global emissions decrease significantly.[12] Regional warming is also expected to increase the risk of infectious and vector-borne diseases, such as malaria and dengue fever.[12]

Representative Concentration Pathway (RCP)4.5 and RCP8.5 are greenhouse gas emissions pathways used by climate scientists to model future climate change, with RCP4.5 representing a high mitigation, low emissions scenario and RCP8.5 representing a low mitigation, high emissions scenario. Under both scenarios, the incidence of heat waves and wildfires in South Africa is expected to increase. A heat wave day is defined as a day forming part of a period of at least three consecutive days during which the maximum temperature at a given geographic location exceeds the average maximum temperature of the warmest month of the year at that location by 5°C.[10]

Under both scenarios, heat wave days over the interior regions of eastern South Africa are projected to increase by approximately 10 to 20 days per year during the 2021 to 2050 period, relative to the baseline 1961 to 1990 period. Larger increases are anticipated over the western interior, particularly under the RCP8.5 scenario. These increases in heat waves are also expected to increase the number of high fire danger days, defined as days on which weather conditions such as heat, dryness, and wind combine to create a heightened risk of wildfires. Increases of between 10 and 30 of these days per year are projected over the eastern interior, with larger increases over the western interior under both scenarios.[10]

Air pollution may also worsen as temperatures increase. Warm conditions favour reactions which lead to a decrease in air quality and can negatively affect respiratory health.[13] An increase in the incidence of wildfires may further worsen air quality through the release of smoke and particulate matter.[10 13]

Rainfall patterns across South Africa are also projected to change under different climate scenarios. Rainfall is expected to increase over parts of the central interior and east coast, while other regions of the country are estimated to become substantially drier.[10] The number of extreme rainfall events, defined as the occurrence of more than 20mm of rainfall within a 24-hour period, is also expected to increase over parts of the central interior and east coast. These changes are expected to increase the risk of flooding in affected regions and may consequently increase the incidence of waterborne diseases.[10]

The southern African region is also susceptible to El Niño events, characterised by the considerable warming of the tropical Pacific Ocean and associated with changes in rainfall patterns across the region. El Niño events can contribute to drought conditions across southern Africa. Significant uncertainty remains regarding how climate change will affect the future frequency and intensity of these climate events.[10] Changes in El Niño events therefore remain an important consideration when assessing future physical climate risk in South Africa.

In summary, an increase in the global average temperature is expected to have significant physical risk implications for South Africa. The associated climate events and effects can be summarised as follows: 1) rising temperatures and an increased incidence of heat waves, 2) an increased risk of infectious and vector-borne diseases, 3) an increased incidence of wildfires, 4) worsening air pollution, 5) an increased risk of droughts, 6) an increased risk of flooding, and 7) an increased risk of waterborne diseases.

4.1.1. THE RISK ASSOCIATED WITH TRIGGERING TIPPING POINTS

Lower climate change mitigation is associated with a greater increase in the global average temperature and consequently greater physical risk. As discussed in Section 2.4, higher levels of warming are also associated with an increased likelihood of triggering climate tipping points.[6] If these tipping points are triggered, substantial and potentially irreversible changes to the climate system could arise, with potentially significant economic consequences.[6]

Research quantifying the economic consequences of triggering climate tipping points remains limited. However, one study has examined the existing economic literature on climate tipping points to estimate their impact on the Social Cost of Carbon (SCC). The SCC represents the economic cost associated with emitting an additional tonne of carbon dioxide. Therefore, it represents the marginal economic damage resulting from these emissions.[14]

Using a meta-analytic integrated assessment model incorporating the existing economic research across eight climate tipping points, the study estimates that collectively triggering these tipping points increases the expected SCC by approximately 25%.[14] The distribution of the projected impact is positively skewed, with an approximately 10% probability that the SCC more than doubles. The study further notes that the estimates are likely to be conservative, as some tipping points and interactions between tipping points have not been incorporated into existing literature.[14]

These findings demonstrate the potentially significant economic consequences associated with triggering tipping points. The research further indicates that tipping points increase economic losses across almost all geographic regions considered and increase the overall economic risk.[14] This is consistent with the general concern raised in climate scenario analyses that the economic losses associated with higher levels of physical risk and the triggering of tipping points may be underestimated.[6]

The substantial uncertainty inherent in both the likelihood and the consequences of triggering tipping points is an important consideration when assessing climate change risk. The available estimates may not reflect the full range of potential outcomes, while the consequences of triggering individual tipping points and the interactions between them remain uncertain.[6]

This research therefore highlights the importance of incorporating scenarios that reflect the uncertainty associated with climate tipping points when assessing climate change risk in the South African context, as proposed in Section 6.

4.2. TRANSITION RISK AND ASSOCIATED TRANSITION EVENTS IN THE SOUTH AFRICAN CONTEXT

The global transition to a low carbon economy poses a significant risk to the South African economy. South Africa's economy is characterised by a high level of carbon intensity, with several economically important sectors, including mining and automotive industries, remaining dependent on carbon-intensive activities. Simultaneously, many of South Africa's major export markets are transitioning towards lower carbon economies.[15] This exposes South Africa to changes in global demand for carbon-intensive exports and is expected to result in several transition events with potentially significant implications for the South African economy. These events may also impact South African life insurers.

The transition to a low carbon economy is expected to affect South Africa's exports, particularly the mining and automotive industries.[15] The mining sector contributed approximately 7.3% to South Africa's nominal GDP in 2022,[16] while the broader automotive industry contributed approximately 5.3% to GDP in 2023.[17] A reduction in global demand for carbon-intensive products and changes in global trade could therefore negatively impact exports from these sectors, with broader implications for South Africa's economic growth.

The financial implications associated with this transition risk could be significant. Research by the Climate Policy Initiative estimates that the cumulative impact of a low carbon transition on South Africa over the period 2013 to 2035 could exceed $120 billion in 2013 present value terms.[18] A significant proportion of this potential loss is expected to affect the government's fiscal position, placing additional pressure on sovereign debt and South Africa's sovereign credit rating.[18] Government support for carbon-intensive companies and state-owned enterprises experiencing financial distress as a result of the transition could lead to further pressure.[18]

Carbon taxes represent another transition event arising from the shift towards a low carbon economy. A carbon tax is levied on entities whose greenhouse gas emissions exceed a prescribed threshold, with the aim of incentivising more sustainable business practices and reducing emissions.[19] Carbon pricing can increase energy and production costs, which may be passed on to business and consumers beyond the entities directly subject to the tax through supply chains.[20]

The broader macroeconomic effects of carbon pricing depend on the implementation of the policy. Research indicates that increases in carbon prices can increase energy prices and reduce economic output, with potential consequences for employment.[20] [21] These effects may therefore contribute to economic pressures during the transition, particularly in carbon-intensive sectors and regions.

Employment represents a further transition risk for South Africa. Carbon-intensive industries employ a substantial number of people. In 2018, approximately 89,000 workers were employed in the coal mining sector, while Eskom employed approximately 50,000 workers and Sasol approximately 26,000 workers in South Africa.[22] Therefore, if transition occurs rapidly, there is a risk of significant job losses in affected sectors.[22] This could place further pressure on employment in South Africa if displaced workers are not absorbed into alternative industries.

In summary, the transition to a low carbon economy is expected to have significant implications for South Africa. The associated transition events can be summarised as follows: 1) a decline in demand for carbon-intensive exports, 2) the introduction and increasing impact of carbon pricing and related policy interventions, 3) an increased risk of unemployment in carbon-intensive sectors, and 4) potential downward pressure on South Africa's fiscal position and sovereign credit rating.

5. IMPACT OF CLIMATE CHANGE RISK ON SOUTH AFRICAN LIFE INSURERS

The previous section outlined the climate and transition events arising from physical and transition risk respectively within the South African context. Each of these events can give rise to specific outcomes which may in turn result in insurance risks affecting South African life insurers. However, the extent of these impacts remains highly uncertain and challenging to quantify. This is because it depends on factors including future greenhouse gas emissions, the resulting increase in the global average temperature, and the nature and timing of policy interventions introduced in response to climate change.

This section examines the insurance risks that may arise from these events. It does not aim to provide an exhaustive assessment, but rather a broad overview of how climate and transition events can give rise to insurance risks that may affect life insurers in the future. The purpose is to provide life insurers with a foundation for understanding which risks may be relevant to their business, enabling them to identify how these risks apply to their own books of business.

The insurance risks considered in this section include mortality risk, longevity risk, morbidity risk, lapse risk, new business risk, retrenchment risk, expense risk, inflation risk, investment risk, and reinsurance risk. Both the first-order and second-order effects of climate change risk are explored below. Second-order effects refer to the indirect consequences arising from climate and transition events, such as a potential decline in economic growth, population migration, and a shift towards a low carbon economy.

5.1. INSURANCE RISK IMPLICATIONS OF PHYSICAL CLIMATE EVENTS

Different temperature pathways result in varying degrees of physical risk and associated climate events. These events can translate into several first-order and second-order risks for life insurers.

The full extent of the impact of physical risk on mortality and morbidity may not be immediately observable. Some effects, such as those associated with malnutrition arising from prolonged droughts or longer-term health consequences following infectious diseases, may take several years to develop.[12] [26] This introduces additional uncertainty when assessing the impact of physical risk on life insurers.

Understanding how these climate events translate into insurance risks enables life insurers to appropriately incorporate them into their risk management processes. This section explores the insurance risks arising from the climate events identified in Section 4.1.

