Be smart about Climate Risk

Taking the guess work out of climate risk and adapting cost effectively

dss+

Protect. Transform. Sustain.

Introduction

Climate risk is no longer a distant concern – it's a material business risk. For executive teams, the challenge is not recognising the issue but determining how to cut through the noise and identify where it truly affects operations, assets, and long-term growth. Too often, climate risk assessments feel abstract, lack clear next steps, and leave leadership guessing.

Extreme weather events are already disrupting operations, insurance markets are tightening, and regulatory pressure is moving faster than many businesses anticipated. At the same time, climate models are becoming far more precise, revealing exposures that were invisible even a few years ago. Companies that rely on broad, qualitative assessments increasingly find themselves surprised by asset degradation, unplanned downtime and escalating recovery costs. Boards and investors are now asking harder questions: not just whether climate risk is understood, but whether it has been quantified in a way that guides capital allocation and operational planning.

This article offers a practical, stepwise approach to do exactly that. It provides a defensible calculation of financial exposure across assets and operations, translating physical hazards into a clear Value at Risk (VAR) framework. It shows where climate-driven failures are most likely, how severe they could be and which interventions reduce exposure at the lowest cost. Instead of treating climate adaptation as an open-ended problem, this approach narrows decisions to the actions that matter most and gives leadership a clear basis for prioritisation, investment and accountability.

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Climate change should not be relegated to a low-value sustainability topic; it is a strategic risk that can be managed with the same rigour and economic discipline as any other.

The framework removes subjectivity and guesswork, giving you clarity and confidence to act, and consists of three distinct phases: calculating VAR, prioritising adaptation measures, and operationalising chosen risk reduction actions. The phases and underlying steps are designed so that a decision can be made at each stage on whether it makes sense to progress to the next. Figure 1 summarises the overall workflow.

