climatexchange

Scotland's centre of expertise connecting climate change research and policy

Using future climate scenarios to support today's decision making

Eva Grace, Charlotte Marcinko, Chris Paterson and Will Stobbs
Government Actuary's Department
December 2024

DOI: http://dx.doi.org/10.7488/era/5567

Executive summary

Project aims

Scottish public bodies need to make long-term investment and planning decisions. It is their responsibility to consider the risks affecting the outcomes of these decisions. These include risks from climate change, which are highly uncertain, difficult to communicate and require specific expertise.

For instance, public bodies need to be able to plan: where to build a new development considering the risk of coastal flooding; how much to invest in protecting a train line from heat damage or coastal change; or the expected increase in winter disruption to services in the coming decades.

Climate scenario analysis (or simply, scenario analysis) is a tool and process developed to help answer questions like these. It assesses the impact of different plausible future climate change scenarios on an organisation, project or strategy. Understanding the impact of climate change under each scenario can inform decisions.

This study reviewed policies, guidance and stakeholder insights, and examined practices and publicly available data. Based on our findings, we make recommendations for the development of a practical scenario analysis tool to help public bodies in climate adaptation planning. Many of the principles can also be applied to resilience and mitigation planning.

Findings

Stakeholders have told us that the main use of these recommendations will be to help with climate adaptation decisions.

We found a gap, as much of the guidance we reviewed focused on climate scenario analysis for financial reporting requirements[1] and often focused on climate transition risks, making it less relevant for adaptation planning.

Scottish Government and other stakeholders relayed that long-term public-sector investment and planning decisions should be based on climate risk information and approaches that are:

- consistent across the public sector; e.g. they use the same scenarios, look at similar time horizons and use the same data to assess the same hazards.
- based on information that is up-to-date, accurate, useable and freely available
- consistent with climate risk information they are required to use for other purposes.

A data review indicated a relatively complex data landscape. Data availability varied significantly depending on the climate hazard. There is a lack of standardisation across data providers when it comes to scenarios, temporal and spatial resolution, and data format. These factors are a significant source of frustration for stakeholders.

Where our recommendations are different from existing regulations and guidance it is because they are intended to help public sector organisations make better long-term decisions to plan for adaptation.

Recommendations

We recommend that the scenario analysis decision tool covers each of the recommendations in Table 1.

Factor	Summary of recommendation on decision tool content
Hazards covered	Scenario analysis should cover both chronic and acute physical climate hazards. Transition risks should be considered separately by organisations, where they may have a significant impact.
Scenario prescription and definition	To drive consistency, organisations should consider both 2°C and 4°C warming scenarios.
Number of scenarios	At least two scenarios should be considered, specifically 2°C and 4°C warming scenarios.
Climate data provider	The tool should point to up-to-date primary sources of data for different hazards as informed by the ongoing climate data review by the Scottish Government.

[1] Usually these are to disclose information in line with ISSB (IFRS, 2023), or TCFD (2017) requirements.

Factor	Summary of recommendation on decision tool content
Scope of scenario analysis	The scope of scenario analysis should be proportional to the use case. Use-case specific guidance should be followed.
Timeframe of scenarios	Short term: In line with business planning cycles. Medium term: 2045-50s. Long term: 2080s-end of century.
Frequency of updates	Scenario analysis should be updated every 3 to 5 years.
Qualitative versus quantitative analysis	Scenario analysis should be quantitative, but qualitative analysis can also be used to provide a richer narrative.
Inclusion of the impact of the organisation on the climate	Analysis only needs to cover the impact of the climate on the organisation.

Table 1: Summary of recommendations

These recommendations aim to support the development of a practical scenario analysis decision tool. This should then enable Scottish public bodies to spend more time on trying to understand how their organisation could respond to those scenarios and less time on identifying plausible scenarios to assess.

Contents

Glossary and abbreviations table

Terms defined in the glossary and abbreviations table are highlighted in bold throughout this report.

Term	Definition
Acute hazard	Acute hazards are event driven (rapid-onset), extremely severe, and short term. These events can include extreme weather such as cyclones, hurricanes or floods (TCFD 2017).
Adaptation planning	Planning that set outs actions to build resilience to climate change (Scottish Government, 2024).
CCC	Climate Change Committee
CCRA	Climate Change Risk Assessment. Under the 2008 Climate Change Act the UK Government is required to publish a CCRA every five years (CCC, n.d.).
Chronic hazard	Longer-term shifts in climate patterns (e.g., sustained higher temperatures) that may cause sea level rise or chronic heat waves (TCFD, 2017)
Climate anxiety	The sense of fear or worry associated with climate change.
Climate scenario analysis	Broadly a tool for assessing what could happen to different aspects of an organisation or project (costs, income, policy, asset values, liability, workforce etc) under different climate scenarios. See section 3.3.
CSRD	Corporate Sustainability Reporting Directive
Defra	Department for Environment, Food and Rural Affairs
Double materiality	Impact materiality and financial materiality. Including both means organisations consider the impact of climate change on the organisation as well as the impact of the organisation on the climate (Commission Delegated Regulation (EU) 2023/2772, 2023).
Earth system tipping points	Earth system tipping points are thresholds beyond which changes in a part of the climate system become self-perpetuating often leading to abrupt and irreversible changes that could have a profound impact on our planet (Armstrong et al., 2022).
Ecosystems	A functional unit consisting of living organisms, their non-living environment and the interactions within and between them.
El Niño	A phenomenon associated with increasing sea surface temperatures that occurs every few years, typically concentrated in the central-east equatorial Pacific.
Emission pathways	See RCP.
EU	European Union
FRC	Financial Reporting Council
GAD	Government Actuary's Department

Global warming levels	Also referred to as temperature-based scenarios. Scenarios based on global mean temperatures regardless of the time at which that level has been reached (Met Office, 2023).
Green Book	Guidance issued by His Majesty's Treasury on how to appraise policies, programmes and projects.
HadGEM3	Hadley Centre Global Environment Model version 3
HMT	His Majesty's Treasury
IFoA	Institute and Faculty of Actuaries
IFRS	International Financial Reporting Standards
IPCC	Intergovernmental Panel on Climate Change
ISSB	International Sustainability Standards Board
Macro-economic	The study of financial systems at a national level.
Micro-economic	The study of the economic problems of businesses and people and the way particular parts of an economy behave.
Physical risk	Also referred to as physical hazards, physical climate hazards or similar. Risks related to the physical impacts of climate change including acute and chronic hazards (TCFD, 2017).
Qualitative analysis	Analysis focused on the identification of trends and on the overarching narratives of the scenarios, often providing insight into less quantifiable company characteristics. It can involve descriptions of plausible future worlds, describing their main characteristics, relationships between key driving forces, and the dynamics of their evolution (TCFD, 2020).
Quantitative analysis	Analysis and presentation of quantified information within a scenario. Quantitative scenario analysis can take many forms, targeting various aspects of an organisation's vulnerability to climate related risks (MIT, 2019).
Radiative forcing	The net amount of the sun's energy absorbed by the Earth.
RCP	Representative Concentration Pathway. RCPs correspond to different levels of total atmospheric radiative forcing by 2100.
Resolution	The number of data points (level of detail or granularity) within a unit of measurement.
Scenario analysis	See climate scenario analysis.
SEPA	Scottish Environmental Protection Agency
SNAP	Scottish National Adaptation Plan
SSP	Shared Socioeconomic Pathways. The SSPs combine socio-economic narratives and approximate global effective radiative forcing levels.
TCFD	Task Force on Climate-related Financial Disclosures
Tipping points	See earth system tipping points.
Transition risk	Risks that arise from efforts to transition to a lower-carbon economy. Transition risks include policy, legal, technological, market and reputational risks (TCFD, 2017).
UKCP	United Kingdom Climate Projections

1 Introduction

1.1 Background

1.1.1 Climate change in Scotland

Scotland's climate is changing due to the rise of global greenhouse gas emissions with further change expected over the coming decades (Scotland's Environment, 2024). Average global temperatures are already 1.2°C above their preindustrial levels. Further warming up to 2°C or more is becoming increasingly likely, resulting in hotter, drier summers, wetter winters, more extreme weather events, and rising sea levels. Despite international efforts to mitigate further global warming, some of these changes are already 'locked in' until 2040 and are unavoidable (Watkiss, 2022). The most recent UK Climate Projections (UKCP18) suggest that Scotland will be exposed to more intense and frequent extreme weather events, such as heatwaves and storms, and long-term shifts in temperature, rainfall and sea level rise (Adaptation Scotland, 2021). These changes will significantly impact Scotland's people, ecosystems, and economy.

Climate policy has also been responding to the changing climate today and future climate projections. Scotland's third National Adaptation Plan (2024) sets out Scottish Government's plans over 2024-2029 to adapt to climate change. Public bodies have a statutory duty to help deliver the Adaptation Plan (Scottish Government, 2011) and Scottish Government has committed to updating its corresponding statutory guidance.

1.1.2 Future climate in decision making

To successfully adapt to climate change, organisations must embed climate change considerations in their decision making over the short and long term. It is crucial for organisations to develop strategies and make decisions with the awareness that our climate is changing.

This is particularly important for public bodies, which often operate over longer time horizons and have a responsibility for decisions that often cannot easily be reversed (infrastructure planning, for example). It is also important they receive help to do this on a more consistent basis to improve the coherence of decision making.

Scenario analysis is a useful tool to help organisations consider climate change implications. It can be used to:

- Test the resilience of their current strategies and business plans to future changes in climate
- Understand the future potential impacts of climate change and actively prepare to adapt to these risks
- Explore and promote strategies to reduce their emissions and therefore mitigate future climate change

1.2 Aims

Adaptation measures can help reduce the risks associated with future climate change in Scotland. However, climate adaptation planning is not straightforward and faces

uncertainties in both the magnitude of future change and timing. A single climate projection is likely to be inaccurate and therefore multiple versions of what could happen in the future need to be assessed to inform robust decision making. Climate scenario analysis addresses this challenge by providing a framework to better understand climate uncertainties by assessing the implications of different plausible climate futures.

As climate change has moved up the agenda over recent years, regulators in various jurisdictions have mandated climate related disclosures for public bodies, companies, and financial institutions. This has also included recommending scenario analysis to assess the resilience of strategies and portfolios to different climate futures and inform decision making (e.g. Taskforce for Climate-related Financial Disclosures (TCFD) in the UK and Corporate Sustainability Reporting Directive (CSRD) in the EU).

Regardless of purpose, conducting climate scenario analysis can feel complex and the choices which need to be made, for example, which scenarios to consider, can often be confusing. To support future-proofed plans and strategic decision making, the Scottish Government (2024) has committed to develop a climate scenario decision tool for the public sector. The tool will aim to provide guidance and support around the implementation of climate scenario analysis to drive robust and consistent analysis of future climate-related risks across the public sector in Scotland and enable cohesion in adaptation planning.