Rising Temperatures and Heat Waves

Increasing temperatures and the frequency of heat waves can lead to various adverse health outcomes. Extreme heat can lead to heat exhaustion and heat stroke. It can also worsen symptoms associated with neurological conditions such as dementia, epilepsy, Parkinson's disease, and multiple sclerosis.[24] These impacts can therefore increase mortality and morbidity risk for life insurers.

The mortality and morbidity impacts associated with rising temperatures and heat waves are not uniform across policyholders. Young children, pregnant women, and older individuals are particularly vulnerable to extreme heat.[31] The extent of the resulting mortality and morbidity risk will therefore depend in part on the age and demographic profile of a life insurer's book of business. Life insurers with greater exposure to vulnerable policyholders may consequently be more affected.

Extreme heat has also been associated with adverse mental health and cognitive outcomes, including irritability, depression, an increased risk of suicide, memory problems, decreased attention, and slower reaction times. Sleeping difficulties associated with extreme heat may further contribute to these effects.[25] Collectively, these impacts may negatively affect productivity and affordability, potentially contributing to increased lapse and retrenchment risk as second-order effects of rising temperatures.

It is also important to note that the impact of rising temperatures on mortality may not be entirely adverse. Although heat-related mortality is expected to increase as temperatures rise, a reduction in cold temperatures may lead to a corresponding decrease in cold-related mortality in some geographic locations.[33] The overall impact of rising temperatures on mortality may therefore reflect a combination of increased heat-related mortality and reduced cold-related mortality.

Infectious and Vector-Borne Diseases

Rising temperatures are expected to increase the risk of infectious and vector-borne diseases in South Africa, including malaria and dengue fever. Under a high emissions scenario, an increase in these diseases could result in higher mortality and morbidity claims for life insurers.[12]

Long-term health consequences associated with infectious and vector-borne diseases may create additional risks. For example, dengue fever has been associated with post-acute complications affecting multiple organ systems.[26] These longer-term health consequences may increase morbidity claims under products such as disability and income protection and could contribute to lapse risk where affected policyholders experience reduced ability to work and affordability concerns.

New business and expense risk may also increase where changing disease prevalence affects underwriting quality, business mix, and new business volumes. More extensive underwriting may be required for certain products or policyholders in areas with higher risk, increasing underwriting costs and consequently contributing to expense risk.

Wildfires

An increase in temperatures and heat waves is associated with a higher risk of wildfires. Exposure to air pollution arising from wildfires has been associated with increased mortality,[32] as well as adverse cardiovascular[27] and respiratory health outcomes.[29] Wildfires may therefore increase both mortality and morbidity for life insurers.

The associated health consequences may also give rise to lapse risk where policyholders experience a reduced ability to work and subsequent affordability concerns. Increased critical illness, disability, and income protection claims may further contribute to morbidity risk.

Wildfires may also affect new business and expense risk through changes in underwriting quality, business mix, and the geographic distribution of policyholders. Population migration away from high-risk areas could change the geographic distribution of both new and in-force business, while higher underwriting and claims processing costs may increase expense risk.

Wildfires can also destroy buildings and other physical assets. This creates investment risk for life insurers with direct exposure to the property asset class.[10]

Air Pollution

The insurance risk implications of worsening air pollution align with those associated with wildfires. Air pollution has been associated with cardiovascular disease[28] and respiratory conditions such as asthma.[29] This can increase mortality and morbidity risk, as well as lead to higher critical illness, disability, and income protection claims.

Changing health risks may also affect underwriting quality, business mix, and new business volumes. Higher underwriting and claims processing costs may contribute to expense risk. Population migration away from areas experiencing persistently poor air quality could further alter the geographic distribution of new and in-force business.

Droughts

An increase in the incidence of droughts can result in crop shortages and reduced food security, contributing to worsening nutrition and associated mortality and morbidity impacts.[12] These effects may not be immediately observable, as the consequences of prolonged droughts for nutrition, food security and health can take years to develop. The timing and extent of the resulting mortality and morbidity impacts therefore introduce additional uncertainty for life insurers.

Food and water shortages may also increase the cost of essential goods, creating inflationary and affordability pressures. This may increase inflation and lapse risk, while businesses facing higher input costs and weaker economic conditions may reduce their workforces, contributing to retrenchment risk.

New business risk may similarly increase where affordability pressures reduce new business volumes and changing health conditions affect underwriting quality and business mix. Expense risk may also increase where additional underwriting is required to assess changing health risks.

Droughts may also have broader economic implications through their impact on agriculture. The agricultural sector is an important contributor to South Africa's economy and exports and is particularly exposed to changing climate conditions.[30] A decrease in agricultural output could therefore contribute to broader economic pressures, creating second-order investment risk for life insurers.

Flooding

An increase in extreme rainfall events and associated flooding can affect South African life insurers. Flooding can result in fatalities and therefore increase mortality risk.[12] It can also damage or destroy buildings and other physical assets, creating investment risk for life insurers with direct or indirect exposure to real estate where these assets are located in flood-prone areas.[10]

Waterborne Diseases

An increase in the incidence of waterborne diseases may arise after flooding and can result in increased mortality and morbidity risk for South African life insurers.[12]

Where affected policyholders are unable to work due to illness, affordability pressures may contribute to lapse risk. Changing disease prevalence may also affect underwriting quality, business mix, and new business volumes, contributing to new business risk. Higher underwriting and claims processing costs may similarly increase expense risk.

5.1.1. REINSURANCE IMPLICATIONS OF PHYSICAL RISK CLIMATE EVENTS

The cumulative effect of the physical climate events outlined above may also have significant implications for the reinsurance arrangements of South African life insurers. As climate-related mortality and morbidity claims increase in frequency and severity globally, reinsurers may reassess their climate change exposures and adjust their pricing and terms accordingly. Reinsurance premiums for mortality and morbidity cover may consequently increase, affecting the reinsurance assumptions of South African life insurers.

Under more severe climate scenarios, certain reinsurance covers may become subject to exclusions or, in some cases, may no longer be available on commercially viable terms. This could increase the cost of risk transfer and require South African life insurers to retain a greater proportion of their climate-related mortality and morbidity risk. This could affect their solvency position and risk management strategy.

5.1.2. IMPLICATIONS OF TIPPING POINTS FOR INSURANCE RISK ASSUMPTIONS

Given the uncertainty associated with the triggering of tipping points and their potential consequences, a margin for prudence should be incorporated into the relevant insurance risk assumptions. The size of the margin applied should reflect the likelihood of tipping points being triggered under the scenario being considered, with larger margins incorporated where this likelihood is higher.

5.2. INSURANCE RISK IMPLICATIONS OF TRANSITION EVENTS

Transition risks similarly present significant direct and indirect impacts on South African life insurers and are important considerations when evaluating the impact of climate change on their business.

Beyond the direct economic consequences of the transition outlined in Section 4.2, South African life insurers also face policy risk. South Africa's transition towards a low carbon economy exposes businesses operating in the country, and life insurers invested in them, to changes in climate-related policies and the resulting economic pressures.[18]

The transition events summarised in Section 4.2 are explored below in terms of the specific insurance risks to which they give rise.

Decrease in Exports

A decrease in South Africa's exports and the resulting decline in GDP can have several implications for South African life insurers. A weaker economy can lead to affordability concerns, with policyholders struggling to pay premiums, thereby increasing lapse risk. Businesses may also reduce their workforce in an effort to reduce costs, leading to an increase in retrenchment risk. New business risk can similarly increase, as both the volume and mix of new business may change under this scenario.

A smaller policyholder base may also increase expense risk, particularly with respect to fixed costs, which would be spread across fewer policyholders. Mortality and morbidity risk may also increase as a second-order effect where affordability concerns and unemployment reduce policyholders' abilities to access medical care. This can potentially lead to worse health outcomes over time.

Carbon Taxes

As outlined in Section 4.2, carbon taxes are introduced with the aim of reducing greenhouse gas emissions. A reduction in greenhouse gas emissions may have beneficial health effects through a reduction in the adverse health impacts associated with emissions and air pollution. This could result in improvements in mortality and morbidity experience and potentially increase longevity risk for life insurers writing annuity business.

However, carbon pricing can also result in a decrease in economic output and an increase in prices.[20] [21] Where additional costs are passed on to consumers, this may contribute to inflationary pressures and reduced affordability, increasing inflation and lapse risk. Some businesses may instead choose to absorb a portion of the additional costs and reduce their workforce to manage costs. This can potentially increase retrenchment risk.

The overall mortality and morbidity impact may therefore be less evident. While a reduction in emissions could have beneficial health effects, reduced access to healthcare arising from affordability constraints could partially offset these improvements. The net impact on mortality and morbidity will therefore depend on the relative magnitude of these opposing effects.

Increasing inflationary pressure may lead to higher interest rates. Higher interest rates reduce the market value of existing fixed-rate bonds, creating investment risk for life insurers with exposure to these assets. Companies directly or indirectly affected by carbon pricing may similarly experience declining valuations, potentially increasing investment risk for life insurers with equity exposure. New business risk may also increase, as affordability concerns and economic uncertainty affect both the volume and mix of new business.

Increase in Unemployment

The transition to a low-carbon economy may result in significant job losses in carbon-intensive sectors, as outlined in Section 4.2.[22] For policyholders employed in these sectors, unemployment may reduce their ability to afford medical care, potentially leading to a second-order increase in mortality and morbidity risk. Retrenchment risk increases directly as jobs are lost in these sectors, while lapse risk may also increase due to reduced affordability.

New business risk may similarly increase, as the volume and mix of new business change in response to reduced affordability and changing employment. Expense risk may also increase where fixed costs are spread across a smaller policyholder base.