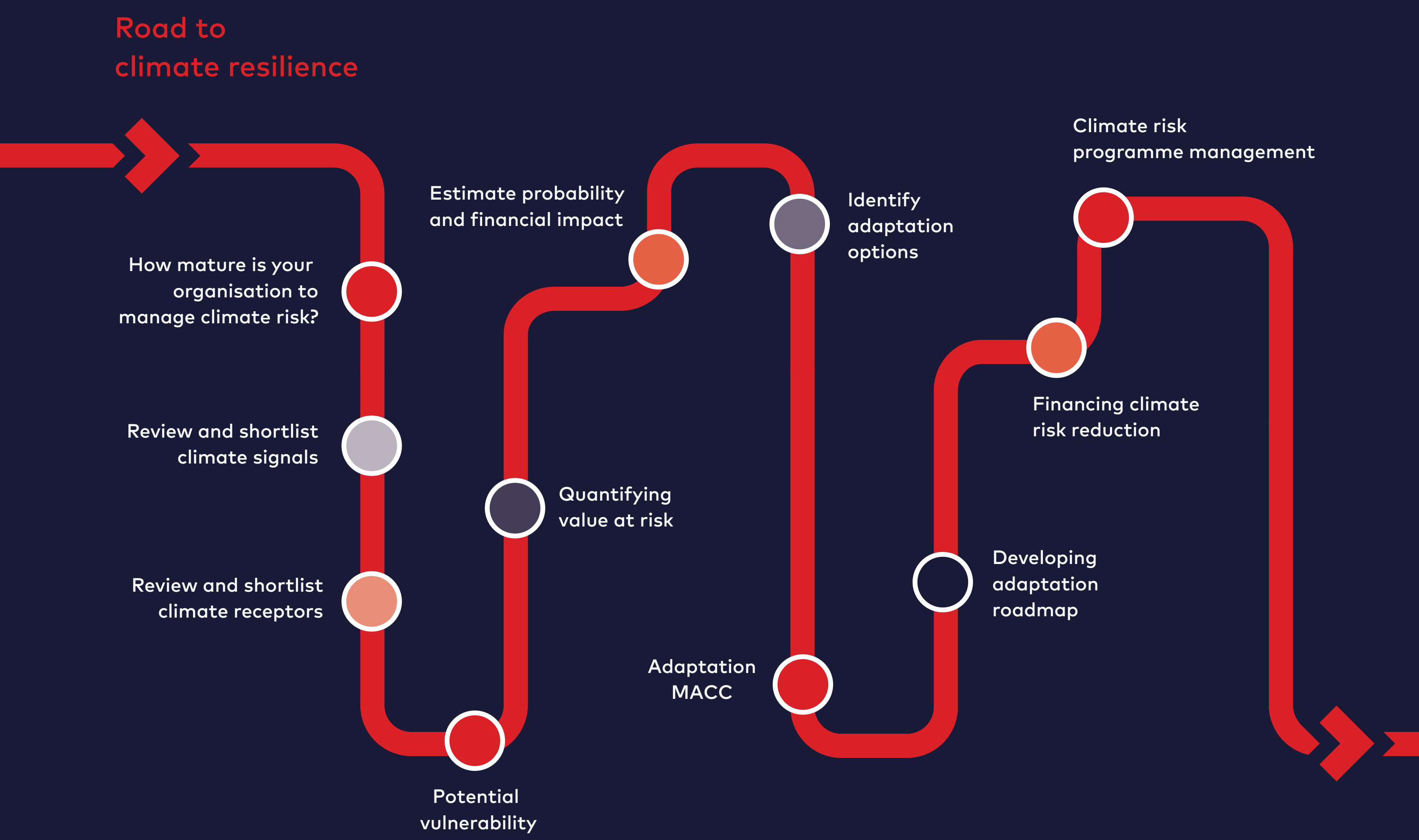
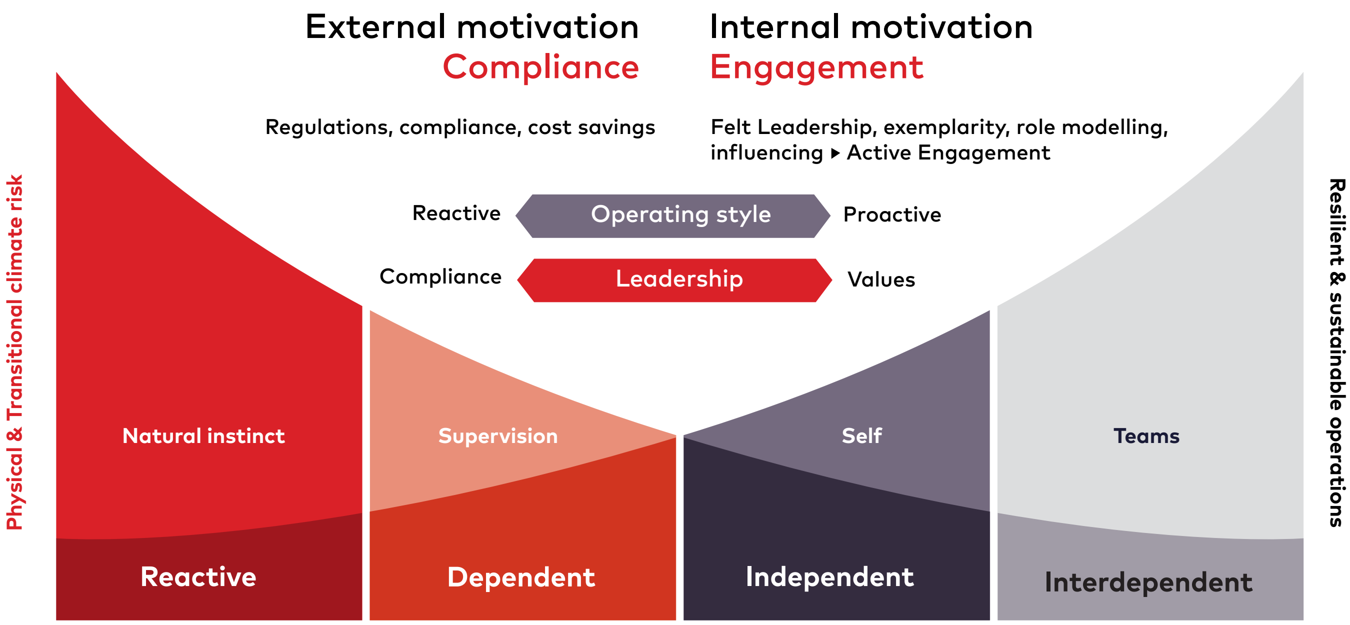


Figure 1: Climate risk workflow

This workflow lays out a clear progression: begin with foundational requirements, build a defensible view of risk, then prioritise and operationalise the most cost-effective actions.

Organisational maturity required to managed climate risk



Physical

Reactive

- Unmitigated exposure to climate events across value chain
- Compliance with legislation
- Decisions based on history

Dependent

- Situational and risk awareness by management
- Climate hotspots identified and integrated into ERM

Independent

- Climate response strategy derived from TCFD aligned assessment
- Detailed asset vulnerability assessment based on flood and climate models

Interdependent

- Risk mitigation is operationalised across business functions
- Continues investment in R&D and climate resilient products & services

Before taking action, it is critical to understand your organisation's current maturity in managing physical climate risks and opportunities.

dss⁺ uses the **Bradley Curve** to evaluate this maturity, which typically ranges from Reactive – where responses are driven by compliance and past events – to Interdependent, where climate resilience is embedded across all functions and supported by a proactive culture of collaboration and innovation.