This report aims to provide advice to the Scottish Government on the development of guidance for climate scenario analysis. Specifically, it provides recommendations on the climate change emissions or temperature scenarios, timeframes, climate hazards and other important factors public sector bodies should consider as part of any climate scenario analysis. The report also sets out additional features and guidance required by a climate scenario decision tool for the public sector, informed by insights from stakeholder consultation and the wider literature.

The findings and recommendation of this report will guide the development of the Scottish Government's climate scenario decision tool, supporting public bodies with climate scenario analysis and enabling climate adaptation planning and decision within Scotland informed by a robust understanding of future climate change.

2 Methodology

The research which forms the basis for the guidance and recommendations in this report was commissioned by CXC and conducted by GAD between March and September 2024. The research was largely based on information from three main sources which are described in Section 4 of this report. The research project was split into three phases.

Phase 1: A review of existing policy, guidance, and stakeholder practice on use of future climate scenarios and climate hazard data when making investment judgements, exploring the resilience of current plans, and developing adaptation strategies.

We undertook a targeted desk-based review of current policy and guidance in relation to climate scenario analysis, consisting of:

- A scoping exercise to map out the volume of literature and collate policy papers and guidance published in the last five years.

- Identification of further key sources underpinning the literature published outside of the five-year timescale.
- A synthesis of the key recommendations and considerations of these for climate scenario analysis.

The review focussed on guidance and policy applicable within Scotland and the UK, and the EU. This included TCFD scenario analysis recommendations and the Climate Change Committee's (CCC) recommendations on global warming scenarios to consider in adaptation planning in Scotland.

For the review of current practice, we worked with ClimateXChange and Scottish Government to identify and prioritise relevant stakeholders to engage with. This included those in Scotland already using climate scenario analysis and future climate hazards data to inform their longer-term planning strategies.

Individual and group stakeholder engagement sessions were conducted over summer 2024 in person and virtually. Sessions sought to understand the purpose and aims of stakeholders' climate scenario and hazard analyses and their experience of it. We examined what hazards and scenarios they had considered, how results had been used, pain points that they had encountered, and what decision-making support could further assist them. We captured stakeholders' views via recording the meetings and using an online whiteboarding tool, Miro, where participants could record their ideas under question prompts. We also shared our key findings with stakeholders following the workshops to ensure we had accurately reflected and understood their views and comments. We engaged with a broad range of stakeholders including:

- Climate Change Committee
- Dynamic Coast
- Edinburgh City Council
- Forestry and Land Scotland
- Highlands and Islands Airports Limited
- Historic Environment Scotland
- Met Office
- NatureScot
- Network Rail
- Paul Watkiss Associates Limited
- Scottish Environmental Protection Agency (SEPA)
- Scottish Government
- Scottish Water
- Sniffer
- Transport Scotland
- University of Glasgow.

To supplement information gathered through stakeholder engagement we also examined current best practice in the private sector, specifically through the work of the Financial Reporting Council (FRC) thematic review of TCFD reports (FRC, 2022).

Phase 2: Identify common themes across existing guidance and stakeholder practice.

We used qualitative content analysis methods to identify commonalities and differences in the policy and guidance and current practice. An analytical framework was developed to provide structured outputs of summarised qualitative data collated in Phase 1. The framework captured key guidance factors that feed into climate scenario analysis such as hazards to consider, scenario definitions, numbers of scenarios, timeframes, frequency of analysis and expected outputs.

This allowed themes in existing guidance to be easily identified whilst also providing a holistic view of the current policy and guidance landscape.

We also considered availability of data. As part of Phase 2, we conducted a rapid review of the latest publicly available physical climate hazard data. This included an assessment of potential data limitations and consideration of whether climatic tipping points are captured. This included an overview of the UKCP18 data from the Met Office.

Phase 3: Options and recommendations for setting national-level guidance to support accounting for future climate hazards in today's decision making.

Outputs from Phases 1 and 2 of the research have been critically assessed to determine the level of prescriptiveness that Scottish Government could take in setting out recommendations for assessing future climate-related risks for strategic planning and adaptation in the public sector.

The recommendations are based on considerations of the consistency required to establish shared planning assumptions across multiple public sector bodies, the needs of stakeholders in considering climate scenarios and hazards in Scotland, the complexity that may be introduced, potential user capability and associated costs. We actively consulted with Scottish Government and public sector stakeholders during this phase of the project to gain feedback and discuss their views.

2.1 Research limitations

As the research was conducted within fixed timelines and budget the level of detail may not meet the needs of all potential audiences, e.g. those requiring climate scenario details to support investigation of highly specific and unusual risks in their planning and decisions.

Indeed, due to the budget and timeline constraints, we carried out three stakeholder workshops as part of our research. With further workshops we could have potentially gathered wider and deeper views on climate scenario analysis from public bodies across Scotland. However, engagement during our workshops was very high and the insights we gained from participants were invaluable in shaping our recommendations.

3 Climate scenario analysis

There is inherent uncertainty in assessing the physical impacts of climate risks. This is due to the uncertain future trajectory of global emissions, and uncertainty around how the planet will respond to those levels of future emissions. The uncertainty at an organisational or project level is impossible to accurately quantify due to the combination and complexity of uncertain inputs.

Scenario analysis relies on defining plausible futures and analysing them to better understand the impacts of the risks being faced. No likelihood is placed on any single scenario. Instead, the relevance of the analysis relies on selecting a range of scenarios under which the risks most relevant to the organisation emerge.

3.1 Defining climate risks

Climate risks can be better understood by using the International Panel on Climate Change (IPCC) framework of hazard, exposure and vulnerability (Cardona et al., 2012). Each of these components should be considered when determining climate risk as part of climate scenario analysis.

Risk = hazard x exposure x vulnerability

Hazard: The possible future occurrence of physical climate events that may have adverse effects (damage and loss) on vulnerable or exposed people, assets, services, resources, infrastructure, or systems. Examples of climate hazards include heatwaves, sea level rise, floods, and storms.

Exposure: The presence of people, assets, services, resources, infrastructure and systems that could be adversely impacted by the hazard. Proximity to the hazard is an important consideration here. For example, buildings close to the coast will have a greater exposure to sea level rise than those further inland.

Vulnerability: The propensity of exposed aspects (people, assets, services, resources, infrastructure, systems) to suffer adverse events when impacted by climate hazards. Vulnerability relates to predisposition, susceptibility, fragility, weakness, deficiency, adaptive capacity etc. For example, elderly people are less able to regulate their core temperature compared to younger adults and therefore more vulnerable to overheating than younger people (Moreira Sousa, 2022).

Exposure and vulnerability are often thought of as one but can be distinguished – it is possible to be exposed to a climate hazard but not vulnerable to it, for example by living in a floodplain but having means to modify building structure to avoid potential loss. However, to be vulnerable to a climate hazard, you must be exposed to it.

Whilst hazard data can be relatively generic, information on exposure and vulnerability is normally specific to an organisation.

3.2 What are climate scenarios?

Climate scenarios are plausible future outcomes of climatic conditions and macro- and micro-economic development in response to climate change and the transition to a low carbon economy. They were brought into the public consciousness in large part by the IPCC. This is a United Nations body for assessing the science related to climate change whose purpose is to provide governments with scientific information that they can use to develop climate policies.

The IPCC define their scenarios by emissions pathways, also known as Representative Concentration Pathways (RCPs). Whilst these emissions pathways are widely used as different climate scenarios for scenario analysis, in recent years there has been a trend to focus on temperature increase scenarios, rather than emissions pathways. Temperature increase scenarios are also known as global warming levels.

Emissions-based pathway scenarios: These are different projections of atmospheric concentration of greenhouse gasses up to 2100. The RCPs correspond to different levels of total atmospheric "radiative forcing" (a direct measurement of the greenhouse effect) meaning that they each produce different degrees of future global temperature increase. There are ranges of temperature increases that could exist for each emissions pathway.

Global warming level scenarios: Global warming level scenarios don't generally include a timeframe. Instead, they represent a world that has reached the stated average warming for the period (Met Office, 2023). The CCC looks at +2°C and +4°C temperature increase scenarios within their most recent Climate Change Risk Assessment (CCRA3) (CCC, 2021); as well as considering higher levels of warming and low-likelihood, high-impact events such as climate tipping points (Betts and Brown, 2021).

The Met Office provides the UKCP18 data which are based on regional climate model[2] simulations. Data is available for different RCP scenarios but also global warming levels of 1.5°C, 2°C, 3°C and 4°C.

3.3 Climate scenario analysis in decision making

There is no single accepted definition of scenario analysis. Broadly it is a tool for assessing what could happen to different aspects of an organisation[3] or project (costs, income, policy, asset values, liability, workforce etc) under different climate scenarios.

Scenario analysis is constantly evolving to better explore the impacts of climate change on the above listed aspects. As climate related risks and opportunities begin to become more

[2] Derived from their global HadGEM3 model.

[3] Whilst the focus of this report is on public bodies, there are many aspects that will be applicable and useful to private sector organisations. Therefore, throughout the report, we refer to "organisations" to encompass both public bodies and private companies.

commonly considered, analysis will become more sophisticated and likely produce outputs that better support decision making.

Scenario analysis is a tool to enhance critical strategic thinking. An initial single analysis is unlikely to capture all climate-related risks at the level of detail required. Scenario analysis should be an iterative process where the objectives and scope of each analysis are well defined and tailored to ensure the output of decision useful information is maximised.

Often there will be a trade-off between:

- Very well defined but near impossible to quantify narrative scenarios; and
- Scenarios that can be quantified, but in doing so need simplifying assumptions which may be unrealistic.

Scenario analysis is a valuable tool for assessing and understanding uncertainty. It can be used by organisations to:

- Challenge their current thinking. It is useful in testing if strategies and plans are resilient to plausible future changes in the climate
- Make better informed decisions by looking over the longer term
- Identify potential changes in the severity and frequency of climate-related risks. Additionally, completing scenario analysis may help organisations to identify new climate-related risks.

3.3.1 Limitations and challenges

Scenario analysis is difficult to carry out. For example, it is hard to know where to start and what scenarios are plausible. There is a need to recognise the limitations and challenges around data, skills, and uncertainty relating to timescales and quantifiability.

3.3.1.1 Data

Data can be hard to obtain and even when available it often has shortcomings like lack of coverage or uncertainty. This includes external data, like those covering the frequency and severity of climate hazards. It also includes lack of data held by the organisation itself on its exposure and vulnerability to climate risks.

3.3.1.2 Skills and risk awareness

A range of skills are needed to carry out scenario analysis. Few organisations will have access to all of those skills. Many address this by employing consultants or contractors, sometimes at great expense. The recommendations in this report will not eliminate this gap but aim to reduce this burden on public sector bodies.

One such skill is the ability to understand and communicate different types of uncertainty. Scenario analysis is a tool designed to help with this but also requires practitioners to have relevant skills in this area. Throughout the workshops, the importance of good communication of climate-related risks was a key theme. Participants noted the various challenges associated with ensuring communication with the public was transparent without causing climate anxiety.

3.3.1.3 Proportionality

Different organisations will be impacted by climate change in different ways, and it is the people who work at the organisation itself who will best understand the climate hazards that are most pertinent to their organisation.