South African Sovereign Credit Rating

As outlined in Section 4.2, the financial consequences of a low carbon transition could place additional pressure on South Africa's fiscal position and sovereign credit rating.[18] A deterioration in South Africa's sovereign credit rating could have implications for the value and risk associated with South African government bonds, creating investment risk for life insurers exposed to these assets.

A further downgrade could also affect investor demand for South African government bonds, particularly where investors are subject to investment-related restrictions. This could place downward pressure on bond prices and upward pressure on yields. Life insurers with exposure to South African government bonds could consequently experience changes in the value and risk profile of these investments.

These effects could therefore increase investment risk for South African life insurers. Depending on the extent of their exposure and the severity of the scenario, these effects could also have implications for their solvency positions.

5.3. FACTORS INFLUENCING EXPOSURE TO CLIMATE-RELATED INSURANCE RISK

The extent to which the insurance risks identified in Sections 5.1 and 5.2 affect an individual life insurer will depend on the rating factors of its book of business. Factors such as the age and geographic distribution of policyholders, product mix, and policyholder income or affordability may influence the insurer's exposure to climate-related insurance risks.

For example, as discussed in Section 5.1, older policyholders and pregnant women may be more vulnerable to the health impacts associated with extreme heat.[31] Therefore, a life insurer with more exposure to these policyholders may experience greater mortality and morbidity impacts under a high emissions scenario involving heat waves. Geographic location is also important due to the spatial nature of climate risk, as the location of policyholders will determine their exposure to climate events such as flooding, droughts, wildfires, and changes in disease prevalence.

Product mix will also influence the resulting insurance risk exposure. For example, climate events resulting in adverse health outcomes may have a greater impact on life insurers selling significant volumes of critical illness, disability, or income protection benefits than on products providing death benefits only. The extent to which the different insurance risks identified in Sections 5.1 and 5.2 affect an insurer will therefore depend on the product within its book of business.

Policyholder income and affordability may further influence the impact of certain climate events. Research indicates that lower income population may be more vulnerable to heat-related mortality due to a reduced ability to adapt to increasing temperatures.[34]

These factors should therefore be considered when determining which climate-related insurance risks are most relevant to a life insurer given the specific risk profile of their business.

5.4. CLIMATE RISK FOR INTERNATIONAL EXPOSURES

If a South African life insurer has international operations or investments, the climate-related risks relevant to these exposures will differ from those identified for South Africa. As discussed in Section 4, physical and transition risks are inherently spatial. They depend on factors such as geographic location, the local climate, the economy, and the nature of climate-related policy interventions.

For international insurance operations, the process used in Sections 4 and 5 should therefore be repeated for each relevant jurisdiction. This involves identifying the physical and transition events applicable to that jurisdiction. Subsequently, it should be considered how these events translate into insurance risks for the insurer's local book of business. International investments should similarly be considered in the context of physical and transition risks relevant to the jurisdictions and sectors to which the insurer is exposed. The investment risks identified in the scenario analysis should therefore reflect both domestic and international exposures where these are material to the insurer.

The South African climate events and transition events identified in this paper should consequently not be applied uniformly to an insurer's international exposures. Where sufficiently granular data is available, insurers should also consider segmenting their book by material exposure factors, such as age, geographic location, product type and policyholder affordability, to allow climate-related stresses to reflect differences in risk exposure across policyholder groups.

6. CLIMATE SCENARIO ANALYSIS FRAMEWORK

Due to the long-term nature of climate change risk and the significant uncertainty associated with future outcomes, scenario analysis is an appropriate risk management tool for life insurers to use. Integrating climate scenarios into existing risk management frameworks allows South African life insurers to assess their financial resilience under different scenarios.

This section outlines the proposed climate scenario analysis framework. The qualitative approach is aligned with the Network for Greening the Financial System (NGFS) scenario analysis framework. Therefore, an overview of the NGFS framework is provided as background to the development of the proposed scenarios. The approach is then adapted to the South African life insurance context.

The quantitative methodology is also outlined, using reverse stress testing to assess the resilience of a life insurer to climate change risk. The methodology has been developed with the aim of aligning with the PA's climate-related guidance while providing a practical approach for South African life insurers to incorporate climate change risk into their existing risk management frameworks.

An overview of how the proposed framework aligns with the PA's climate-related guidance is also provided. Finally, the limitations of the framework are also outlined.

6.1. OVERVIEW OF THE NGFS CLIMATE SCENARIO ANALYSIS FRAMEWORK

Several climate scenario analysis frameworks have been developed globally, including those created by the Intergovernmental Panel on Climate Change (IPCC) and the Network for Greening the Financial System (NGFS). The NGFS framework is commonly referred to as the reference framework within the financial services industry. Originally developed to assist central banks and supervisors in assessing climate risks, the scenarios are subsequently applied more broadly across the financial sector as a common framework for the climate scenario analyses.[35]

The NGFS framework classifies seven long-term climate scenarios into four quadrants according to the degree of physical and transition risk associated with each scenario. The four quadrants are briefly outlined below:

- Orderly: Policy interventions are introduced early and gradually. This facilitates a gradual transition to a net zero economy, avoiding aggressive policy interventions, while the transition to a low carbon economy prevents significant increases in global average temperatures. In this quadrant, both physical and transition risks remain low.[35]
- Disorderly: Policy interventions are delayed and once introduced, must be implemented more aggressively. Transition risks are high in this quadrant, while physical risks remain relatively low due to the policy interventions limiting increases in global average temperatures.[35]
- Hot House World: Policy interventions are insufficient to prevent a significant increase in global average temperatures. In this quadrant, physical risks are high, while transition risks remain relatively low due to the absence of sufficiently stringent policy interventions.[35]

- Too Little, Too Late: Introduced in a subsequent version of the framework, this quadrant represents a late and uncoordinated transition that fails to sufficiently limit physical risks. Both physical and transition risks are therefore high, making this the most severe quadrant from a financial risk perspective.[35]

Each of the seven long-term scenarios is categorised into one of the four quadrants outlined above, with examples of scenarios including Net Zero 2050, Current Policies, and Fragmented World.[35]

The NGFS framework continues to evolve, with the publication of short-term scenarios in 2025 aimed at capturing the near-term impacts of physical and transition risks. These scenarios span a five-year horizon and complement the longer-term scenarios by providing greater insight into climate risks that may arise over shorter decision-making horizons.[35]

More information on the NGFS climate scenarios framework is available on the NGFS website.[35]

While the NGFS framework provides a valuable foundation for climate scenario analysis, certain considerations arise when applying this framework within the South African life insurance context.

6.1.1. CONSIDERATIONS FOR APPLYING THE NGFS FRAMEWORK TO SOUTH AFRICAN LIFE INSURERS

Although the NGFS framework considers temperature pathways, policy interventions, and the relationship between physical and transition risk when deriving its scenarios, it remains a generalised framework.

It provides high-level macroeconomic and financial outputs, rather than outputs specific to insurance liabilities. The framework also does not indicate how these scenarios affect the assumptions underlying a life insurer's liabilities or translate these effects into insurance liability stresses. This makes it difficult for life insurers to quantify the impact of climate risks on their insurance liabilities based purely on the NGFS framework.

The NGFS framework has been developed for global application. Therefore, the NGFS scenarios do not capture vulnerabilities specific to South Africa, such as the dependence on carbon-intensive sectors, local policy interventions, and local climate events likely to occur as the global average temperature increases.

Additionally, the NGFS framework does not explicitly account for climate tipping points or their potential consequences. As discussed in Section 2.4, tipping points introduce additional uncertainty due to their potential irreversibility and the uncertainty surrounding the temperatures at which they may be triggered. This is an important consideration for life insurers when assessing long-term solvency, particularly for products with extended time horizons such as whole of life insurance and retirement annuities.

Taking into account these considerations, a proposed climate scenario analysis framework is outlined below. The proposed approach develops the NGFS framework by incorporating these additional factors, with the aim of providing a practical method for South African life insurers to incorporate climate change risk into their risk management frameworks.

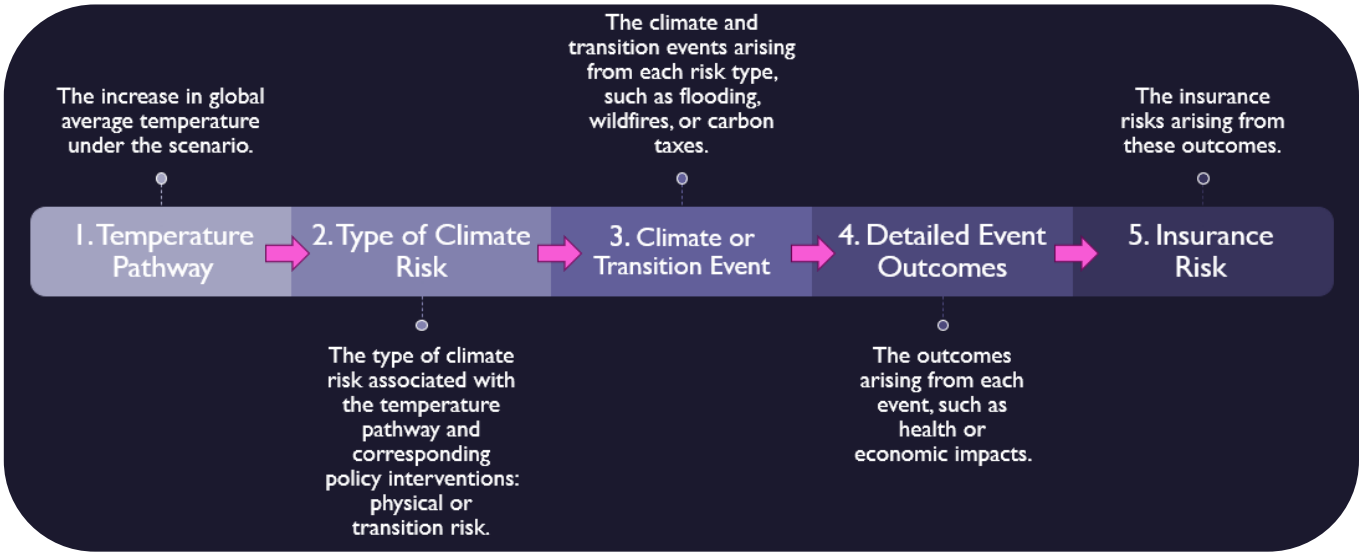
6.2. PROPOSED CLIMATE SCENARIO ANALYSIS FRAMEWORK

The proposed climate scenario analysis framework qualitatively develops scenarios by translating temperature pathways into insurance risks. Thereafter, reverse stress testing is applied within the ORSA framework to assess the life insurer's financial resilience to climate change risk.