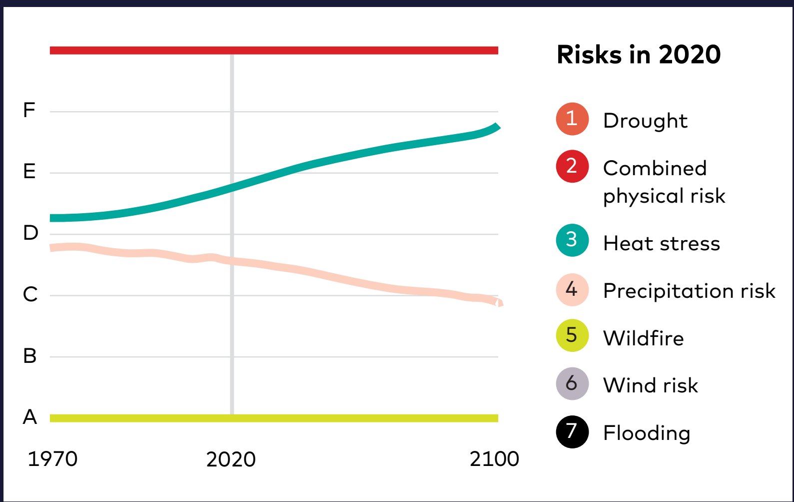
This assessment highlights the gap between your current state and what is required to reduce climate risk to as low as reasonably possible. Moving up the curve involves shifting from isolated, compliance-driven actions to integrated strategies that anticipate future climate impacts, operationalise risk mitigation, and foster continuous improvement. Understanding where you stand today is the foundation for building a roadmap toward resilient and sustainable operations.

STEP 1

Review and short list climate hazards

The first step is to identify climate hazards – such as temperature extremes, wildfire risk, wind intensity and tropical storms – that could impact your operations or supply chain. The EU Taxonomy provides a useful reference list for consideration.

> Hazards should be shortlisted using historic incidence, insurance data, academic research, and industry-specific trends, focusing only on those expected to change significantly over time.



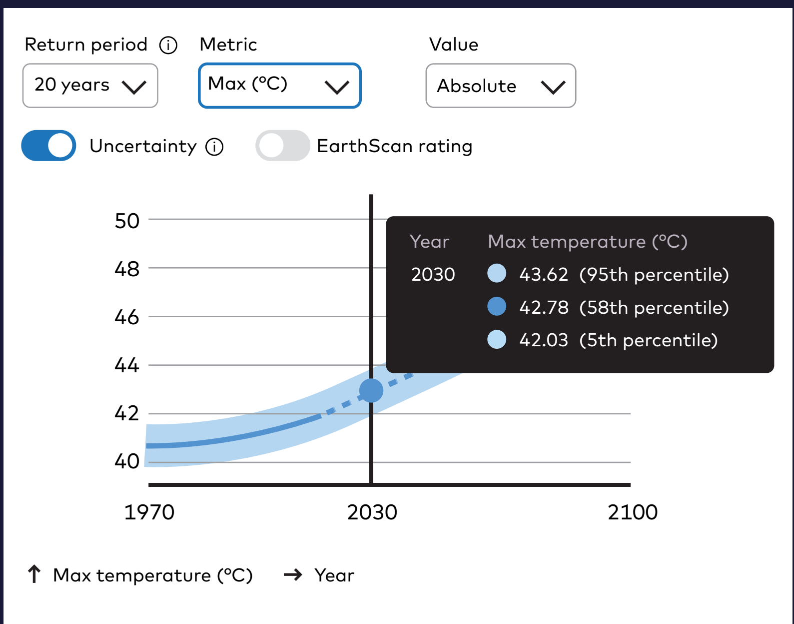


Figure 2: Climate scenario data

At dss⁺, we leverage **Earthscan by Mitiga Solutions** to model anticipated changes under low, medium, and high emissions scenarios across multiple timeframes through the end of the century. Figure 2 provides an example of increased risk indices for several climate signals and a detailed maximum temperature assessment over time.

To keep analysis practical, limit hazards to no more than 10, reducing complexity in signal-receptor mapping. If no material changes are projected for your sites or logistics network, no further analysis is required, saving time and cost.

Historical dry areas are of particular interest because they are prone to more erratic precipitation or flooding events. A good example here are legacy tailings dams in arid parts of Chile that will be subject to increases in probable maximum precipitation (PMP) that exceeds dam design limits with failure a significant threat to communities and the environment.