Organisations should therefore take a proportionate approach to completing scenario analysis. When certain climate hazards are irrelevant for the organisation (for example, they have no exposure or are not vulnerable even where they are exposed), it is acceptable for these to be left out of climate scenario analysis. The organisation should satisfy itself that these hazards have been considered and agreed not to be investigated further. Stating this explicitly would be considered best practice and ensures transparency in any publications or disclosures.

4 Research findings

Recommendations presented in Section 5 are informed by three main sources of information:

- **Policy and guidance:** Review of documents including policy, scenario analysis guidance, and reviews of existing practices.
- **Data:** Rapid review of 21 commonly used data sources to understand data availability for different climate hazards.
- **Stakeholder views and experience:** Three workshops with stakeholders including Scottish Government, public sector organisations, and experts in climate risks.

4.1 Policy and guidance review

We reviewed over 50 documents setting out policy, guidance and best practice examples of climate scenario analysis in Scotland and further afield. There are different legislations and regulations that bring climate reporting (such as that compliant with the TCFD (2017) recommendations including climate scenario analysis) into scope for various organisations and entities. We also considered any application guidance that went with the legislation and regulation.

Many of the sources considered covered more than just climate scenario analysis, and in contexts wider than just adaptation planning. Due to the focus of this review, greater consideration was made where sources spoke specifically about scenario analysis and in contexts relevant to adaptation planning. These sources are listed in **Appendix C**.

We identified nine factors that can be used to guide scenario analysis and that are frequently referred to within the policy and guidance literature. These were:

- Which climate hazards should be covered?
- What climate scenarios should be used?
- How many climate scenarios should be considered?
- Where data should be sought from?
- The scope of the climate scenario analysis (i.e. whether analysis should cover the entire organisation / project or only certain parts of it).

- Timeframes to be considered (i.e. how far into the future and at which specific time periods to look).
- Frequency of updates to analysis.
- Whether the analysis should be qualitative or quantitative.
- Materiality (including double materiality).

The accompanying spreadsheet to this report, Technical appendix - Review of current policy and guidance, sets out a framework which compares each climate scenario analysis factor to the guidance and policy reviewed. The framework also provides a cross comparison with insights from the stakeholder workshops and the recommendations given in Section 5.

Key findings from the review indicated:

- The current published guidance is primarily focused on scenario analysis based on requirements for financial reporting. The most obvious example of this is the recommendations of the TCFD (2017), but many other sources are also routed in this, including the requirements for pension schemes (The Occupational Pension Schemes (Climate Change Governance and Reporting) Regulations 2021) and companies (The Companies (Strategic Report) (Climate-related Financial Disclosure) Regulations 2022) in the UK.

- TCFD (2017) mainstreamed the categorisation of climate-related risks as either physical or transition. Although transition risks (risks associated with the transition to net zero) can impact organisations and projects, they are generally less relevant to adaptation planning which is predominantly focused on reducing vulnerability to physical climate hazards. Physical hazards can be divided into acute hazards (specific events, such as floods or storms) and chronic hazards (events that gradually evolve over time, such as average temperature increase or sea level rise). Considering both acute and chronic physical hazards is consistent with a range of guidance, including that from Defra (2023) and the CCC (2024).

- Due to the nature of sea level rise, including its lagged response to emissions of greenhouse gases, and the complex and dynamic nature of coastal change, alternative or additional scenario analysis guidance may be required for this climate hazard.

- Guidance related to financial reporting, often mentions considering a +2°C or lower or "Paris-aligned" scenario. Emissions or temperature scenarios below +2°C may be more appropriate for analysing transition risks rather than physical risks. The His Majesty's Treasury Green Book (2020), CCC (2022), and Defra Adaptation Reporting Power (2023) all use scenarios based on global warming levels focussed on +2°C and +4°C by the end of the century.

- The more scenarios considered, the more analytical work and data gathering is required. Using fewer scenarios may allow organisations to consider each scenario in greater depth. However, multiple scenarios are needed to capture uncertainty associated with future climate change and allow for more robust decision making.

- Guidance is conflicted regarding the required scope of climate scenario analysis. For example, some sources state the full organisation should be covered (e.g. Defra, 2023), whilst others restrict scope, initially at least, to cover more significant areas of an organisation (e.g. Department for Business, Energy and Industrial Strategy, 2022).

- There is a lack of guidance on length of timescales to consider; analysis of reporting shows that many consider "long" timescales to be 10 years.

- From an adaptation perspective, it is important to focus on climate change impacts on the organisation, rather than the organisation's impact on the climate. Considering both aspects is sometimes referred to as "double materiality" (Commission Delegated Regulation (EU) 2023/2772, 2023).

- Finally, published guidance makes clear that transparency around assumptions and limitations of analysis is vital.

4.2 Rapid data review

We reviewed 21 publicly available climate data sources commonly used to source data for climate scenario analysis (Appendix B). These included the providers of UK wide data (e.g. Met Office climate data portal and the UKCP18 user interface), global data (e.g. IPCC's Interactive Atlas, Copernicus climate data store) and the Scotland focused data (e.g. Nature Scot GIS, Marine Scotland).

We found that there was a very wide variation in the data provided across this small sample of sources. Different data sources provided data on different climate hazards at different levels of spatial resolution and over different time projection periods. They also varied between using emissions-based (RCP) and temperature-base/global warming level scenarios. Climate projections based on the fifth phase of the Coupled Model Intercomparison Project (CMIP5), which are used as the basis of the IPCC's fifth assessment report (AR5), were the most readily available. This is despite updated CMIP6 model simulations being used for the more recent sixth assessment report (AR6) (IPCC, 2021), demonstrating the long time lag often experienced for climate data updates. This lack of standardisation across climate hazard data providers was a source of frustration for those we spoke to in our workshops.

Chart 1 indicates that data availability varies significantly depending on the climate hazard under investigation. Of the 21 data sources reviewed, the greatest data availability is for temperature-based hazards, such as chronic temperature change and extreme heat events, whilst there is very limited data available for more complex hazards such as soil movement and landslip.

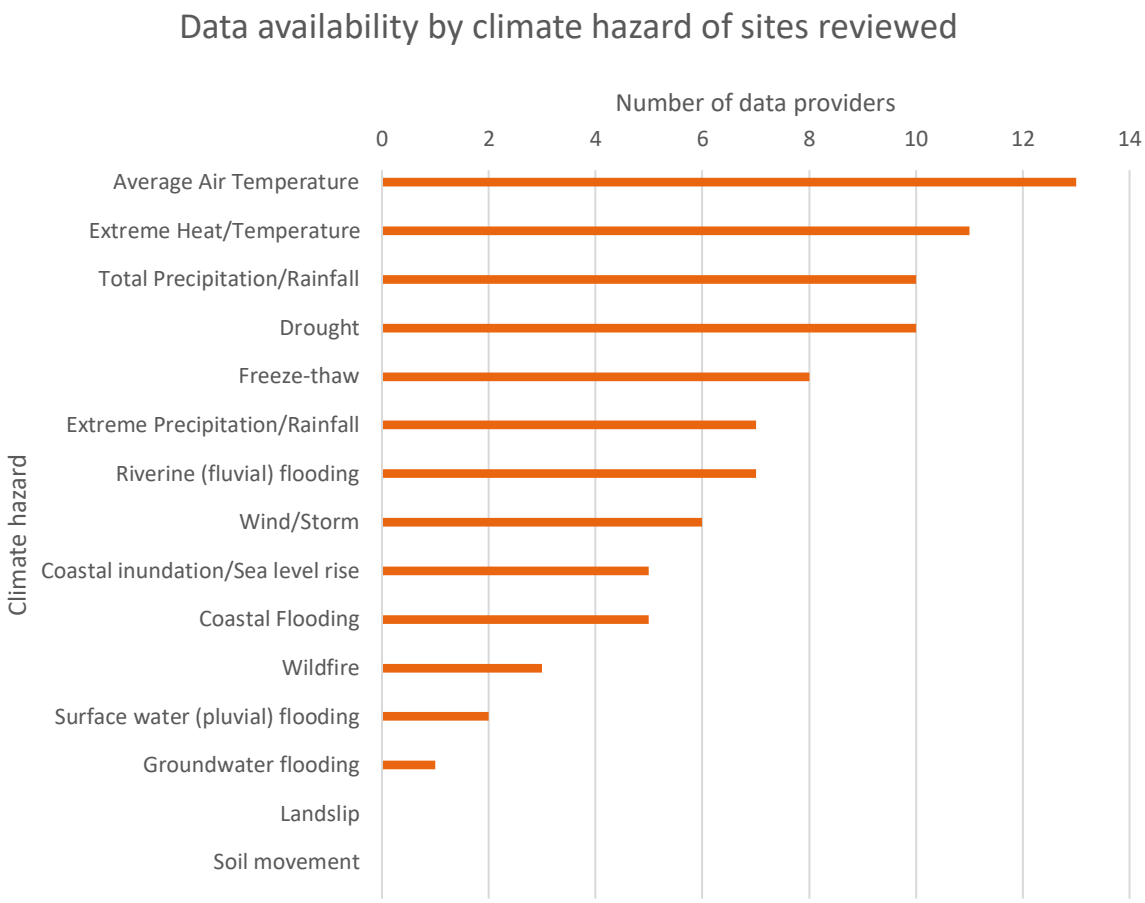

Chart 1: Data availability by climate hazard (21 data providers reviewed)

ClimateXChange is conducting a geospatial climate hazard data review project which should improve the understanding of the data landscape for those carrying out scenario analysis.

4.3 Current practice and insight from stakeholders

4.3.1 Workshops on climate scenario analysis

We engaged with multiple Scottish public bodies and other relevant stakeholders (Appendix D) across two separate workshops to discuss their experience of climate scenario analysis. Stakeholders shared their experience of completing (or advising others on completing) climate scenario analysis, their key challenges and what would have helped to alleviate them, the tools and resources they used along with limitations, and their ability to quantify the climate impacts on their organisation.

A summary of key findings from these workshops were:

- There was strong appetite across the stakeholders to learn more about how to conduct better scenario analysis. It was felt that nationally defined climate scenarios would help reduce conflict between parties using different data.

- Scenario analysis is carried out for many purposes which lead to different needs for data and expertise. However, stakeholder primary use cases were to inform risk management strategies and plans and inform business decision making. Most organisations need to bring in outside expertise to help.

- Stakeholders agreed that quantification of analysis should be a clear aim, but the importance of qualitative analysis is also recognised.

- Analysis should aim to increase the ability of organisations to make decisions under uncertainty. The impact of "doing nothing" should also be considered.

- There are advantages and disadvantages to using emissions-based scenarios and global warming levels – each have their place. Emissions based scenarios may be more suitable for climate hazards which do not scale well with global mean temperature (CCC, 2024). This includes sea level rise where a long lag time exists between global temperature increase and the full sea level response.

- Stakeholders can often find it hard to obtain or understand climate data. Data availability can be limited as can the in-house capability to analyse it. Data does not always extend to the local level needed.