6.2.1. QUALITATIVE DERIVATION OF SCENARIOS

The qualitative scenarios are developed with reference to the NGFS scenarios and by applying the causal relationships established in Sections 2 to 5 of this paper. The process followed in deriving the qualitative scenarios is summarised in Figure 4 below.

Figure 4: Process for developing qualitative climate scenarios for climate risk management.



When selecting the temperature pathways underlying the proposed scenarios, the NGFS scenarios are considered first. Two contrasting scenarios within the NGFS framework are Net Zero 2050 and Current Policies. The Net Zero 2050 scenario assumes the introduction of stringent policy interventions to achieve net zero, resulting in higher transition risk and lower physical risk. The Current Policies scenario, by contrast, assumes that only currently implemented policies are maintained, leading to insufficient emissions reductions and consequently higher physical risk and lower transition risk.[35]

By considering the relationships between temperature pathways, policy interventions, and physical and transition risk, three increases in global average temperature are chosen as the starting points for the proposed scenarios: 1.5°C (low), 2.5°C (medium), and 4.5°C (high). These temperature pathways form the basis of the scenarios presented in Appendix 1 and are outlined below:

- Low Increase: An increase of 1.5°C is consistent with the targeted temperature increase associated with achieving net zero. Achieving this requires stringent policy interventions, thereby increasing transition risk while reducing the physical risk associated with this scenario. This temperature pathway therefore leads to a High Transition Risk scenario.
- Medium Increase: An increase of 2.5°C exceeds the net zero target, representing an intermediate scenario in which policy interventions are introduced but are insufficient to prevent a greater increase in global average temperature. Both physical and transition risks are therefore present, leading to a Medium Physical Risk, Medium Transition Risk scenario.
- High Increase: An increase of 4.5°C represents a significant rise in global average temperature, consistent with insufficient policy interventions to prevent substantial warming. This results in increased physical risk, while transition risk remains relatively low. This temperature pathway therefore leads to a High Physical Risk scenario.

The Low Increase scenario is therefore analogous to the NGFS Net Zero 2050 scenario, while the High Increase scenario is analogous to a Current Policies scenario, with a more severe temperature increase applied to distinguish it from the Medium Increase scenario. The Medium Increase scenario represents an intermediate pathway in which both physical and transition risks remain relevant.

The proposed temperature pathways, chosen with reference to the NGFS scenarios, aim to provide a practical starting point for life insurers, rather than a prescribed set of scenarios. The aim is to consider a wide range of plausible climate outcomes which reflect different combinations and severities of physical and transition risk. Life insurers should therefore select scenarios that are feasible at the time of the analysis and that provide a sufficiently broad range of outcomes for assessing their climate-related exposures, instead of placing emphasis on the precise magnitude of temperature increase chosen.

Once the temperature pathways and associated physical and transition risks have been established, the causal relationships identified in Sections 4 and 5 are applied, as illustrated in Figure 4. The relevant climate or transition events are identified for each risk type, followed by the resulting event outcomes and corresponding insurance risks. This allows the analysis developed in Sections 4 and 5 to be applied consistently across each of the three scenarios.

A 25-year period has been chosen for the qualitative analysis, although the choice of timeframe remains at the discretion of the life insurer. This period represents the horizon over which the impacts of each scenario are assessed and does not imply that the specified global average temperature increases are necessarily reached within the 25-year period. The 25-year horizon reflects the long-term nature of climate change risk and allows sufficient time for the cumulative effects of changing climate conditions and transition policies to emerge. At the same time, it avoids the additional uncertainty associated with a significantly longer projection period. Life insurers may therefore adjust the timeframe to reflect the nature and duration of their own assets and liabilities.

Tipping points are incorporated into the framework through margins for prudence applied to the relevant insurance risk assumptions. As discussed in Section 2.4, the temperatures at which individual tipping points may be triggered remain uncertain. The degree of prudence applied therefore increases as the temperature pathway becomes more severe:

- Low Increase (1.5°C): No additional margin for tipping points is incorporated.
- Medium Increase (2.5°C): A small additional margin for tipping points is incorporated.
- High Increase (4.5°C): A larger additional margin for tipping points is incorporated.

The appropriate margins are considered further as part of the quantitative methodology outlined in Section 6.2.2.

In this framework, a life insurer's portfolio is stressed at an overall level rather than individually by product line. However, when deriving the qualitative scenarios and determining the appropriate stresses, assurance and annuity business are considered separately to reflect the different impacts that climate events may have on mortality and longevity. The resulting stresses are combined when assessing the overall portfolio. For example, as discussed in Section 5.2, a reduction in emissions associated with climate-related policy interventions may have beneficial health effects, potentially reducing mortality risk for assurance business while increasing longevity risk for annuity business.

The detailed application of the qualitative framework is presented in Appendix 1, which sets out the climate and transition events, their associated outcomes, and the corresponding insurance risks under each scenario. The tables have been constructed for a generic life insurer for illustrative purposes and should be adapted to reflect the specific risk profile of an individual insurer's book of business, as discussed in Section 5.3. The scenarios and insurance risks identified are therefore not necessarily exhaustive. The tables focus primarily on assurance business, with an additional table illustrating the application to annuity business.

The tables presented in Appendix 1 are summarised below:

- Table 1: High Temperature Increase (4.5°C), High Physical Risk Scenario, for Assurance Business
- Table 2: Medium Temperature Increase (2.5°C), Medium Physical Risk, Medium Transition Risk Scenario, for Assurance Business
- Table 3: Low Temperature Increase (1.5°C), High Transition Risk Scenario, for Assurance Business
- Table 4: Low Temperature Increase (1.5°C), High Transition Risk Scenario, for Annuity Business

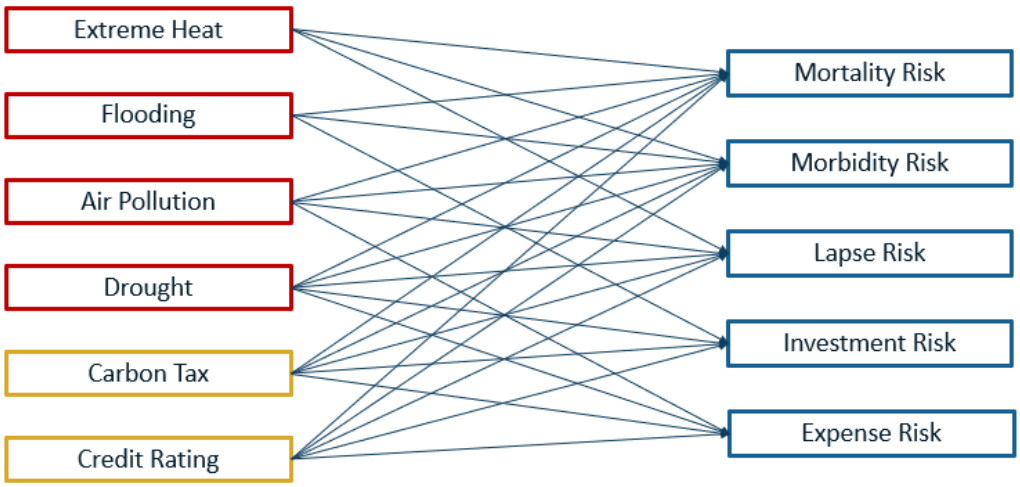
6.2.2. QUANTITATIVE REVERSE STRESS TESTING

Following the qualitative derivation of the scenarios in Section 6.2.1, the insurance risks relevant to the life insurer's book of business are identified. The next step is to assess the extent to which these risks could affect the life insurer's financial resilience.

The process illustrated in Figure 4 demonstrates the considerable uncertainty associated with each stage of translating a temperature pathway into an insurance risk. Each stage introduces further uncertainty, from the climate or transition event itself, through to the associated event outcomes and the insurance risks arising from these outcomes. As outlined in Section 3, historical data may not provide an appropriate basis for estimating future climate-related impacts. This increases the difficulty of reliably determining the magnitude of the stresses that should be applied to individual insurance risk assumptions.

A further challenge arises from the interrelationships between the insurance risks identified under each scenario. Several climate and transition events may lead to the same insurance risk, while individual events may simultaneously affect several insurance risks. These relationships may also change under extreme events, meaning that dependencies observed under historical conditions may not necessarily remain appropriate under the climate stress scenarios.[36] These potential interrelationships between climate and transition events and the resulting insurance risks are illustrated in Figure 5 below.