STEP 2

Review and short list receptors

Once climate hazards are identified, the next step is to determine which systems or components – known as receptors – could be impacted. This process is conducted at the site or operations level and should cover all locations in the value chain where significant changes in climate signals are anticipated.

Our approach includes:

- **Industry Scan:** Review annual reports of peers to identify reported climate physical risks and adaptive strategies.
- **Articles & Publications Research:** Examine literature to understand common receptor systems for mining facilities and known vulnerabilities to climate hazards.
- **Review Site Documents:** Analyse existing assessments (e.g., HAZID, COMAH, HAZOP) to identify nodes, hazard sources, and facility components.
- **Selective System Deep-dives:** Conduct site visits and targeted reviews of critical components to map key system elements and product flow paths.

This structured approach ensures a comprehensive yet focused receptor list for subsequent risk analysis.

STEP 3

Potential vulnerability

Receptor & Hazard Combinations

With climate hazards and receptors identified, the next step is to combine them into a Vulnerability Matrix. This matrix assesses how each climate hazard **could** impact critical systems, operations, value chain components or any known receptors.

Our approach begins with an AI-assisted literature review to identify known or anticipated vulnerabilities – such as increased temperature driving higher cooling and ventilation energy demand or extreme rainfall requiring upgraded stormwater infrastructure. This desktop analysis is then validated through site visits with subject matter experts to stress-test the resilience of equipment, systems, and processes against projected climate changes.

Engagement with maintenance engineers, facility managers, plant managers, OEMs, and procurement teams ensures practical insights into operational constraints and failure modes. Preliminary hotspots are flagged based on potential infrastructure damage, increased corrosion-related maintenance, production losses and risks to personnel safety.

These findings form the foundation for quantifying value at risk and prioritising adaptation measures in subsequent steps.

Key system	Climate hazards			
	Heatwave	Flood	Extreme wind	Extreme precipitation
Tailings dam	Increased evaporation → water balance issues; heat stress on liners	Structural failure risk due to water ingress; erosion of embankments	Wind-driven waves may destabilise exposed surfaces	Overtopping risk; slope failure; erosion of spillways
Open pit operations	Heat stress on workers; reduced equipment efficiency	Pit flooding; haul road washouts	Dust storms and flying debris affecting visibility and safety	Accelerated slope failure; increased geotechnical instability
Underground shafts & levels	Ventilation strain; cooling costs increase	Shaft inundation; pump overload	Wind damage to shaft headframes and hoisting systems	Water ingress causing equipment damage and production delays
Haul roads & transport routes	Asphalt softening; tire blowouts	Road washouts; bridge failures	Wind damage to overhead power lines and transport structures	Erosion and collapse of access roads
Processing plant	Overheating of crushers and conveyors; reduced cooling efficiency	Flooding of plant floor; electrical short circuits	Roof and structural damage; disruption of material flow	Water ingress into crushers and conveyors; corrosion acceleration
Water supply & pumping systems	Increased evaporation → water scarcity	Pump station flooding; contamination of water sources	Wind damage to exposed pipelines and pumping	Overload of pumping systems; sedimentation in water channels
Power supply & electrical systems	Overheating transformers; reduced efficiency	Substation flooding; short circuits	Wind damage to transmission lines and substations	Water ingress causing electrical faults
Stockpiles & waste dumps	Spontaneous combustion risk in coal stockpiles	Saturation and collapse of waste dumps	Wind erosion and dust dispersion	Liquefaction and slope failure of waste dumps
Personnel safety & emergency response	Heat stress; reduced productivity	Restricted evacuation routes; increased slip hazards	Falling debris; structural instability	Poor visibility; increased accident risk