- More data on asset vulnerability to hazards is also needed so that risk can be fully assessed.

- Secondary and indirect climate impacts are particularly difficult to quantify and more guidance in these areas would be welcome.

- Consideration of climate tipping points in adaptation planning is challenging due to large associated uncertainties in probability of occurrence, impact, and timing. It was noted that even when tipping points are breached, the impact may take many years to be felt.

- Communication of the results of scenario analysis to users and the public was a key consideration for stakeholders and something that was often found to be challenging. Comparisons with other risks to communicate uncertainty may be helpful along with improvement of climate literacy beyond climate experts.

4.3.2 Workshop on scenario analysis for coastal change

'Compared to other factors, sea level only gets worse.'
Insight from a stakeholder at the coastal change workshop, June 2024.

In addition to the two workshops held on climate scenario analysis, we held a dedicated workshop with coastal change experts. This was to allow a better understanding of specific scenario analysis guidance that may be required for coastal hazards such as sea level rise, which has a significant lagged response time and that impacts highly complex coastal processes. CXC has also commissioned a piece of research on coastal change adaptation

planning conducted by the University of Glasgow which will further contribute to improving future guidance on coastal change adaptation planning.

A summary of key findings from this workshop were:

- Sea level rise and coastal change can be considered to have a unique risk profile compared to other climate hazards. This is because 1) impact is always negative 2) timescales of impact are much longer and 3) the impacts are irreversible. Sea level rise is a chronic risk where the entire current baseline state is shifting.

- Sea level rise will affect erosion rates and wave heights. It will impact drainage systems, structures, natural features and ecosystems. The complex interaction between sea level rise and other systems and services needs to be better mapped.

- There was strong agreement that a precautionary approach was required for assessing the impacts of sea level rise and coastal change due to the permanent nature of the risk and the uncertainties associated with modelling, tipping points, and current understanding of dynamic processes.

- Due to the chronic nature of sea level rise, assessments need to look over long time periods. As in the climate scenario analysis workshops, stakeholders were very supportive of ensuring scenario analysis considered a long-term timeframe to ensure adaptation measures represented maximum cost-effectiveness.

- However, for adaptation planning, a focus on timescales may be a barrier to action as we are generally bad at long-term thinking. Instead, a focus on "what would the impact of a x meter rise in sea level be?" could be taken, analogous to the global warming level approach.

- Consideration should be given to where assets/infrastructure affected by sea level rise will need to be moved to.

- Coastal literacy is particularly poor among the public and within organisations. This prevents a comprehensive understanding of the associated risks. This has led to push back on modelled results in areas such as land use planning as there is an assumption that risks are being overstated.

- The stakeholders felt strongly that there should be better communication of the risks and uncertainties associated with impacts of sea level rise and coastal change. Scenarios should be communicated not as pessimistic but realistic given what is currently known and the associated uncertainties.

- The UK Met Office provide a range of datasets for the examining sea level rise under climate change and are in the process of updating these based on the more recent IPCC emissions scenarios.

4.3.3 Additional stakeholder insights

Stakeholder consultation as part of the 2024 SNAP statutory consultation process, indicated that there was strong support from organisations for any guidance to align scenarios with those recommended by the CCC (adapt to 2°C of warming, plan for the risks associated with 4°C of warming). Stakeholders also stated they would welcome guidance on the interpretation of data particularly relating to understanding climate data terminology (e.g. on emissions pathways and global warming levels).

Many stakeholders had previously considered flood risk, but the consideration of other hazards was less consistent. The Scottish Government (2023a) also confirmed this through the Business Insights and Conditions Survey. Over 60% businesses surveyed reported that they had not assessed for coastal erosion, increased flooding, temperature increases or water scarcity.

A scenario analysis decision tool has the potential to help ensure a range of hazards are considered in adaptation planning decisions, encouraging consistency and robustness. Whilst not all hazards will be material for all organisations, organisations should include all hazards that they deem to be material within their analysis.

Case Study: Climate Resilience Strategy (SP Energy Networks, 2021)

The Climate Resilience Strategy sets out how SP Energy Networks will maintain a safe and resilient network despite climate change. The analysis was done considering "four key climate change projection variables (temperature, precipitation, sea level rise, and wind speed/storminess) over three time periods (2030s, 2050s and 2100s) and two Representative Concentration Pathways (RCP) projection scenarios (RCP6.0 and RCP8.5)".

Here, by considering chronic risks alongside acute ones, SP Energy Networks can ensure they understand interdependencies between different risks. For example, they note that "sea level and storm surge" could lead to an impact on their operations with sea level rise and coastal erosion increasing the exposure of their assets to storm surge events.

5 Recommendations

Our recommendations on the content of the decision tool are summarised below and more detail on these can be found throughout this section. There is also a section on our recommendations for the tool development (Section 5.10). These recommendations are designed to support adaptation planning so may not be suitable for scenario analysis carried out for other purposes such as financial reporting.

Factor	Summary of recommendation on decision tool content
Hazards covered	Scenario analysis should cover both chronic and acute physical climate hazards. Transition risks should be considered separately by organisations, where they may have a significant impact.
Scenario prescription and definition	To drive consistency organisations should consider both 2°C and 4°C warming scenarios.
Number of scenarios	At least 2 scenarios should be considered, specifically 2°C and 4°C warming scenarios.
Climate data provider	The tool should point to up-to-date primary sources of data for different hazards as informed by the ongoing climate data review by the Scottish Government.
Scope of scenario analysis	The scope of scenario analysis is proportional to the use case, and use-case specific guidance should be followed.
Timeframe of scenarios	Short term: In line with business planning cycles. Medium term: 2045-50s. Long term: 2080s-end of century.
Frequency of updates to analysis	Scenario analysis should be updated every 3-5 years.
Qualitative versus quantitative analysis	Scenario analysis should be quantitative, but qualitative analysis can also be used to provide a richer narrative.
Inclusion of the impact of the organisation on the climate	Analysis normally needs only to cover the impact of the climate on the organisation.

Table 2: Summary of recommendations

5.1 Hazards covered

Our research confirms that scenario analysis can consider both physical climate hazards and climate-related transition risks. However, as the decision tool will be designed to support adaptation planning, **we recommend that the focus is on physical hazards only**.

Transition risks should be considered separately by organisations, where they have the potential to have a significant impact on the organisation.

Scenario analysis should however cover different types of physical hazards, specifically it should cover both acute and chronic hazards (see Figure 1):

- Acute hazards are specific events such as floods or storms.
- Chronic events gradually evolve over time, such as average temperature increase or sea level rise.

5.1.1 Coastal change and sea level rise

While coastal change does pose specific threats, as indicated by the Scottish Government's (2023b) Coastal Change Adaptation Plan Guidance and the Dynamic Coast (accessed 2024) project and explored further in the specific stakeholder workshop on this topic, we recommend considering it alongside other chronic risks as the first stage of the climate decision tool.

This will then enable stakeholders to get a better understanding of the shifting baseline in the future they are analysing, before assessing acute risks under that scenario. For example, sea level rise may bring with it a greater number and intensity of storm surges closer to shore. This is an important consideration for an organisation with infrastructure or physical assets that cannot be moved inland.

5.1.2 Chronic and acute hazards

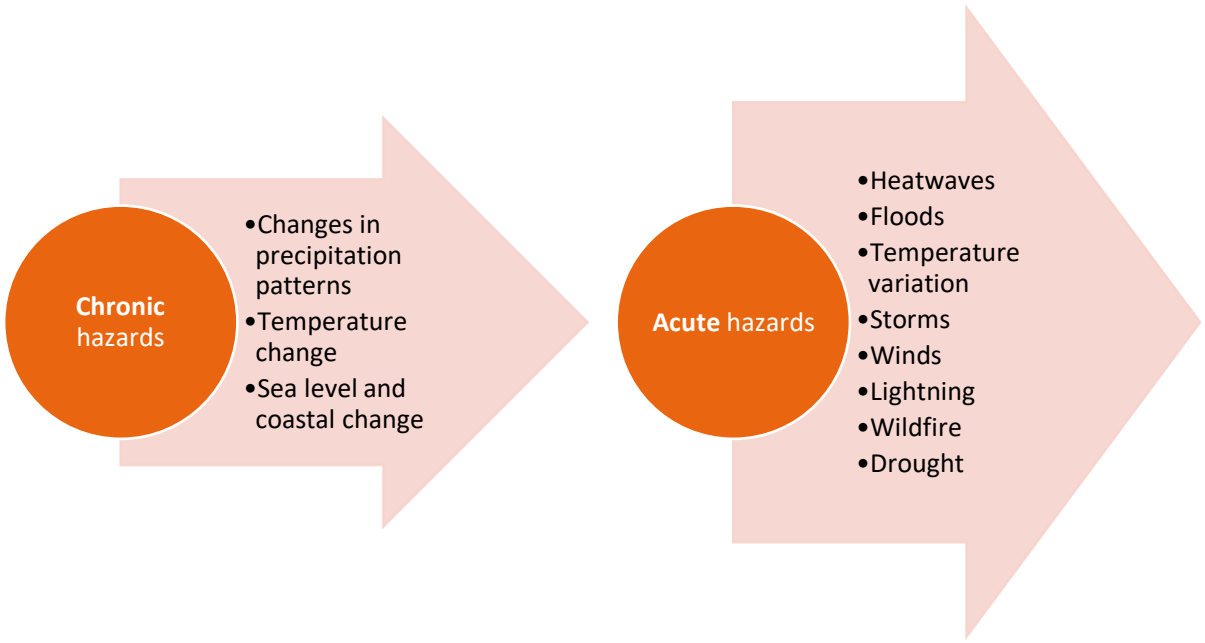

Figure 1: Proposed structure of tool, considering chronic hazards before **acute** ones

Framing hazards as chronic and acute, with the sequencing set out as **in Figure 1,** should help tool users:

- Understand how baselines like current coastlines, precipitation levels and average temperatures are expected to change over time under different climate scenarios.
- Ensure that chronic physical risks are not overlooked, given their more gradual change which could lead to a progressive decline in service delivery rather than acute hazards that can cause more noticeable impacts and disruption.

- Consider connections and interactions between different physical risks, that in aggregate may provide a different risk profile than when considered independently.
- Ultimately provide a more holistic view, which will improve the standard of scenario analysis.

There will, however, be some challenges, specifically around data availability as revealed by the rapid data review.

An alternative would be to consider sea level rise and coastal change in a separate tool, noting some of the unique challenges posed by the risk. However, our recommendation encourages all risks to be considered in a single tool to help ensure interdependencies (and/or entire risks) are not missed.

5.2 Scenario prescription and definition

Prescribing the use of specific scenarios in the tool drives consistency across organisations and projects. This will enable better communication and comparisons supporting improved adaptation planning, particularly where several organisations are impacted by, or involved in, adaptation measures.

We recommend considering specific scenarios, aligned with other reporting frameworks we reviewed which organisations may be required/choose to comply with. This will further improve consistency (by allowing more consistency within organisations) and minimise additional work and costs for organisations.