Figure 5: Illustrative relationships between climate and transition events and insurance risks.



Given these uncertainties, directly estimating a set of climate-related assumption stresses and applying them to the life insurer's cash flow model may require estimates that cannot be derived from available information. The proposed framework therefore applies reverse stress testing. Rather than attempting to estimate the assumption stresses that climate change will produce, the framework determines the level of deterioration in the relevant assumptions that would cause the insurer to reach a predefined risk appetite threshold.

Reverse stress testing is appropriate for this purpose because it begins with a predefined adverse outcome and works backwards to identify the stresses that would result in the outcome. Campbell[37] describes a similar approach within the ORSA context, proposing the identification of the least extreme scenarios across relevant risk dimensions that would result in a defined adverse outcome. Furthermore, since there may be many possible solutions to such an inverse problem, the search can initially be simplified by identifying key risk drivers and considering them both individually and in combination.[37]

The proposed quantitative framework applies a simplification of these concepts suitable for climate-related insurance risks and integration within the ORSA process. The steps involved in the proposed quantitative approach are outlined below.

Definition of the Risk Appetite Threshold

The life insurer defines the financial threshold against which the reverse stress test is performed.

The threshold should reflect the insurer's existing risk appetite and may, for example, be expressed as a ratio of Available Capital to Solvency Capital Requirement. The threshold does not necessarily need to represent insolvency. It may instead represent a financial threshold at which the insurer requires management intervention.

The quantitative analysis has been developed with the aim of incorporating it into the life insurer's existing ORSA process and performing the analysis over an appropriate ORSA projection period. This allows the climate reverse stress test to form part of the insurer's existing risk management framework rather than requiring a separate solvency assessment specifically for climate change risk.

The purpose of the reverse stress test is to determine the combination of assumption stresses required for the insurer to breach the threshold under each climate scenario.

Identification of Material Insurance Risks

The qualitative scenarios developed in Section 6.2.1 identify several insurance risks. However, the materiality of these risks will differ between life insurers depending on the characteristics of their books of business.

To determine the material risks, the insurer can perform univariate reverse stress tests on the assumptions corresponding to the insurance risks identified under each scenario. Each assumption is stressed individually until the insurer reaches its predefined risk appetite threshold.

The magnitude of the stress required provides an indication of the insurer's sensitivity to the individual assumption. An assumption requiring a relatively small shock to reach the threshold may indicate greater sensitivity to that risk.

The results of the univariate reverse stress tests can therefore be used, together with the insurer's risk profile and the qualitative assessment developed in Section 6.2.1, to identify the most material assumptions to include in the subsequent multivariate reverse stress test.

The selection of material risks should also consider the specific characteristics of the insurer's book of business. As outlined in Section 5.3, factors such as the age and geographic distribution of policyholders, product mix, and policyholder income or affordability may significantly influence the insurer's exposure to the insurance risks identified under each scenario.

Identification of Primary and Secondary Risk Drivers

Once the most material risks have been identified, these risks are classified as either primary or secondary drivers under each climate scenario.

The classification should reflect both the nature of the scenario and the risk profile of the life insurer's book of business.

For example, under the Low Increase scenario, transition-related risks such as lapse, retrenchment, or inflation risk may be more prominent due to the stringent policy interventions associated with transition. Under the High Increase scenario, mortality and morbidity risk may become more prominent due to the greater physical impacts associated with the higher temperature pathway.

The risk profile of the insurer's policyholder base should also influence this classification. An insurer with greater exposure to older policyholders may, for example, classify mortality as a primary risk under a high temperature scenario. An insurer with a younger policyholder base may instead have higher exposure to lapse or retrenchment risk arising from economic disruption and productivity impacts.

The factors identified in Section 5.3 should therefore be considered when determining the primary and secondary risk drivers for each insurer and scenario.

For the purpose of the framework, primary risk drivers are assigned twice the relative weight of secondary risk drivers. This 2:1 relationship is a simplifying assumption introduced within this proposed framework to reflect the greater relative importance of primary risks where reliable dependency estimates are not available. It should not be interpreted as an estimate of the correlation between the insurance risks. Given the judgement inherent in this assumption, insurers should consider sensitivity testing alternative weightings, such as 1:1 or 3:1 relationships, to assess whether these materially affect the results.

Let r_i represent the relative score assigned to assumption i, such that:

$$r_i = \begin{cases} 2, & \text{where assumption } i \text{ represents a primary risk driver} \\ 1, & \text{where assumption } i \text{ represents a secondary risk driver} \end{cases}$$

The corresponding weight is then calculated as:

$$w_i = \frac{r_i}{\sum_{j=1}^{n} r_j}$$

where n represents the number of assumptions included in the multivariate reverse stress test.

This normalisation ensures that the weights across the selected assumptions sum to one while maintaining the 2:1 relative relationship between primary and secondary risks. The weights determine the relative magnitude of the stresses applied simultaneously to the selected assumptions and do not represent the assumption stresses themselves. For example, where one primary and one secondary risk are included, the respective weights would be ⅔ and ⅓ respectively.

Incorporation of Tipping Point Uncertainty

In addition to determining the relative weights assigned to the selected assumptions, the proposed framework also incorporates additional uncertainty associated with climate tipping points. As discussed in Sections 2.4 and 5.1.2, tipping points introduce uncertainty due to the possibility of more severe and potentially irreversible climate impacts.

This uncertainty should be reflected in the quantitative assessment. However, the margin associated with tipping point uncertainty should be considered separately from the loading parameter λ.

The reverse stress testing process determines the selected assumption shocks required for the insurer to reach its risk appetite threshold. In contrast, the tipping point margin reflects the additional prudence associated with uncertainty regarding the severity of the underlying pathway.

Consistent with Section 6.2.1, no additional tipping point margin is incorporated under the Low Increase scenario, while a small additional margin is incorporated under the Medium Increase scenario and a larger margin under the High Increase scenario.

The tipping point margin is not necessarily applied uniformly across all assumptions. Instead, it is applied to the assumptions considered relevant to the potential consequences of tipping points under the scenario being assessed.

These margins are incorporated in the adverse direction relevant to each assumption before determining the value of the loading parameter required for the insurer to reach its predefined risk appetite threshold.

The magnitude of this margin should be determined by the insurer using available climate research and expert judgement. The purpose of including the margin is therefore not to quantify the impact of a tipping point. Instead, it is to allow additional prudence to be incorporated to account for the uncertainty associated with tipping points.

Directional Reverse Stress Testing

A purely univariate assessment does not capture the potential combined impact of these risks materialising together. To account for this, the selected assumptions are stressed simultaneously, once the material assumptions and their relative weights have been determined and any relevant tipping point margins have been incorporated.

The proposed framework applies this principle through a simplified directional search. The relative magnitude of the selected assumption stresses is determined by the weights derived above, while a common loading parameter λ determines the overall severity of the stress.

The stressed value of assumption i is expressed as:

$$\mu_i^*(\lambda) = \mu_i(1 + d_i \lambda w_i)$$

where:

$\mu_i^*(\lambda)$ represents the stressed assumption i;
μ_i represents the starting value of assumption i, incorporating any applicable tipping point margin determined in the preceding step;
w_i represents the relative weight assigned to assumption i;
d_i represents the direction of the adverse stress applied to assumption i, taking a value of $+1$ where an increase in the assumption represents the adverse stress and -1 where a decrease in the assumption represents the adverse stress;
λ represents the common loading parameter, where $\lambda \geq 0$

The value of λ is progressively increased until the insurer reaches its predefined risk appetite threshold.

This provides a practical method of reverse stress testing several assumptions simultaneously without requiring the insurer to estimate a complete dependency structure between the underlying climate-related insurance risks.

The value of λ at which the insurer reaches its predefined risk appetite threshold represents the required severity of the joint stress. The corresponding values of the individual assumptions represent the combination of assumption movements required for the insurer to reach that threshold.

The methodology does not attempt to estimate the true correlations between the insurance risks. Rather, it allows the selected assumptions to deteriorate jointly in a predetermined direction. This simplification is intended to provide a practical starting point for quantifying climate change risk where the historical data and dependency information required for more complex modelling are not available.

This approach is intended to provide a practical method for considering scenarios in which multiple risks move simultaneously, while acknowledging the simplifications and approximations involved.[37]

Interpretation of the Reverse Stress Test

The output of the reverse stress test is the combination of assumption stresses required for the insurer to reach its predefined risk appetite threshold under the relevant climate scenario.

The resulting stresses can then be assessed against available climate evidence to determine whether they could plausibly arise under the climate scenario being considered. For example, the reverse stress test may indicate that the insurer reaches its risk appetite threshold where mortality, lapse, and expense assumptions are shocked by specified amounts under the selected relative weighting.

The purpose of the framework is not to assert that these specific assumption stresses will occur, but rather to identify the shock that would become material to the insurer. The insurer can assess the plausibility of these stresses using available climate research, expert judgement, reinsurer expertise, and other relevant sources. Where the stresses required to reach the threshold are substantially more severe than those considered plausible under the relevant climate scenario, the scenario may present a lower risk to the insurer's financial resilience. Conversely, where the stresses approach levels that could plausibly arise, the scenario may require greater consideration within the insurer's risk management process.

An illustrative application of the proposed quantitative methodology is provided in Appendix 2.

Application of the Reverse Stress Testing Results

The results of the reverse stress test can be incorporated into the life insurer's existing risk management and ORSA processes to support the assessment of its financial resilience to climate-related risks.