Table 1: Vulnerability matrix

STEP 4

Quantify value at risk

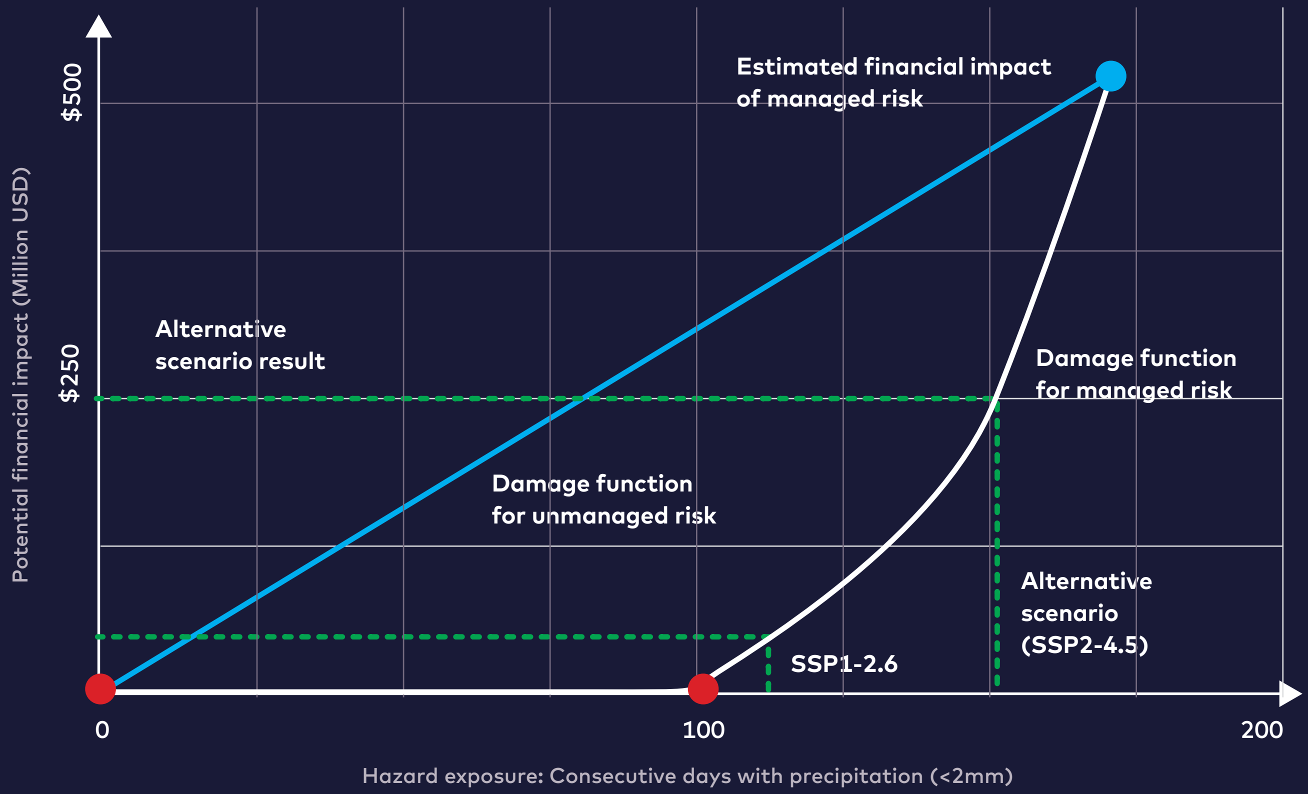


Figure 3: Damage function

Once vulnerabilities are identified, the next step is to translate them into financial terms. This is achieved by developing damage functions – mathematical models that estimate potential losses for each receptor-hazard combination under specific climate scenarios.

For example, if extreme precipitation of 500 mm in a day is projected under SSP5-8.5 by 2030, and a tailings dam is designed for only 400 mm, failure could result in millions in damages and possible mine closure. Conversely, if the dam meets the design threshold, the value at risk (VAR) is zero. Another example is provided in Figure 3 to indicate the damage associated with consecutive dry days that may result in disruptions to processing plants in the absence of water resources.

Damage functions also capture less severe impacts, such as increased energy costs for ventilation systems due to rising temperatures. These functions are informed by asset values from insurance schedules, revenue impacts and productivity losses, while accounting for existing controls and response plans that mitigate risk.

The outcome is a clear visualisation of VAR across the value chain, enabling identification of financial hotspots and guiding cost-effective adaptation strategies.

Most damage functions will be based on original design criteria and the state of equipment when commissioned but ignores poor asset integrity or inadequate maintenance that amplifies climate-related VAR. Degraded equipment and infrastructure have less resilience to hazards like floods, heatwaves, and extreme precipitation, increasing failure likelihood and associated costs. Climate risk assessments should factor asset condition and maintenance into damage functions for accurate VAR calculations and effective adaptation planning.

STEP 5

Estimate probability and financial impact

Incorporating climate-driven changes to SIF risks into the risk matrix ensures decisions reflect both financial and human exposure, creating a more complete picture of organisational vulnerability.

To identify the most significant risks, we apply a simple 5×5 risk matrix combining probability and impact. Probability ranges from "possible to occur" to "multiple events at the site," while impact spans from negligible to catastrophic. Each vulnerability is scored, and multiplying the risk rating by its Value at Risk (VAR) provides a clear view of financial exposure across the value chain. This approach highlights where climate-related risks could materially affect operations and revenue, setting the stage for prioritising adaptation measures in the next step.