We recommend considering both of the following scenarios:

- **2°C global warming level** (above pre-industrial levels) by end of century.
- **4°C global warming level** (above pre-industrial levels) by end of century.

When communicating the results of scenario analysis it is important to clearly articulate the rationale for choosing particular scenarios. Hence, we would recommend justifications for the choices of scenario are included in the tool, in particular, these could include:

- alignment with the updated CCC methodology (2024) and Defra's Adaptation Reporting Power (2023).
- choosing a 2°C warming scenario allows organisations to assess their resilience against the lower end of plausible temperature outcomes by the end of the century.
- choosing a 4°C warming scenario allows organisations to assess their resilience to much higher physical risk, towards the upper end of plausible temperature outcomes by the end of the century.
- scenarios of 2°C and 4 °C gives a sensible range of likely futures based on current global efforts to reduce greenhouse gas emissions (CCC, 2020).

To enable a greater volume of the available climate data to be used we recommend that organisations can make use of emission pathways-based data, as well as data focused on global warming levels.

We have set out a table in Appendix FAppendix F that can be used as a reference when comparing and contrasting emissions-based and temperature-based scenarios. In particular, the pathways best aligned to the scenarios prescribed above are:

Global warming level (above pre-industrial levels) by end of century	RCP (5-95% temperature increase range at end of century)	SSP-RCP (5-95% temperature increase range at end of century)
2°C	RCP 2.6 (1.1 – 2.3°C) RCP 4.5 (1.8 – 3.2°C)	SSP1 – 2.6 (1.0 – 2.2°C)
4°C	RCP 8.5 (3.2 – 5.5°C)	SSP3 – 7.0 (2.8 – 5.5°C) or SSP5 – 8.5 (3.6 – 6.6°C)

Table 3: Global warming levels and equivalent RCPs and SSP-RCPs for prescribed scenarios

What are earth system tipping points?

Earth system tipping points are thresholds beyond which changes in a part of the climate system become self-perpetuating often leading to abrupt and irreversible changes that could have a profound impact on our planet (Armstrong et al., 2022).

Examples include melting of the major ice sheets or significant changes in the fundamental ocean circulation patterns.

GAD also recommends that earth system tipping points are excluded from the analysis at present due to the significant uncertainty and difficulty in robustly modelling their timing and impact. The tool should ensure this is explicitly stated so that users are aware of this limitation.

This guidance should be kept under review. Over time, as our understanding of tipping points develops, it may be reasonable to allow for them in the relevant scenarios. For this to be the case more data on their onset, the pace at which the impacts of tipping points occur, and the severity and extent of the potential impact will be needed. It is worth noting that CCRA3 includes some consideration of low likelihood, high impact risks (Watkiss and Betts, 2021).

Organisations may find it valuable to also consider a reasonable worst-case scenario. However, it is likely that this is more appropriate to do as part of emergency planning exercises, rather than scenario analysis for adaptation planning. Reasonable worst-case scenarios could include tipping points being breached and other thresholds being crossed beyond which the organisation may struggle to operate.

5.3 Number of scenarios

We recommend the use of at least two scenarios, in particular those described above being a +2°C and +4°C futures.

Considering two scenarios means that the scenario analysis meets the expectations of all the policy and guidance sources we reviewed in this project, detailed in Appendix C.

5.4 Climate data provider

Climate data is available from a large number of providers. While some of this data must be purchased, we recommend using publicly available data wherever possible as this increases transparency and reproducibility of the scenario analysis.

We recommend that the tool should point to primary sources of data for different hazards, informed by the ongoing climate data review by the Scottish Government.

Sources of data may be preferred based on a number of criteria:

Criteria	Description
Coverage of different climate hazards	Sources that cover multiple hazards may enable more consistent scenario analysis across different hazards as well as improve internal efficiency and capability.
Reliability of source	UKCP and data from the Met Office are generally regarded as the best publicly available data that is specific to the UK.
Spatial granularity of data	Some data are available on a 1x1km grid, whereas other data are only available at the country-wide level. Techniques are available which can sometimes be appropriate to increase the granularity of the data. Assessing different climate hazards also requires different data granularity. The tool should allow for this and differences in spatial granularity between hazards should be communicated in the output of the scenario analysis.
Timeframe of the data	Ideally this should cover the end of the century. Different data sources may include different frequency, horizons, and baseline periods. The producer of the scenario analysis should make sure they understand these differences and communicate any implications of these in their scenario analysis output.
Scenarios for which data is available	For example, some data providers only have data relating to specific scenarios.
Format and ease of accessibility of data	This is particularly important for organisations that are inexperienced in conducting scenario analysis.
Familiarity with data	Organisations will be more efficient when using data with which they are already familiar. They may have already carried out relevant analysis using this data which can be reused. However, some caution should be exercised as there is a risk of familiarity bias.

Table 4: Criteria for climate data provider selection

5.5 Scope of scenario analysis

We believe the most significant factor in determining a suitable scope for the scenario analysis will be the context and purpose of the analysis. There are also advantages of

considering a broader scope for the analysis to ensure that interconnected risks are understood and analysed appropriately.

For adaptation planning, we recommend that the entire organisation is included within the scope of the scenario analysis[4]. There will be instances where certain hazards will be more material for certain areas of the organisation. However, including the entire organisation within the scenario analysis will ensure that adaptation measures are well considered and have less chance of creating unintended consequences to seemingly less-affected areas.

Depending on the nature of the organisation, or adaptation measure under consideration, it may be proportional to limit the scope of any analysis, in line with any specific guidance relevant to its use. The principle of proportionality was discussed further in Section 3.3.1.3.

The scope of scenario analysis should include a range of external factors which could affect an organisation such as energy supply, communications and transport systems.

'Cross-boundary issues and wider interdependencies should also be considered with neighbouring bodies and wider stakeholders such as Network Rail, Transport Scotland, Scottish Water and SEPA.'
NHS Scotland Climate Emergency & Sustainability Strategy 2022-2026 (Scottish Government, 2022).

5.6 Timeframe of scenarios

A large volume of the scenario analysis literature reviewed refers to the use of short-, medium- and long-term timeframes. These are, however, seldom defined, leaving it up to the organisation to define timeframes relevant to them. This might, however, come at the expense of consistency which is needed when organisations are collaborating on adaptation planning.

There is also a risk that the timeframes considered are too short, preventing an organisation from taking a sufficiently long-term view for adaptation planning. To enable more consistency, we recommend that the timeframes are prescribed, and are aligned to those commonly cited, including mid-century and end-of-century.

GAD recommends the following timeframes**:**

Term	Definition
Short	Defined by an organisation based on their business planning cycle.
Medium	Mid-century with organisations likely to use 2050s or 2045 to align with Scotland's net zero target.
Long	End-of-century, i.e. 2080 – 2100.

Table 5: Timeframes for **scenario analysis**

[4] In some instances (for example Local Authorities) this will include the whole area where the organisation has influence.

We have left the most flexibility around the short-term timeframe recommendation. We think that this is most helpful for organisations who have different planning cycles. It will allow them to have a greater level of internal consistency between their adaptation and other business planning, which should lead to a greater incentive to integrate climate considerations into business-as-usual planning. However, by not defining this timeframe, there will be less consistency in scenario analysis between organisations. Given the longer-term nature of many climate risks, this is considered to be a reasonable compromise.

The recommendations for the medium- and long-term still offer some flexibility, as mid- and end-of-century, as opposed to specific years such as 2050 or 2100. This is intended to make it possible for organisations to use a range of data sources more easily, or to align with other work they are doing. We believe that this will give a sufficiently high level of consistency across organisations whilst not becoming too onerous.

Carrying out scenario analysis over a longer timeframe adds greater complexity. However, we believe there is good reason to consider timeframes to the end of the century for most adaptation decision making. Through the stakeholder consultation there was a clear steer to ensure scenario analysis covered sufficiently long timeframes.

There is a delay, often lasting decades, between global climate action and the resulting impact on temperature rise and other climate risks. This means that physical risk scenarios are often very similar to each other in the short to medium term. For example, up to 2050 a +2°C end of century warming scenario may be very similar to a +4°C end of century warming scenario. This should give opportunity to consolidate analysis for the earlier years to make it more efficient.

The long timeframe of the analysis can allow false comfort as it can show that the risks are unlikely to affect the organisation for many years. However, actions to address the risks can take a similar amount of time or longer and the longevity of a physical or infrastructure asset as well as the projected sustainability of the business or organisation are more often measured in decades rather than shorter term. The uncertainty inherent in the analysis should also be considered as it means the risks may appear sooner.

5.7 Frequency of updates to analysis

Understanding of our climate and how it is changing is constantly improving. Practice in scenario analysis is also improving. In this rapidly evolving field, it is therefore important to ensure that scenario analysis is not seen as a one-off activity, but as an iterative process. In this way, the results from one scenario analysis exercise can inform the input to the next.

As updating scenario analysis can be a significant undertaking, we recommend a pragmatic approach, updating scenario analysis every 3-5 years. This can be more frequent if, for example, there are significant developments in climate science or events mean that the assumptions used are no longer suitable. Scenarios, by design, should be plausible and hence new information may mean they need to be changed.

Events that could trigger an update to a scenario analysis include, but are not limited to, the following:

- New IPCC analysis or report, which has a significantly different future climate outlook affecting the hazard facing an organisation.

- New data with a greater spatial resolution is realised, allowing a more accurate assessment of an organisation's exposure to a hazard.
- Assets moving from the planning to design to operational phases, affecting the organisation's vulnerability as a result.

As with other factors, a proportionate approach should be taken, and organisations should consider the extent to which an update is needed. This will differ depending on what has changed since the last analysis. It may be appropriate for organisations to update scenario analysis at different frequencies to better align with internal planning and decision-making processes. This should be justified appropriately.

5.8 Qualitative versus quantitative analysis

What is the difference between qualitative and quantitative analysis?

Qualitative scenario analysis focuses on the identification of trends and on the overarching narratives of the scenarios, often providing insight into less quantifiable organisation characteristics. It can involve descriptions of plausible future worlds, describing their main characteristics, relationships between key driving forces, and the dynamics of their evolution (TCFD, 2020).

Quantitative scenario analysis refers to the presentation of quantified information within a scenario. Quantitative scenario analysis can take many forms, targeting various aspects of [an organisation's] vulnerability to climate-related risks (MIT, 2019).

Quantification is often useful for adaptation planning as it can form part of a cost benefit analysis or support business cases for different adaptation measures. Quantitative analysis can allow for an easier comparison of alternatives.

However, there is also value in qualitative exploratory analysis, particularly where climate data may be limited. Qualitative analysis can also be easier to communicate to a broader audience.

We recommend that organisations carry out quantitative analysis. We recommend the decision tool also suggests where qualitative analysis could be most helpful. This could be in the short term where it can be used alongside quantitative analysis results to supply a richer narrative.

Case Study: No Time To Lose: New Scenario Narratives for Action on Climate Change (Cliffe et al., 2023)

This report by the Universities Superannuation Scheme and University of Exeter focuses on the power of qualitative analysis, with four short-term scenario narratives defined by assumptions for a range of drivers.