Under climate scenarios where the stresses required to breach the insurer's risk appetite threshold are considered plausible, the results may support a review of the insurer's risk appetite, capital management, and underlying assumptions, as well as inform appropriate management actions.

Furthermore, the results may assist in identifying areas of the life insurer's book of business that are particularly vulnerable to climate-related risks, such as portfolios with greater exposure to older policyholders. These findings may also inform future product design decisions.

An important benefit and outcome of implementing the proposed framework is the experience gained through its application. By incorporating climate scenario analysis into existing risk management processes, life insurers can identify practical challenges, areas requiring further development, and opportunities to refine the approach. This allows the framework to be progressively improved as additional information, experience, and expertise become available, supporting the continued integration of climate-related risks into the life insurer's risk management process.

6.2.3. RECALIBRATION OF QUALITATIVE SCENARIOS

An important feature of the proposed framework is that the scenarios derived are not static. As outlined in Section 2.3, with the progression of time, the scale should be periodically recalibrated to reflect the latest available information. This includes the observed changes in global average temperature, developments in climate science, and the extent to which policy interventions have been introduced. This recalibration will influence which scenarios remain relevant, whether new scenarios require inclusion, and the extent to which physical and transition risks are present within each scenario.

To illustrate this, consider a situation in which no meaningful interventions are introduced over the next five years. In this case, the scale recalibrates towards physical risk, with the likelihood of triggering tipping points increasing. A scenario involving both significant physical risk and aggressive policy interventions may consequently become relevant and require inclusion in the framework. Conversely, should meaningful policy interventions be introduced over this period, the scale recalibrates towards transition risk, the potential for severe physical risk reduces, and the Current Policies scenario becomes progressively less relevant, with the framework adjusting accordingly.

The proposed framework treats the three scenarios outlined in Section 6.2.1 as the appropriate starting point given the current state of the scale and the climate system. However, it recognises that the scenarios considered and the degree of physical and transition risk present within each scenario should be reassessed periodically. At each recalibration, the scenarios should reflect both developments since the previous assessment and the latest available information regarding future climate and transition events.

An illustrative example of how the qualitative scenarios may be recalibrated in response to varying degrees of policy intervention is provided in Appendix 3.

6.2.4. ALIGNMENT WITH REGULATORY GUIDANCE

The proposed framework aligns with the principles outlined in the PA's climate-related guidance notes for insurers. G1/2024[38] provides guidance on the assessment and management of climate-related risks, while GN3-2025[39] provides guidance on climate-related disclosures.

The proposed framework considers both physical and transition risks and their potential impacts on a life insurer's assets and liabilities. It integrates climate-related risks into existing insurance risk categories and the ORSA process, rather than considering climate risk separately from the insurer's existing risk management framework. The framework also incorporates both qualitative and quantitative scenario analysis, with the quantitative assessment linked to the insurer's existing risk appetite.

The framework therefore provides a practical approach for South African life insurers to incorporate the principles outlined in the PA's climate-related guidance into their existing risk management and ORSA processes.

6.2.5. LIMITATIONS OF THE PROPOSED FRAMEWORK

The proposed framework is subject to several limitations. Firstly, the limited availability of research on the potential consequences of tipping points being triggered makes it difficult to determine the appropriate margins for prudence to incorporate into relevant insurance risk assumptions. The framework therefore relies on available climate research and expert judgement when determining these margins.

Secondly, the quantitative methodology applies a simplified directional approach in which selected insurance risk assumptions are stressed simultaneously using predetermined relative weights. This does not explicitly model the underlying dependencies between insurance risks and may therefore not fully capture complex or non-linear relationships that could emerge under climate stress scenarios. The results may also be sensitive to the classification of risks as primary or secondary and to the relative weights assigned to these risks.

Finally, as discussed in Section 3, the limited availability of relevant historical data creates uncertainty in the quantitative method proposed.

Despite these limitations, the proposed framework provides a practical starting point for South African life insurers to translate climate scenarios into relevant insurance risks and assess their potential impact within existing risk management frameworks.

7. FURTHER CONSIDERATIONS

The assessment and management of climate change risk will continue to evolve as climate science, available data, and technology develop. Life insurers should therefore consider not only the actions to be taken immediately, but also developments that may influence the assessment and management of climate change risk in the future.

This section outlines further considerations across different time horizons. It considers immediate actions that life insurers can take, as well as near-term and longer-term technological advancements that may influence climate risk modelling and the application of the proposed framework.

7.1. IMMEDIATE CONSIDERATIONS

In the immediate term, life insurers can take several practical steps to improve their ability to assess and manage climate change risk.

Life insurers should ensure that the necessary technical expertise is available to adequately understand climate change risk and adapt climate scenarios to the specific risk profile of their book of business. Developing this expertise will also provide a foundation for future considerations, such as the potential repricing of existing products or development of new products as the impacts of climate change become better understood.

Furthermore, appropriate data collection and storage processes should be reviewed. Subject to applicable data privacy requirements, relevant policyholder information such as age, income, occupation, and geographic location should be collected and retained where appropriate. These factors may influence exposure to climate-related insurance risks, as discussed in Section 5.3. Sufficient claims information, including the cause of claim, should similarly be retained over an appropriate period. Where possible, life insurers should aim to record more detailed causes of claims, rather than relying on broad classifications such as natural causes, which may obscure potential relationships between climate-related events and insurance claims.

Maintaining a sufficiently long history of claims data may become increasingly valuable as climate science and modelling capabilities develop. Although historical experience may not necessarily provide an appropriate basis for predicting future climate-related impacts, historical claims data could be analysed alongside climate and weather data to identify emerging relationships and changes in experience over time. Data retention practices should therefore consider the potential future application of this data in climate risk assessment and monitoring.

Finally, life insurers should be aware of the latest developments in regulatory guidance concerning climate risk. Life insurers should also begin incorporating climate change risk into their existing risk management frameworks. Establishing these processes at an early stage allows life insurers to develop and refine their approach to incorporating climate risk into their risk management processes over time.

Taking these steps proactively, rather than reactively, will better position life insurers to manage climate risk and refine their approaches as the field continues to develop.

7.2. NEAR-TERM CONSIDERATIONS

Artificial intelligence (AI) is an important near-term consideration due to its potential to further develop climate modelling and improve the use of climate-related data. AI is increasingly being applied to weather and climate modelling. It can assist in analysing large volumes of structured and unstructured data.[40]

The ability to incorporate and analyse a broad range of data may improve the understanding of climate events and their impacts. For example, AI can be used to analyse satellite imagery relating to physical climate events such as wildfires.[40] As these capabilities develop, this type of information could potentially be combined with insurance data to improve the understanding of how climate events translate into insurance risks.

Improved data and modelling capabilities may also allow life insurers to better understand the relationships between individual climate events and insurance risks. Over time, this could enable more sophisticated dependency assumptions to be incorporated into the quantitative methodology proposed in Section 6.2.2. This will allow the simplifying assumptions currently applied, such as the 2:1 relative weighting between primary and secondary risk drivers, to be replaced with more empirically informed estimates where sufficiently credible data is available.

AI therefore has the potential to improve both climate modelling and its application to life insurance risk assessment. Life insurers should therefore monitor emerging trends in AI and their potential application to climate science and climate risk modelling.

7.3. LONGER-TERM CONSIDERATIONS

Quantum computing has the potential to transform climate and actuarial modelling.[41] Due to its computational capabilities, quantum computing may eventually allow certain complex, multivariable problems to be analysed more efficiently than is possible using classical computing. It therefore has the potential to allow more complex scenarios and tail risk events to be analysed. This may improve the quantification of climate-related risks as this technology develops.

However, quantum computing remains an emerging field and its practical application to climate and actuarial modelling is still developing.[41] It is therefore not an immediate consideration for the implementation of the proposed framework. Life insurers should, however, remain aware of the developments in quantum computing and its potential future application to climate risk modelling.

8. CONCLUSION

Climate change risk is becoming an increasingly important consideration for South African life insurers. Significant uncertainty remains regarding the future impacts of climate change. This uncertainty highlights the importance of life insurers incorporating this risk into their existing risk management frameworks.

This paper has proposed a practical climate scenario analysis framework developed specifically for South African life insurers. The qualitative component of the framework translates increases in global average temperature into physical and transition risks, the climate and transition events relevant to the South African context, and identifies the insurance risks that may arise from these events. Subsequently, the quantitative component applies reverse stress testing within the existing ORSA process. Rather than estimating the precise assumption stresses arising from climate change, the methodology identifies the stresses required for relevant insurance risks to reach a life insurer's defined risk appetite threshold. This provides a practical method for assessing the life insurer's financial resilience to climate change risk while recognising the uncertainty associated with this risk.

The proposed framework is intended to provide a starting point rather than a fully developed methodology. The scenarios and assumptions applied should be adapted to reflect the specific risk profile of an individual life insurer's portfolio. These scenarios should also be recalibrated periodically to account for developments in policy interventions and climate change.

Climate change risk, available data, modelling capabilities and the regulatory environment will continue to evolve. South African life insurers should therefore begin developing and refining their approaches to managing climate risk, while remaining aware of future developments. The proposed framework provides a foundation for incorporating climate change risk into existing risk management frameworks and progressively refining the approach as understanding of this risk develops.

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APPENDICES

The following three appendices provide illustrative applications of the qualitative and quantitative components of the proposed scenario analysis framework outlined in Section 6. Appendix 1 outlines the qualitative scenarios developed for different temperature pathways and insurance portfolios. Appendix 2 uses a hypothetical South African life insurer to demonstrate the application of the quantitative reverse stress testing methodology. Appendix 3 illustrates how the qualitative scenarios may be recalibrated over time in response to varying degrees of policy intervention.