Value at Risk (VAR) typically rises under higher emissions scenarios (e.g., SSP5-8.5) and further into the future, such as 2050 and beyond. Mines must decide which scenario to plan for and calculate VAR across short-, medium-, and long-term horizons. A conservative approach sets adaptation ambitions to minimise current risk while considering potential 2050 exposure. Given the numerous scenario and timeline combinations, a flexible system is essential – one that updates calculations as global climate models evolve or risk appetite changes over time.

Climate change also alters the company's operational risk and Serious Injury and Fatality (SIF) profile. Some climate-related hazards increase the likelihood or severity of existing SIF risks – for example, extreme heat elevates risks during confined space entry, hot work, and heavy manual handling; high winds increase the danger of working at height or crane operations; heavy rainfall and flooding complicate vehicle movements, electrical work, and emergency access.

In other cases, new SIF exposures emerge altogether, such as increased geotechnical instability from intense rainfall or higher wildfire risk affecting evacuation routes and shelter-in-place procedures. These impacts are harder to quantify than equipment damage or production loss, but they are no less material.

Incorporating climate-driven changes to SIF risks into the risk matrix ensures decisions reflect both financial and human exposure, creating a more complete picture of organisational vulnerability.

High Risk		Probability				
Medium Risk		Possibility to occur	Has occured in other places	Has occured in the region	Has occured on the site	Multiple events at the site
Low Risk		A	B	C	D	E
Catastrophic	5	1				
Severe	4					3
Critical	3		5		4 6	
Marginal	2		2			
Negligible	1					

Table 2: Risk Matrix

Climate physical risk identified:

1. **Slope stability**
(Past fatalities, no clear link or sensitivity relating to climate hazards)

2. **Pit Dewatering**
(Known area of risk, redundant pumps, long timeline before operations at risk)

3. **Water stress on production**
(Known risk, several adaptation / response actions in place, still remains as risk)

4. **Site flooding**
(Has occurred, poor housekeeping, recent events impacting operations, not insured)

5. **Tailings dam wall failure**
(Known risk, managed according to GISTM standard)

6. **Supply chain interruptions**
(Occurred in 2024, no clear adaptation actions or redundancy from ports authority.

STEP 6

Identify adaptation options

The purpose of this step is to develop a comprehensive portfolio of adaptation measures – structural, nature-based, policy, and behavioural – targeting the highest value-at-risk first. This process should be co-designed with clients and stakeholders to ensure practicality and buy-in.

Start with quick wins such as early warning systems, emergency response plans, and insurance coverage, then progress to capital-intensive solutions like infrastructure upgrades, flood defenses, and retrofitting thermal-resistant equipment. All options should align with national adaptation plans and sectoral strategies.

Importantly, this step is about creating a full "wish list" of potential actions, regardless of cost or complexity, to ensure no viable measure is overlooked. This comprehensive view enables informed prioritisation in the next phase, balancing risk reduction with cost-effectiveness.

STEP 7

Marginal adaptation cost curve

Similar to Marginal Abatement Cost Curves (MACCs) for carbon reduction, a Marginal Adaptation Cost Curve (Adaptation MACC) ranks adaptation measures based on their cost-effectiveness in reducing Value at Risk (VAR). Each option is plotted according to its implementation cost and the degree to which it lowers financial exposure, providing a clear visual for prioritisation.

The Adaptation MACC considers the entire value chain, not just individual sites, and accounts for multiple options addressing the same vulnerability. Each measure modifies the damage function for that vulnerability, and this reduction in VAR - combined with cost – is what the curve captures. The result is a practical tool for decision-makers to identify the most cost-effective interventions that deliver the greatest risk reduction.