The resulting analysis is colourful and highly descriptive. "In 2024, the world confronts the challenges of a "Super El Niño" event, exacerbated by human-induced climate change,

resulting in powerful and prolonged weather phenomena. Southern Africa and India experience prolonged droughts exacerbating water scarcity and food insecurity, as changing rainfall patterns disrupt crop yields and livestock production. Record temperatures and prolonged droughts lead to 'heatflation' due to smaller harvests and higher prices."

Qualitative analysis of this type can be a powerful communication tool, especially when quantitative analysis would require a considerable number of assumptions that may make communication challenging.

Good quality communication of the results of climate scenario analysis, whether analysis has been quantitative or qualitative is imperative. This includes communication to others involved with or affected by the analysis, disclosures or publications both inside and outside of the organisation. When communicating climate risks, organisations may find it helpful to compare these risks to others with which readers may be more familiar (Reisinger et al., 2020).

5.9 Inclusion of the impact of the organisation on the climate

We recommend that analysis should focus on the impact of climate on the organisation. Requirements to consider the impact of the organisation on the climate arise from other existing legislation and duties.

5.10 Additional recommendations for tool development

The decision tool could take many forms. Based on the literature and data review, insight from stakeholders and experience, we set out key recommendations for tool development below, split by tool content and tool features. We consider the design of both the content and features to be important to ensure public bodies use the tool. In producing the tool not all these features and content are needed at once. They can be released and updated in stages.

5.10.1 Tool content recommendations

The tool needs to include the recommendations summarised in Section 5. Additional content is needed to provide context, technical guidance, and links to useful resources. We recommend the following are considered:

- A step-by-step process for public bodies and/or types of adaptation decision-makers to follow to complete scenario analysis in their context.
- Technical guidance on assessment of risk, using the exposure / hazard / vulnerability framework (Cardona et al., 2012).
- Technical guidance on how to translate data between RCPs and global warming levels, see Appendix FAppendix F.
- Material helping with communication of risk and uncertainty.
- Worked examples of analysis.
- Educational materials describing scenario analysis.
- A description of the limitations of the approach and data.

5.10.2 Tool features recommendations

The platform and format of the tool should be selected to provide the following features:

- Accessibility to public bodies including consideration of software requirements.
- Ability to roll out updates of the content effectively when new data becomes available.
- A clear guided pathway through the parts of the tool, potentially with interaction to allow users to make decisions based on their needs.

As well as this we recommend an awareness campaign and engagement or training programme to encourage use of the tool.

Examples of scenario analysis tools

Most examples available of scenario analysis tools are aimed at organisations in the private sector preparing climate-related disclosures. There are good examples of toolkits for scenario analysis from New Zealand's Ministry for the Environment (no date) and for adaptation from Local Partnerships (no date). These examples take different approaches to different use cases, but both set out a clear process and link to further helpful resources.

6 Conclusions

This research has highlighted the importance of climate scenario analysis for effective adaptation planning, despite the lack of policy and guidance specific to this area. Our research findings were derived from a holistic review of policies, guidance and stakeholder insights, as well as an examination of current practices and publicly available data.

Our findings underscore the importance of considering a broad array of climate hazards, noting however this may be limited by data availability. The review also confirmed the importance of considering multiple scenarios across a variety of timeframes, including into the long term, to capture the uncertainty of future climate change.

Stakeholder engagement revealed a significant need for improved communication of climate risks and greater climate literacy. It also demonstrated clear support for a decision tool that can help standardise and streamline the scenario analysis process, making it more accessible and consistent across Scottish organisations.

Based on our research findings, we have made recommendations covering nine key factors that should be considered when undertaking scenario analysis.

The recommendations provided aim to guide the Scottish Government in developing a clear, practical decision tool for public bodies to use, which can make scenario analysis easier and more consistent. These include prescribed scenarios, consistent timeframes and a focus on quantitative analysis while recognising the value of qualitative insights. Additionally, we emphasise the need for iterative updates to scenario analysis to incorporate new data and evolving climate science.

We hope with this report that by defining some factors of the scenarios that organisations should consider within their scenario analysis, they will be able to spend more time on trying to understand how their organisation could respond to those scenarios and less time on identifying plausible scenarios to assess.

Ultimately, by implementing these recommendations and developing a robust decision tool, we hope public bodies in Scotland can enhance their climate resilience, ensuring that adaptation measures are well-informed, cost-effective and aligned with broader climate goals.

7 References

Adaptation Scotland (2021). *Climate Projections for Scotland – Summary*. Available at: climate-projections-scotland-summary-dec21.pdf

Armstrong McKay, D.I., Staal, A., Abrams, J.F., Winkelmann, R., Sakschewski, B., Loriani, S., Fetzer, I., Cornell, S.E., Rockström, J. and Lenton, T.M. (2022). *Exceeding 1.5°C global warming could trigger multiple climate tipping points.* Science, 377(6611). doi:10.1126/science.abn7950

Betts, R.A. and Brown, K. (2021). *Introduction. In: The Third UK Climate Change Risk Assessment Technical Report* [Betts, R.A., Haward, A.B. and Pearson, K.V. (eds.)]. Prepared for the Climate Change Committee, London. Available at: Introduction - UK Climate Risk

Cardona, O.D., van Aalst, M.K., Birkmann, J., Fordham, M., McGregor, G., Perez, R., Pulwarty, R.S., Schipper, E.L.F., and Sinh, B.T. (2012). *Determinants of risk: exposure and vulnerability. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge: Cambridge University Press, pp. 65-108. Available at: 2 - Determinants of Risk: Exposure and Vulnerability (ipcc.ch)

CCC (2020). *Why do we look at high warming levels when assessing UK climate risk?* Available at: Why do we look at high warming levels when assessing UK climate risk? - Climate Change Committee

CCC (2021). *Independent Assessment of UK Climate Risk - Advice to Government - For the UK's third Climate Change Risk Assessment (CCRA3)*. Available at: Independent-Assessment-of-UK-Climate-Risk-Advice-to-Govt-for-CCRA3-CCC.pdf (theccc.org.uk)

CCC (2022). *Is Scotland climate ready? 2022 Report to Scottish Parliament.* Available at: Is Scotland climate ready? 2022 Report to Scottish Parliament (theccc.org.uk)

CCC (2023). *Adapting to climate change - Progress in Scotland.* Available at: Adapting to climate change - Progress in Scotland (theccc.org.uk)

CCC (2024). Proposed methodology for the Fourth Climate Change Risk Assessment – Independent Assessment (CCRA4-IA). Available at: Proposed methodology for the Fourth Climate Change Risk Assessment - Independent Assessment (CCRA4-IA) - Climate Change Committee (theccc.org.uk) [Accessed: September 2024]

CCC (no date). *Introduction to the CCRA*. Available at: Introduction to the CCRA - Climate Change Committee (theccc.org.uk)

Cliffe, M., Abrams, J.F., Barker, M., Branum-Burns, K., Campbell, R., Cordinale, M., Clark, M., Clark, N., Lalande, W., Laskey, T., Lenton, T.M., Matthews, L., Oliver, J., Picot, R., and Pilcher, S. (2023). *No Time To Lose: New Scenario Narratives for Action on Climate Change*. Available

at: No-Time-To-Lose-New-Scenario-Narratives-for-Action-on-Climate-Change-Full-Report.pdf (greenfuturessolutions.com)

Climate Change (Scotland) Act 2009. Available at: Climate Change (Scotland) Act 2009.

Commission Delegated Regulation (EU) 2023/2772 of 31 July 2023 supplementing Directive 2013/34/EU of the European Parliament and of the Council as regards sustainability reporting standards (2023). Available at: Delegated regulation - EU - 2023/2772 - EN - EUR-Lex (europa.eu)

Defra (2023). *Climate Adaptation Reporting - Fourth round guidance*.

Department for Business, Energy and Industrial Strategy (2022). *Mandatory climate-related financial disclosures by publicly quoted companies, large private companies and LLPs – Non-binding guidance*. Available at: Mandatory climate-related financial disclosures by publicly quoted companies, large private companies and LLPs (publishing.service.gov.uk)

Dynamic Coast (accessed 2024). Available at: Dynamic Coast [Accessed: September 2024]

FRC (2022). *CRR Thematic review of TCFD disclosures and climate in the financial statements.* Available at: FRC TCFD disclosures and climate in the financial statements July 2022

HM Treasury (2022, last updated 2024). *The Green Book (2022)*. Available at: The Green Book (2022) - GOV.UK (www.gov.uk) [Accessed: September 2024]

IFRS (2023). *IFRS S2 Climate-related Disclosures.* Available at: ISSB-2023-A – Issued IFRS Standards

Lee, J.-Y., Marotzke, J., Bala, G., Cao, L., Corti, S., Dunne, J.P., Engelbrecht, F., Fischer, E., Fyfe, J.C., Jones, C., Maycock, A., Mutemi, J., Ndiaye, O., Panickal, S., and Zhou, T. (2021). *Future Global Climate: Scenario-Based Projections and Near-term Information* in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R., and Zhou, B. (eds.)]. Cambridge: Cambridge University Press, pp. 553–672. doi:10.1017/9781009157896.006.

Local Partnerships (no date). *Climate adaptation toolkit and risk generator.* Available at: Climate adaptation toolkit and risk generator (localpartnerships.gov.uk) [Accessed: September 2024]

Met Office (2023). *Making sense of climate change projections*. Available at: Making sense of climate change projections | Official blog of the Met Office news team

MIT (2019). *Climate-Related Financial Disclosures - The Use of Scenarios*. Available at: Climate Finance Disclosures - Scenarios.pdf (mit.edu) [Accessed: September 2024]

Ministry for the Environment [New Zealand] (no date). *Climate scenarios toolkit*. Available at: Climate scenarios toolkit | Ministry for the Environment [Accessed: September 2024]

Moreira Sousa, A. (2022). *Staying safe in extreme heat – UK Health Security Agency*. Available at: Staying safe in extreme heat – UK Health Security Agency (blog.gov.uk)

Reisinger, A., Howden, M., Vera, C., Garschagen,M., Hurlbert, M., Kreibiehl, S., Mach, K.J., Mintenbeck, K., O'Neill, B., Pathak, M., Pedace, R., Pörtner, H., Poloczanska, E., Rojas Corradi, M., Sillmann, J., van Aalst, M., Viner, D., Jones, R., Ruane, A.C., and Ranasinghe, R. (2020) *The Concept of Risk in the IPCC Sixth Assessment Report: A Summary of Cross-Working Group Discussions*. Geneva: Intergovernmental Panel on Climate Change, pp15. Available at: Risk-guidance-FINAL_15Feb2021.pdf (ipcc.ch)

Scotland's Environment (2024). *Changing climate.* Available at: Changing climate | Scotland's environment web [Accessed: September 2024]