APPENDIX 1: ILLUSTRATIVE APPLICATION OF THE QUALITATIVE SCENARIO DEVELOPMENT FRAMEWORK

The following tables illustrate the application of the qualitative scenario development framework outlined in Section 6.2.1 to a generic South African life insurer. Climate and transition events associated with each scenario are identified, along with the potential outcomes of these events and the corresponding insurance risks.

The tables are illustrative and do not represent an exhaustive assessment of all potential risks. The relevance and materiality of each risk will depend on the characteristics of the life insurer's book of business, as discussed in Section 5.3.

Table 1: High Temperature Increase (4.5°C), High Physical Risk Scenario for Assurance Business

This is an illustrative assessment over a 25-year time horizon.

Climate Event	Climate/Transition Event	Detailed Event Outcome	Insurance Risk
Physical Risk	Rising temperatures and heat waves	Increased heat-related illness, including heat exhaustion, heat stroke and worsening neurological conditions.	Mortality, Morbidity
		Reduced productivity and ability to work, potentially affecting policyholder affordability and employment.	Lapse, Retrenchment
	Infectious and vector-borne diseases	Increased prevalence of diseases such as malaria and dengue fever, with potential longer-term health complications.	Mortality, Morbidity, Lapse
		Changing disease prevalence may affect underwriting quality, business mix, and underwriting costs.	New Business, Expense

	Wildfires	Increased exposure to smoke and particle matter, contributing to cardiovascular and respiratory conditions.	Mortality, Morbidity
		Destruction of buildings and other physical assets in which the life insurer is invested.	Investment
		Population migration away from affected areas and increased underwriting or claims processing costs.	New Business, Expense
	Air pollution	Worsening air quality contributing to cardiovascular and respiratory illness.	Mortality, Morbidity
	Droughts	Reduced agricultural output and food security, contributing to malnutrition and adverse health outcomes.	Mortality, Morbidity
		Increased food and water prices, reducing affordability and potentially affecting employment.	Inflation, Lapse, Retrenchment
		Reduced agricultural output and broader economic pressures affecting investment performance.	Investment
		Changing health conditions and affordability affecting underwriting requirements and new business volumes.	New Business, Expense
	Flooding	Increased flooding resulting in fatalities and damage to physical assets.	Mortality, Investment
	Waterborne diseases	Increased incidence of waterborne illnesses following flooding.	Mortality, Morbidity
		Illness-related affordability pressures and changing underwriting requirements.	Lapse, New Business, Expense
	Increased mortality and morbidity claims across climate events	Reinsurers may increase premiums, impose exclusions or reduce the availability of cover.	Reinsurance
Transition Risk	Decline in carbon-intensive exports	Reduced demand from trading partners transitioning towards lower-carbon economies, contributing to weaker economic growth and investment performance.	Investment
		Reduced economic activity may affect employment, policyholder affordability and new business volumes.	Lapse, Retrenchment, New Business

Table 2: Medium Temperature Increase (2.5°C), Medium Physical Risk and Medium Transition Risk Scenario for Assurance Business

This is an illustrative assessment over a 25-year time horizon.

Climate Event	Climate/Transition Event	Detailed Event Outcome	Insurance Risk
Physical Risk	Rising temperatures and heat waves	Increased heat-related illness and worsening of existing health conditions.	Mortality, Morbidity
		Reduced productivity and ability to work, affecting affordability and employment.	Lapse, Retrenchment
	Infectious and vector-borne diseases	Increased prevalence of diseases such as malaria and dengue fever, including potential longer-term complications.	Mortality, Morbidity, Lapse
	Wildfires and worsening air pollution	Increased exposures to smoke and air pollution, contributing to cardiovascular and respiratory conditions.	Mortality, Morbidity
	Wildfires	Damage to buildings and physical assets in which the insurer is invested.	Investment
	Droughts	Reduced food security and worsening nutrition, potentially resulting in adverse health outcomes.	Mortality, Morbidity
		Higher food and water prices and reduced agricultural output, contributing to affordability and economic pressures.	Inflation, Lapse, Investment
	Flooding	Increased risk of fatalities and damage to buildings and other physical assets.	Mortality, Investment
	Waterborne diseases	Increased prevalence of waterborne illnesses following flooding.	Mortality, Morbidity
	Changing climate-related health risks	Changes in underwriting requirements, new business mix and claims processing costs.	New Business, Expense
	Increased mortality and morbidity claims	Changes in reinsurance pricing, terms, and availability of cover.	Reinsurance
Transition Risk	Decline in carbon-intensive exports	Reduced demand for carbon-intensive products, contributing to weaker economic growth and employment.	Investment, Lapse, Retrenchment, New Business
	Carbon taxes and related policy interventions	Increased energy and production costs passed on to consumers, contributing to inflation and reduced affordability.	Inflation, Lapse
		Inflationary pressures may lead to higher interest rates, affecting bond values, with affected businesses may experience declining valuations.	Investment
	Increased unemployment in carbon-intensive sectors	Job losses reduce policyholder affordability and may limit access to healthcare.	Retrenchment, Lapse, Mortality, Morbidity

		Increased sovereign credit risk and changes in government bond yields and valuations.	Investment
	Pressure on South Africa's sovereign credit rating	Increased sovereign credit risk and changes in government bond yields and valuations.	Investment

Table 3: Low Temperature Increase (1.5°C), High Transition Risk Scenario for Assurance Business

This is an illustrative assessment over a 25-year time horizon.

Climate Event	Climate/Transition Event	Detailed Event Outcome	Insurance Risk
Physical Risk	Rising temperatures and heat waves	Physical climate risk remains present despite greater migration, with potential heat-related health impacts.	Mortality, Morbidity
	Other physical climate events	Continued exposure to events such as droughts, flooding and changing disease prevalence, although physical risk is relatively lower than under the higher-temperature scenarios.	Mortality, Morbidity, Investment
Transition Risk	Decline in carbon-intensive exports	Reduced international demand for carbon-intensive products, affecting South Africa's economic growth and investment performance.	Investment
		Reduced economic activity and employment, contributing to affordability concerns and changes in new business volumes.	Lapse, Retrenchment, New Business
	Carbon taxes and related policy interventions	Increased energy and production costs passed on to consumers, contributing to inflation and affordability pressures.	Inflation, Lapse
		Higher inflation and interest rates may affect bond valuations, while businesses exposed to carbon pricing may experience declining valuations.	Investment
		Reduced emissions and improved air quality may have been beneficial health effects, potentially improving mortality and morbidity experience.	Mortality, Morbidity
	Increased unemployment in carbon-intensive sectors	Job losses reduce affordability and may restrict access to healthcare.	Retrenchment, Lapse, Mortality, Morbidity
		Changes in employment and affordability affect new business volumes and fixed expenses per policyholder.	New Business, Expense
	Pressure on South Africa's sovereign credit rating	Fiscal pressures associated with the transition may increase sovereign credit risk and affect government bond valuations.	Investment

Table 4: Low Temperature Increase (1.5°C), High Transition Risk Scenario for Annuity Business

This is an illustrative assessment over a 25-year time horizon.

Although annuity business should be considered under all three temperature pathways, only the 1.5°C scenario has been included in the appendices for illustrative purposes. Life insurers need to develop the corresponding annuity scenarios for the remaining temperature pathways, taking into account the characteristics and risk exposures of their own portfolios.

Climate Event	Climate/Transition Event	Detailed Event Outcome	Insurance Risk
Physical Risk	Rising temperatures and heat waves	Continued heat-related health impacts may increase mortality among vulnerable populations, including older policyholders.	Longevity
	Other physical climate events	Droughts, flooding and changing disease prevalence may continue to affect policyholder health, although physical risk is relatively lower than under higher-temperature scenarios.	Longevity
Transition Risk	Carbon taxes and related policy interventions	Reduced greenhouse gas emissions and improved air quality may reduce adverse health outcomes and increase life expectancy.	Longevity
		Increased energy and production costs may contribute to inflation, affecting inflation-linked annuity liabilities and operating costs.	Inflation, Expense
		Inflationary pressures may lead to higher interest rates and changes in fixed-rate bond valuations.	Investment
	Decline in carbon-intensive exports	Weaker economic growth and declining valuations in affected sectors may negatively affect investment performance.	Investment
	Increased unemployment in carbon-intensive sectors	Reduced affordability and access to healthcare may adversely affect mortality experience, potentially offsetting some improvements in longevity.	Longevity
	Pressure on South Africa's sovereign credit rating	Increased sovereign credit risk and changes in government bond yields and valuations may affect assets backing annuity liabilities.	Investment

APPENDIX 2: ILLUSTRATIVE APPLICATION OF THE QUANTITATIVE REVERSE STRESS TESTING FRAMEWORK

The following example illustrates the application of the quantitative reverse stress testing framework outlined in Section 6.2.2 to a hypothetical South African life insurer.

The hypothetical life insurer is assumed to have a mixed assurance portfolio, a sizeable investment portfolio and a five-year ORSA projection period. The example demonstrates how the framework can be applied under different climate scenarios, and how the results may differ across these scenarios, with the classification and relative weighting of material insurance risks reflecting the characteristics of each scenario. It further illustrates the incorporation of tipping point uncertainty and the application of the directional reverse stress testing methodology.