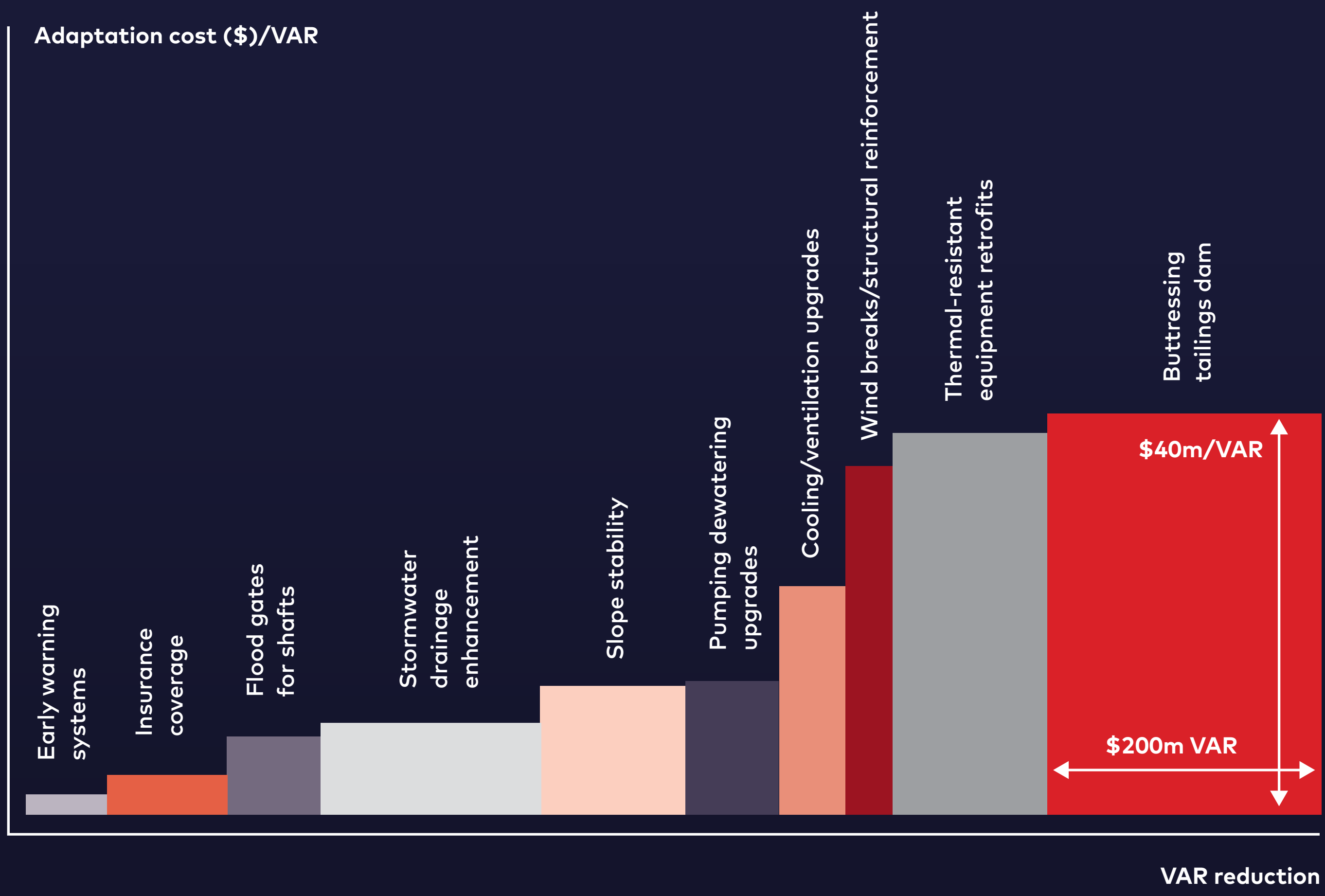


Figure 4: Adaptation cost curve

STEP 8

Develop adaptation roadmap and integrate into business

To minimise Value at Risk (VAR) within operational and capital constraints, the next step is to translate the analysis into a practical, prioritised adaptation roadmap. This roadmap weighs technical feasibility, cost, social impacts, and institutional capacity, using multi-criteria decision analysis (MCDA) to balance trade-offs and set clear implementation milestones.

However, technical choices alone do not ensure resilience. Most adaptation efforts fail not because the risks or solutions are unclear, but because organisations lack the governance, capabilities, or processes to execute them. Using insights gathered through steps 1 to 7, we assess organisational readiness to implement the roadmap across four pillars: mindset and behaviours, governance and management processes, capabilities and competencies, and enabling technologies.

This allows us to define the organisational conditions required for success and design targeted interventions—from clarifying decision rights and accountabilities, to embedding climate considerations into budget cycles, maintenance strategies, asset integrity reviews, site performance dialogues, and internal H&S audits.

The result is an adaptation roadmap that is both technically robust and organisationally executable: a plan that aligns with capital allocation processes, withstands scrutiny from investment committees, and can be integrated into day-to-day operations and long-term planning.

STEP 9

Financing climate risk reduction

Financing determines the pace and scale at which climate risks can be reduced. The quantified Value at Risk (VAR), the Adaptation MACC, and the roadmap developed in previous steps provide the analytical foundation for investment decisions, enabling companies to prioritise the highest-impact, lowest-cost interventions.

From here, **two financing pathways** are available.

The first is self-funding, where climate adaptation measures are integrated into capital allocation frameworks and compete for investment on the basis of risk reduction and economic return. The Adaptation MACC strengthens the business case by showing precisely how each intervention lowers financial exposure, providing the level of evidence typically required by investment committees and CFOs to approve projects within existing operational and capital constraints.