Scottish Government (2011). *Public bodies climate change duties: putting them into practice, guidance required by part four of the Climate Change (Scotland) Act 2009*. Available at: Public bodies climate change duties: putting them into practice, guidance required by part four of the Climate Change (Scotland) Act 2009 - gov.scot

Scottish Government (2022). *NHS Scotland Climate Emergency & Sustainability Strategy 2022-2026.* Available at: NHS Scotland Climate Emergency and Sustainability Strategy 2022-26 (www.gov.scot)

Scottish Government (2023a). *BICS weighted Scotland estimates: data to wave 88.* Available at: BICS weighted Scotland estimates: data to wave 88 - gov.scot (www.gov.scot)

Scottish Government (2023b). *Coastal Change Adaptation Plan Guidance*. Available at: Coastal Change Adaptation Plan Guidance

Scottish Government (2024). *Scottish National Adaptation Plan 2024 – 2029 Actions today, for a climate resilient future.* Available at: Scottish National Adaptation Plan (2024-2029) (www.gov.scot)

Seneviratne, S.I., Zhang, X., Adnan, M., Badi, W., Dereczynski, C., Di Luca, A., Ghosh, S., Iskandar, I., Kossin, J., Lewis, S., Otto, F., Pinto, I., Satoh, M., Vicente-Serrano, S.M., Wehner, M., and Zhou, B. (2021) *Weather and Climate Extreme Events in a Changing Climate Supplementary Material* in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S.L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J.B.R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R., and Zhou, B. (eds.)]. Available at: 11SM -

Weather And Climate Extreme Events in a Changing Climate Supplementary Material (ipcc.ch)

SP Energy Networks (2021). *Climate Resilience Strategy*. Available at: Annex_4A.7-Climate_Resilience_Strategy.pdf (spenergynetworks.co.uk)

Sustainable Scotland Network (2023). *Public Bodies Climate Change Reporting 2021/22 Analysis Report.* Available at: Sustainable Scotland Network Analysis Report 2021 to 2022

Swinney, J (2024). *Priorities for Scotland: First Minister's statement*. Available at: Priorities for Scotland: First Minister's statement - 22 May 2024 - gov.scot (www.gov.scot)

TCFD (2017). *Recommendations of the Task Force on Climate-related Financial Disclosures.* Available at: FINAL-2017-TCFD-Report.pdf (bbhub.io)

TCFD (2020). *Guidance on Scenario Analysis for Non-Financial Companies*. Available at: 2020-TCFD_Guidance-Scenario-Analysis-Guidance.pdf (bbhub.io)

The Companies (Strategic Report) (Climate-related Financial Disclosure) Regulations 2022 (SI 2022/31). Available at: The Companies (Strategic Report) (Climate-related Financial Disclosure) Regulations 2022

The Occupational Pension Schemes (Climate Change Governance and Reporting) Regulations 2021 (SI 2021/839). Available at: The Occupational Pension Schemes (Climate Change Governance and Reporting) Regulations 2021

Watkiss, P. and Betts, R.A. (2021). *Method. In: The Third UK Climate Change Risk Assessment Technical Report* [Betts, R.A., Haward, A.B. and Pearson, K.V. (eds.)]. Prepared for the Climate Change Committee, London. Available at: Chapter 2: Method - UK Climate Risk

Watkiss, P (2022). *The Costs of Adaptation, and the Economic Costs and Benefits of Adaptation in the UK*. Available at: The Costs of Adaptation, and the Economic Costs and Benefits of Adaptation in the UK (theccc.org.uk)

8 Appendices

Appendix A Limitations, reliance and liability

This report has been prepared by the Government Actuary's Department (GAD) at the request of ClimateXChange on behalf of the Scottish Government.

The report has been prepared for the use of ClimateXChange and the Scottish Government and is published on ClimateXChange's website. Therefore, we acknowledge that it will likely have a wider audience than the intended recipients. However, other than ClimateXChange and Scottish Government, no person or third party is entitled to place any reliance on the contents of this report, except to any extent stated herein. GAD has no liability to any person or third party for any action taken or for any failure to act, either in whole or in part, on the basis of this report.

In preparing this report, GAD has relied on publicly available data and other information as described in the report. Any checks that GAD has made on this information are limited to those described in the report, including any checks on the overall reasonableness and constancy of the data. These checks do not represent a full independent audit of the data supplied. In particular, GAD has relied on the general completeness and accuracy of the information supplied without independent verification.

GAD provides both actuarial and other advice. For clarity, this report provides research findings and recommendations and as a result is not subject to the Technical Actuarial Standard TAS 100 issued by the Financial Reporting Council (FRC) for actuarial work in the UK.

There is significant uncertainty involved when assessing climate risks. Care has been taken to ensure that, where material, this work has taken into consideration the latest climate change research and appropriate climate data.

The Institute and Faculty of Actuaries (IFoA), the regulatory body for GAD's actuaries, has issued three climate change related risk alerts to members. These have all been considered when preparing this work.

Over time, as the global emissions pathway becomes clearer and there are advances in science and technology, our view of future climate risks will undoubtably change. Future developments may have a material impact on the results and conclusions contained in this work and care should be taken when referring back to this analysis after the date of issue.

One of the challenges for public sector organisations (and others) conducting scenario analysis is the range of potential approaches and assumptions that can be taken. Through preparing this guidance we have considered various other approaches in producing the final recommendations, some of which have been outlined in Section 45.

Appendix B Data sources reviewed[5]

IPCC WG1 Interactive Atlas
Climate Analytics Climate Impact Explorer
Climate Analytics Climate Risk Dashboard
Global Infrastructure Climate-Related Risk Analytics
Environment Agency Climate Impacts Tool
Met office Climate Data Portal
UK Climate Projections User Interface (UKCP18)
NatureScot GIS database
Marine Scotland
Copernicus Climate Data Store (extreme climate indices)
Copernicus Climate Data Store (changes in water levels)
Copernicus Climate Data Store (climate and energy indicators)
Copernicus Bioclimatic Indicators
World Resources Institute Aqueduct
UK Climate Risk Indicator Explorer
SEPA Flood Maps
SEPA Flood Risk Management Maps
World Bank Climate Knowledge Portal
Climate Central's Coastal Risk Screening Tool

[5] Links correct at date of publication.

Appendix C Policy and guidance review

Documents reviewed:

Title	Category	Publication Year	Overview
Financial Reporting Council (FRC): CRR Thematic review of TCFD disclosures and climate in financial statements	Best practice	2022	The FRC reviewed the TCFD disclosures and climate related reporting of twenty-five premium listed companies.
European Environment Agency (EEA): European Climate Risk Assessment	Best practice	2024	The EEA named 36 climate risks across Europe, considering factors such as severity, policy readiness and risk ownership.
HM Government: UK Climate Change Risk Assessment	Best practice	2022	HM Government outlined the key climate change risks and opportunities faced by the UK today, considering 61 UK-wide climate risks across various sectors in the economy. Prioritised areas for action include risks to habitats, soil health, carbon stores, food supply, power systems, and human health from increased heat exposure.
FRC and the University of Manchester: Climate Scenario Analysis: Current Practice and Disclosure Trends	Best practice	2021	Research conducted by the Alliance Manchester Business School in collaboration with the FRC delves into the practical processes and approaches used by UK companies engaged in climate scenario analysis. The report sheds light on motivations, value, common phases and challenges faced during this analysis, helping companies identify and prepare for climate change impacts on their business models. The study emphasises the importance of embedding climate-related scenario analysis into strategic planning processes.
Transport Scotland: Transport Scotland's Approach to Climate Change Adaptation & Resilience	Best practice	2023	The report outlines key climate risks affecting Scotland's transport system and discusses strategic outcomes for road, rail, aviation and maritime networks. It emphasises a well-adapted, safe, reliable and resilient transport system, providing a framework based on up-to-date climate science addressing each network's specific challenges.
Climate Change Committee (CCC): Is Scotland climate ready?	Best practice	2022	The CCC assesses Scotland's climate resilience progress. The report highlights adaptation efforts have stalled across sectors. CCC recommends clear targets, improved monitoring, and local initiatives are recommended for effective climate adaptation.
Scottish Government: Climate Ready Scotland: Second Scottish Climate Change Adaptation Programme 2019-2024	Policy	2019	A 5-year initiative aimed at preparing Scotland for the challenges posed by climate change. The report emphasises urgent action on emissions cuts and links adaptation and mitigation efforts. It outlines policies and proposals to address climate risks across

Title	Category	Publication Year	Overview
			sectors, including threats to food, water, health, biodiversity and Scotland's historic environment.
Scottish Government: Draft Scottish National Adaptation Plan (2024-2029)	Policy	2024	Scottish Government outlines actions to enhance Scotland's resilience to climate change. It addresses challenges like heatwaves, flooding and sea-level rise which are already affecting the country. The plan focuses on five outcomes: Nature Connects, Communities, Public Services and Infrastructure, Economy, Industry, and Business, and international Action.
UK Legislation: The Companies (Strategic Report) (Climate-related Financial Disclosure) Regulations 2022	Policy	2022	Department of Business and Trade (DBT) outlines regulations requirements on certain publicly quoted companies and large private companies to incorporate TCFD-aligned climate disclosures in their annual reports. Companies must reveal climate risks, management strategies, and the impact of climate change on their business. Focuses on enhancing transparency and informed decision-making about climate risks and opportunities.
UK Legislation: Limited Liability Partnerships (Climate-related Financial Disclosure) Regulations 2022	Policy	2022	DBT outlines regulations enhancing transparency for large UK traded and limited liability partnerships (LLPs) (meeting specific employee criteria) to include climate related disclosures in their strategic reports, including risks and opportunities.
UK Legislation: The Occupational Pension Schemes (Climate Change Governance and Reporting) Regulations 2021	Policy	2021	The Department for Work and Pensions (DWP) regulations outline regulations requiring trustees of occupational pension schemes to understand climate change risks and opportunities, aligning with TCFD recommendations. The goal is to enhance governance quality and encourage proactive management of climate-related risks.
Department for Environment and Rural Affairs (DEFRA): Consultation on the Fourth Round of the Climate Adaptation Reporting: Summary of responses and government response	Other	2023	Defra outlines approach for enhancing climate adaptation reporting in the UK. Consultation seeks input from stakeholders on reporting requirements, guidance and risk assessment related to climate change impacts. Aims to improve transparency, informed decision-making and proactive management of climate risks within various sectors.
CCC: Adapting to climate change Progress in Scotland	Policy	2023	CCC evaluates Scotland's progress in climate adaptation, particularly during the second Scottish Climate Change Adaptation Programme (SCCAP2). Overall progress remains slow, with gaps in delivery and implementation. The (now recently published) SNAP3 must address these challenges, embed adaptation in legislation