Table 5: Illustrative Application of the Quantitative Reverse Stress Testing Framework across Climate Scenarios

Step	Description	1.5°C Scenario	2.5°C Scenario	4.5°C Scenario
1) Definition of the Risk Appetite Threshold	Define the financial threshold against which the reverse stress test is performed.	The insurer uses its solvency coverage ratio, calculated as Available Capital divided by Solvency Capital Requirement. A predefined risk appetite threshold is selected, with the analysis performed over the insurer's five-year ORSA period.	The same solvency coverage ratio, predefined risk appetite threshold and five-year ORSA projection period are applied.	The same solvency coverage ratio, predefined risk appetite threshold and five-year ORSA projection period are applied.
2) Identification of Insurance Risks	Identify the insurance risks arising from the qualitative scenarios developed in Section 6.2.1.	Mortality, morbidity, lapse, new business, retrenchment, expense, inflation, and investment risks are identified as potentially relevant.	Mortality, morbidity, lapse, new business, retrenchment, expense, inflation, and investment risks are identified as potentially relevant.	Mortality, morbidity, lapse, new business, retrenchment, expense, inflation, and investment risks are identified as potentially relevant.
3) Identification of Material Insurance Risks	Perform univariate stress tests to assess the insurer's sensitivity to individual assumptions. Use the results, together with the insurer's risk profile and qualitative scenario assessment, to	The hypothetical univariate assessment identifies mortality, lapse and investment risks as the most material risks. These are selected for the subsequent	The hypothetical univariate assessment identifies mortality, lapse and investment risks as the most material risks. These are selected for the subsequent	The hypothetical univariate assessment identifies mortality, lapse and investment risks as the most material risks. These are selected for the subsequent

	identify the most material assumptions for the multivariate reverse stress test.	multivariate assessment.	multivariate assessment.	multivariate assessment.
4) Identification of Primary and Secondary Risk Drivers	Classify the material risks as primary or secondary drivers, considering the nature of each climate scenario and the insurer's risk profile.	Primary: Lapse and investment risks. Secondary: Mortality risk.	Primary: Mortality and lapse risks. Secondary: Investment risk.	Primary: Mortality and investment risks. Secondary: Lapse risk.
5) Determination of Relative Weights	Assign a relative score of 2 to primary risk drivers and 1 to secondary risk drivers. Normalise these scores to determine the relative weights applied to the selected assumptions.	Mortality: 20% Lapse: 40% Investment: 40%	Mortality: 40% Lapse: 40% Investment: 20%	Mortality: 40% Lapse: 20% Investment: 40%
6) Incorporation of Tipping Point Uncertainty	Incorporate an additional prudence margin into assumptions relevant to the potential consequences of tipping points. The margin is considered separately from the loading parameter and incorporated before determining the stress which breaches the threshold.	No additional tipping point margin is incorporated.	A small additional tipping point margin is incorporated into relevant assumptions, with its magnitude informed by available climate research and expert judgement.	A larger additional tipping point margin is incorporated into relevant assumptions, with its magnitude informed by available climate research and expert judgement.
7) Directional Reverse Stress Testing	Stress the selected assumptions simultaneously in predetermined adverse directions, using their relative weights and a common loading parameter (λ). Progressively increase λ until the insurer reaches its	Mortality, lapse, and investment assumptions are stressed simultaneously using relative weights of 20%, 40% and 40%, respectively. The loading parameter is increased until	Mortality, lapse, and investment assumptions are stressed simultaneously using relative weights of 40%, 40% and 20%, respectively, after incorporating the relevant tipping point margin. The	Mortality, lapse, and investment assumptions are stressed simultaneously using relative weights of 40%, 20% and 40%, respectively, after incorporating the relevant tipping point margin. The

	predefined risk appetite threshold.	the threshold is reached.	loading parameter is increased until the threshold is reached.	loading parameter is increased until the threshold is reached.
8) Interpretation of the Reverse Stress Test	Assess the resulting combination of assumption stresses against available climate evidence and expert judgement to determine whether the stresses could plausibly arise under the relevant scenario.	Assess whether the resulting stresses could plausibly arise under a high transition risk scenario, considering the potential economic and financial market impacts of the transition.	Assess whether the resulting stresses could plausibly arise under a scenario involving a combination of physical and transition risks.	Assess whether the resulting stresses could plausibly arise under a high physical risk scenario, considering the potential impacts of more severe physical climate events.

The classification of primary and secondary risk drivers, and the resulting relative weights, differ between the three scenarios. Under the 1.5°C scenario, lapse and investment risks are considered primary drivers due to the potential economic and financial market impacts of the transition towards a low carbon economy. Under the 2.5°C scenario, mortality and lapse risks are considered primary drivers, reflecting the combined physical and transition impacts. Under the 4.5°C scenario, mortality and investment risks are considered primary drivers due to the greater physical impacts associated with higher temperatures.

These classifications and relative weights are illustrative and are not empirically calibrated. Life insurers would need to determine the appropriate classifications and weights based on their own risk profiles and the characteristics of the relevant climate scenarios.

Illustrative Calculation of Assumption Stresses

To illustrate how the relative weights are applied in the directional reverse stress test, consider the 1.5°C scenario, where mortality, lapse, and investment risks have relative weights of 20%, 40%, and 40% respectively.

The stressed value of each assumption is determined using the formula outlined in Section 6.2.2:

$$[\mu_i^*(\lambda) = \mu_i(1 + d_i\lambda w_i)]$$

For illustrative purposes, assume that the common loading parameter is set to $\lambda = 0.5$, and that an increase in the mortality and lapse assumptions, and a decrease in the investment return assumption, represent adverse stresses. The resulting assumption stresses are calculated as follows:

Table 6: Illustrative Calculation of Assumption Stresses under the 1.5°C Scenario

Insurance Risk	Relative Weight (w_i)	Adverse Direction (d_i)	Relative Assumption Stress ($d_i\lambda w_i$)
Mortality	20%	+1	+10%
Lapse	40%	+1	+20%
Investment Return	40%	-1	-20%

For example, the stressed mortality would be:

$$\left[\mu^{*}_{\text{mortality}} = \mu_{\text{mortality}}(1 + 0.5 \times 0.2) = 1.10\mu_{\text{mortality}}\right]$$

Similarly, the lapse assumption would increase by 20%, while the investment return assumption would decrease by 20%, relative to their respective base assumptions.

These stresses are applied simultaneously within the life insurer's cash flow model. The loading parameter is progressively increased until the insurer reaches its predefined risk appetite threshold.

The value of $\lambda = 0.5$ is used purely to illustrate the calculation and does not represent a stress which breaches the threshold or a climate-calibrated estimate.

Interpretation of the Illustrative Results

The reverse stress testing process determines the combination of assumption stresses required for the insurer to reach its predefined risk appetite threshold under each climate scenario. Where applicable, tipping point margins are incorporated into the relevant assumptions before determining the loading parameter required to reach that threshold.

The resulting assumption stresses can be assessed against climate research, expert judgement, reinsurer expertise, and other relevant sources to determine whether stresses of this magnitude could plausibly arise under the relevant climate scenario.

The example is illustrative and does not represent the actual solvency modelling results. The selection of material risks, their relative classification, the magnitude of the resulting assumption stresses and their climate plausibility need to be determined by each insurer based on its own risk profile and available information.

APPENDIX 3: ILLUSTRATIVE RECALIBRATION OF QUALITATIVE CLIMATE SCENARIOS

The following example illustrates how the qualitative climate scenarios developed under the proposed framework may be recalibrated over time to reflect changes in observed climate conditions, policy interventions and the latest available climate research.

For illustrative purposes, consider a recalibration of the framework in five years' time, under two hypothetical states of the world reflecting different degrees of policy intervention over the preceding five-year period. The example demonstrates how developments up to the point of recalibration may influence the climate scenarios considered plausible moving forward.

Table 7: Illustrative Recalibration of Qualitative Climate Scenarios under Different States of the World

	Illustrative State 1: Limited Policy Intervention	Illustrative State 2: Stringent Policy Intervention
Development preceding recalibration	No meaningful climate policy interventions have been introduced over the preceding five-year period.	Stringent climate policy interventions have been introduced over the preceding five-year period.
Implications for future physical and transition risk	Continued delays in policy intervention increase the potential for more severe physical climate impacts. Should stringent interventions subsequently be introduced, significant transition risk may also arise alongside the increasing physical risk.	Earlier and more stringent policy interventions increase transition risk, while potentially limiting the severity of longer-term physical climate impacts.
Recalibration of qualitative scenarios	Higher-temperature pathways may become more plausible, while lower-temperature pathways become less plausible. A scenario involving both high physical and high transition risk may also become relevant as the opportunity for a gradual transition diminishes.	Lower-temperature pathways may remain plausible, while higher-temperature pathways may become less plausible. The balance of risks shifts towards greater transition risk and potentially lower longer-term physical risk.
Illustrative temperature pathways considered following recalibration	2.5°C and 5.0°C, with consideration of an additional scenario involving high physical and high transition risk.	1.5°C and 2.5°C, reflecting the continued relevance of lower-temperature pathways.

The example illustrates the state-dependent nature of the proposed framework. The climate scenarios considered plausible at a future point in time depend not only on the policy interventions that may be introduced going forward, but also on interventions and climate developments that have already occurred.

Delayed policy intervention may reduce the opportunity for a gradual transition, potentially resulting in a situation where significant physical and transition risks arise simultaneously. Conversely, earlier policy interventions may preserve the plausibility of lower-temperature pathways and reduce the potential severity of longer-term physical risks.

The temperature pathways presented are illustrative and do not represent forecasts of future warming. The scenarios selected at each recalibration would need to reflect the latest available climate research, observed developments and the potential implications for future physical and transition risks.