The second pathway is climate finance, which leverages external funding sources such as concessional loans, grants, blended finance mechanisms, and resilience bonds. These sources – including Green and Climate Resilience Bonds, multilateral funds such as the Green Climate Fund, disaster risk finance, and payment-for-ecosystem-services schemes – can significantly reduce upfront capital requirements. Accessing them generally requires alignment with national adaptation plans, demonstration of measurable resilience outcomes, and collaboration with public agencies or private financiers through pooled or partnership models. When used effectively, climate finance not only lowers the cost of adaptation but also de-risks investments and enables more ambitious or capital-intensive resilience measures.

Together, these pathways allow organisations to match financing options to risk priorities, ensuring that high-value adaptation measures are both economically justified and financially feasible.

STEP 10

Climate risk programme management

Climate risk management is not a one-time exercise but a continuous improvement program designed to maintain momentum in reducing Value at Risk (VAR) – similar to pathways toward net-zero. Success requires embedding resilience into the organization through mindset and behaviors, governance structures, management processes, capabilities, and enabling technologies.

In our experience, organisations do not fail to adapt to climate change because they fail to recognise the risks and the technical solutions but rather because once understood and identified, gaps in the organisational readiness remain to effectively execute the adaptation plan.

Those gaps include:

- Lack of clear roles and responsibilities and allocation of accountability;
- Reporting lines, monitoring routines and processes lacking or inadapted;
- Decision process to include adaptation mechanisms in financial planning unclear;
- Scope of emergency plans unadapted;
- Required capabilities not clearly identified and developed.

Companies that succeed, establish a cross-functional project management office to monitor progress and lift roadblocks that are bound to appear along the way, while ensuring their organisational key success factors are implemented in parallel to technical solutions, with a continuous improvement mindset to gradually increase their maturity and the level of integration into standard processes.
We can support organisations through the training and coaching of key personnel to ensure they understand and fulfil their new responsibilities.

Automation is critical to ensure efficient reassessment aligned with annual budget cycles and updates to global climate models (typically every five years). Systems and processes should be designed for scalability and integration, enabling rapid recalculation of VAR and adaptation priorities. By institutionalising climate risk governance and building competencies across teams, organisations can mainstream adaptation into core business planning and sustain long-term resilience.

Technical measures

Mindsets & behaviours

Despite the adoption of a clear adaptation roadmap, **limited visible support from leadership** can result in adaptation initiatives being seen as a **secondary priority** for the organisation.

Roadmaps are deployed at site level, with no coordination from corporate. **Limited exchanges between sites** results in slow learning and **missed opportunities for best- practices sharing.**

Governance & management process

While leadership may review VAR once a year, **no real governance or steering process** is installed at group level, **slowing down** the implementation.

While site management may have been involved in the definition of the adaptation roadmap, value at risk drivers are rarely addressed in managerial site routines.

Integration **into budget cycles** are hazy at best, with systemic limitations making it difficult to get a centralised overview.

Capabilities & competencies

Responsibilities for the whole adaptation roadmap implementation process are rarely defined. At best, someone has been put in charge of the roadmap at site-level but may not have influence or power over key implementation levers.

Cascading of objectives related to key responsibilities and accountabilities from group to site to teams to individuals is rarely clear.

Systems, processes & technologies

Unclear monitoring frameworks and **data architecture** limits **automation** and data analysis making it difficult to track progress and measure impact of initiatives.

The initial adaptation roadmap, usually built in complex Excel files, is **difficult** to **keep up-to-date**. As a result, only one or two people know the status of each action, creating a **bottleneck when reporting** is necessary.

Outcomes

- Partial implementation of technical initiatives
- Difficulty to measure impact of what has been implemented

Figure 5: Critical organisational factors for successful adaptation

Conclusion

Climate risk is no longer an abstract sustainability issue – it is a material business risk that demands structured, data-driven action. The ten-step framework outlined here transforms uncertainty into clarity by quantifying Value at Risk (VAR), prioritising adaptation measures, and embedding resilience into core business processes. From identifying climate signals and receptors to developing damage functions, estimating financial exposure and ranking interventions through a Marginal Adaptation Cost Curve, this approach ensures decisions are grounded in both science and economics.

Critically, the roadmap integrates adaptation into corporate strategy, governance, and financing mechanisms, enabling organisations to act within operational and capital constraints while leveraging external climate finance opportunities. By institutionalising continuous improvement and automation, companies can maintain momentum, reassess risks efficiently and align with evolving climate models and regulatory requirements.

This is not just about compliance – it is about safeguarding assets, operations and growth in a changing climate. Organisations that adopt this structured approach will not only reduce risk but also unlock competitive advantage through resilience, cost efficiency and stakeholder confidence.

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