Title	Category	Publication Year	Overview
			and enhance monitoring and evaluation systems.
Taskforce on Climate Related Financial Disclosures (TCFD): TCFD Recommendations	Recommendations and Guidance	2017	TCFD aims to ensure consistent, comparable and reliable climate-related financial disclosures by companies. It covers four key areas: governance, strategy, risk management, and metrics and targets.
EU Regulation: European Sustainability Reporting Standards	Policy	2023	The European Sustainability Reporting Standards (ESRS) were adopted by the EU commission in 2023 to make corporate economic, social and governance (ESG) reporting across the EU more consistent, comparable, and achieve greater standardisation.
IFRS: S2 Climate-related Disclosures	Recommendations and Guidance	2023	The ISSB outlines requirements for disclosing information about an entity's climate-related risk and opportunities. This standard enhances transparency by guiding organisations in reporting climate impacts, strategies, and metrics.
TCFD: Implementing the Recommendations of the Task Force on Climate-related Financial Disclosures	Application Guidance	2021	The TCFD provides widely adoptable recommendations for organisations across sectors and jurisdictions, which aim to elicit decision-useful, forward-looking information that can be incorporated into mainstream financial findings.
TCFD: Guidance on Scenario Analysis for Non-Financial Companies	Application Guidance	2020	The TCFD released guidance helping non-financial companies in using climate-related scenarios to assess risks and opportunities, contributing to strategy resilience and flexibility.
Accounting for Sustainability (A4S): TCFD Climate Scenario Analysis	Application Guidance	2021	Accounting for Sustainability (A4S) has published guidance for finance teams on frequently asked questions on scenario analysis, which is useful for preparers of TCFD reports, although targeted towards the private sector.
Department for Work and Pensions (DWP): Governance and reporting of climate change risk: guidance for trustees of occupational schemes	Application Guidance	2021	DWP brought in regulation for private sector pension schemes to complete TCFD reporting in 2021.
Department for Business and Trade (DBT): Mandatory climate-related financial disclosures by publicly quoted companies, large private companies and LLPs	Application Guidance	2022	The Financial Conduct Authority (FCA) updated their listing rules (in 2020 for premium listed and 2021 for standard listed companies), and DBT amended the Companies Act in 2022 to bring in TCFD aligned reporting requirements for publicly listed companies and LLPs in the UK.
Coalition for Climate Resilient Investment: Guidelines for Integrating	Application Guidance	2021	The Physical Climate Risk Assessment Methodology (PCRAM) developed by the Coalition for Climate Resilient Investment

Title	Category	Publication Year	Overview
Physical Climate Risks in Infrastructure Investment Appraisal			(CCRI), integrates physical climate risks (PCRs) into investment appraisal practices. It guides infrastructure investment practitioners in assessing climate risk analytics, credit quality and investment decisions. The CCRI aims to enhance investment decision-making and foster resilient economic and communities world-wide.
Transition Plan Taskforce (TPT): Building Climate-ready Transition Plans: Including adaptation and resilience for comprehensive transition planning approaches	Other	2024	The Transition Plan Taskforce (TPT) provides guidance for comprehensive transition planning, emphasising the integration of adaptation and physical resilience considerations into transition plans.
TPT: Disclosure Framework	Other	2023	The TPT sets out gold standard recommendations for developing and disclosing robust and credible transition plans. Aligned with international standards, this framework provides essential tools for businesses navigating the global transition to net zero.
TPT: Explore the Disclosure Recommendations	Recommendations and Guidance	2024	The TPT provides essential guidance for robust and credible plan transition plan disclosures. It builds upon the TPT Disclosure Framework, offering practical recommendations and a valuable resource for navigating their global transition to net zero.
ClimateXChange: Taking a managed adaptive approach to flood risk management planning - evidence for guidance	Recommendations and Guidance	2022	ClimateXChange investigates adaptive flood risk management planning in Scotland, focusing on addressing barriers identified in a 2019 report and examinates three case studies: Outer Hebrides coastal adaptation, Moray fluvial adaptation, and The Clyde tidal adaptation. The research implies the importance of a managed adaptive approach, flexibility, stakeholder involvement, and readiness assessments for successful adaptation investments.
Scottish Government: Coastal Change Adaptation Plan Guidance	Recommendations and Guidance	2023	The Scottish Government's interim guidance on Coastal Change Adaptation Plans aims to support local authorities and their partners across Scotland. These plans go beyond Shoreline Management Plans by considering long-term adaptation and resilience for coastal communities and assets in the face of climate change and coastal shifts. The guidance emphasises principles of adaptation, natural system collaboration, and community engagement, providing a framework for safeguarding coastlines.
Network Rail: Third Adaptation Report	Best practice	2021	Network Rail published this report that focuses on understanding and managing climate change impact. It emphasises

Title	Category	Publication Year	Overview
			weather and climate risks, policy alignment, and investments in resilience. Implementation is still a challenge, but the organisation is committed to enhancing on-ground resilience.
Network Rail: Scotland's Railway Climate Ready Plan 2024 - 2029	Best practice	2024	Scotland's Railway climate ready plan discusses improving railway assets to withstand climate challenges, incorporating expertise into decision-making, and laying groundwork for managing climate risks.
Intergovernmental Panel on Climate Change (IPCC): Climate Change 2022: Mitigation of Climate Change	Recommendations and Guidance	2022	The IPCC report provides a comprehensive assessment of global climate change mitigation efforts. It covers near-to-mid-term strategies, sectoral perspectives, policy considerations, innovation, and technology. The report aims to guide stakeholders in addressing the climate crisis while ensuring sustainable development.
CCC: Progress in reducing UK emissions	Recommendations and Guidance	2023	The CCC's report assesses the UK Government's actions in reducing emissions. Key highlights include the need for urgent policy implementation, transparent reporting, and collaboration with international frameworks. The report emphasises specific strategies such as demand-side policies, land use planning, and transitioning away from fossil fuels.
Scottish Government: Scotland's response to the CCC Annual Progress Report 2022 Recommendations	Recommendations and Guidance	2022	This Scottish Government report was a response to the 2022 CCC annual progress report. The report evaluates recommendations from the CCC with the Scottish Government accepting or partially accepting 98/99 recommendations.
Sustainable Scotland Network (SSN): Public Bodies Climate Change Reporting 2021/2022	Best practice	2022	This report presents summary analysis and key findings from 188 public sector bodies' annual climate change reporting across the 2021/22 reporting period
Network Rail: Scotland's Railway CP6 Weather Resilience and Climate Change Adaptation Plans	Best practice	2020	The aim of the report is to define Scotland's Railway Weather Resilience and Climate Change Adaptation (WRCCA) Plan for Control Period 6 (2019-2024)
Defra: Accounting for the effects of climate change - Supplementary Green Book guidance	Recommendations and Guidance	2024	Supplementary guidance to HM Treasury's Green Book supports analysts and policy makers to ensure, where appropriate, that policies and projects are resilient to the effects of climate change and that these are considered when appraising options.
National Audit Office: Overcoming challenges to managing risks in government	Other	2023	A guide outlines the challenges to managing risks in government and ways senior leaders and risk practitioners can overcome these challenges.

Title	Category	Publication Year	Overview
Sniffer: Evidence for the third UK Climate Change Risk Assessment CCRA3 - Summary for Scotland	Recommendations and Guidance	2022	The summary presents comprehensive evidence on the current and future impacts of climate change in Scotland. It details the specific risks facing Scotland, including those related to weather extremes, biodiversity loss, and economic vulnerabilities. It aims to inform policy and action to enhance resilience and adaptability in the face of climate change across Scotland.

Appendix D Stakeholder engagement

D.1 Organisations and individuals engaged with

We would like to thank the following organisations who contributed to our research and provided useful insights on their areas of expertise and experience of completing climate scenario analysis:

Climate Change Committee
Dynamic Coast
Edinburgh City Council
Forestry and Land Scotland
Highlands and Islands Airports Limited
Historic Environment Scotland
Met Office
NatureScot
Network Rail
Paul Watkiss Associates Limited
Scottish Environmental Protection Agency (SEPA)
Scottish Government
Scottish Water
Sniffer
Transport Scotland
University of Glasgow.

Appendix E Climate risks and opportunities

Climate risks and opportunities are often broken down into risks related to the physical impacts of climate change and risks related to the transition to a lower-carbon economy. The TCFD (2017) further breaks down transition and physical climate risks as summarised below.

E.1 Physical risks

Acute:

- River and coastal flooding
- Surface water flooding
- Storm events – cyclone, hurricane etc
- Storm sea level surge

Chronic:

- Change in precipitation
- Rising mean temperatures
- Sea level rise and coastal change

E.2 Transition risks

Policy and legal:

- Increasing price of GHG emissions
- Enhanced emissions reporting requirements
- Regulation of products and services
- Exposure to litigation

Technology:

- Substitution with lower emitting products and services
- Unsuccessful investment in new technologies
- Costs to transition to lower emissions technologies

Market:

- Change in customer behaviour
- Uncertainty in market systems
- Increased cost of raw materials

Reputation:

- Change in customer preferences
- Stigmatisation of sector
- Increased stakeholder concern or negative stakeholder feedback

Appendix F Emission-based scenarios and global warming levels

IPCC Coupled Model Intercomparison Project Phase 5 (CMIP5) – used for the IPCC's 5th assessment report and UKCP18 (Seneviratne et al., 2021):

RCP	Associated mid-century temperature increase relative to pre-industrial temperature (°C) Multi-model average, 5-95% range	Associated end of century temperature increase relative to pre-industrial temperature (°C) Multi-model average, 5-95% range
RCP 2.6	1.7 (1.3-2.2)	1.7 (1.1-2.3)
RCP 4.5	2.0 (1.5-2.6)	2.5 (1.8-3.2)
RCP 6.0	1.9 (1.4-2.4)	2.8 (2.3-3.6)
RCP 8.5	2.5 (1.9-3.2)	4.4 (3.2-5.5)

IPCC Coupled Model Intercomparison Project Phase 6 (CMIP6) – used for the IPCC's 6th assessment report (Lee et al., 2021):

SSP-RCP	Associated mid-century temperature increase relative to pre-industrial temperature (°C) Multi-model average, 5-95% range	Associated end of century temperature increase relative to pre-industrial temperature (°C) Multi-model average, 5-95% range
SSP1 – 1.9	1.7 (1.1-2.4)	1.5 (1.0-2.2)
SSP1 – 2.6	1.9 (1.2-2.7)	2.0 (1.3-2.8)
SSP2 – 4.5	2.1 (1.5-3.0)	2.9 (2.1-4.0)
SSP3 – 7.0	2.3 (1.6-3.2)	3.9 (2.8-5.5)
SSP5 – 8.5	2.6 (1.8-3.4)	4.8 (3.6-6.5)

How to cite this publication:
Grace, E., Marcinko, C., Paterson, C., Stobbs, W. (2024) 'Using future climate scenarios to support today's decision making' ClimateXChange. http://dx.doi.org/10.7488/era/5567

This work was supported by the Rural and Environment Science and Analytical Services Division of the Scottish Government (CoE – CXC).

ClimateXChange
Edinburgh Climate Change Institute
High School Yards
Edinburgh EH1 1LZ
+44 (0) 131 651 4783

info@climatexchange.org.uk
www.climatexchange.org.uk

If you require the report in an alternative format such as a Word document, please contact info@climatexchange.org.uk or 0131 651 4783.