A Framework for Measuring and Reporting of Climate-related Physical Risks to Built Assets

FEBRUARY 2022

Resilience and Nature-based Solutions Programme Partners:

Citation: *A Framework for Measuring and Reporting of Climate-related Physical Risks to Built Assets.* UK Green Building Council, 2022, London, UK.

Contents

Foreword

In April 2015, the Financial Stability Board (FSB) was asked to review how the financial sector can account for climate-related issues. Their response called for an improved understanding of climate-related risks, to be underpinned by better analysis and disclosure methods. Since then, the Task Force on Climate-related Financial Disclosures (TCFD) has been established, resulting in a series of reports and recommendations promoting transparency in pursuit of better climate-risk management.

In 2020, HM Treasury published its 'Roadmap towards mandatory climate-related disclosures', setting-out a path to align the UK economy with TCFD recommendations. Promisingly, more and more companies are now committed to measurement and reporting on the climate-related risks facing their assets and operations. However, to date, their focus has been on the transitional risks associated with a move away from fossil fuel dependency, as opposed to the impacts of physical risks that have been exacerbated by continued climate change, and so their approach needs to evolve.

This report provides comprehensive guidance for organisations to consider these physical climate risks in more detail, to understand how they are or will be impacted at the built asset scale. By measuring, interpreting, and reporting on the physical climate risks posed to assets, organisations can make better informed decisions that have benefits for their own operations and the future of the built environment.

The guidance comes at a critical point for organisations right across the built environment value chain, supporting TCFD alignment and providing an important step on the journey towards accurate and transparent physical climate-related risk measurement and disclosure.

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Legal & General Investment Management
and UKGBC Trustee

Glossary

Where relevant, working definitions related to the built environment are provided in *italics*.

Acute hazard: Sudden climatic impacts such as storm, flood or extreme heat events.

Built environment: The environment encompassing all forms of building (housing, industrial, commercial, hospitals, schools, etc.), and civil engineering infrastructure, both above and below ground and includes the managed landscapes between and around buildings[1]

Capacity: The combination of all the strengths, attributes and resources available within an organisation, community or society to manage and reduce disaster risks and strengthen resilience[2]. *In the built environment, capacity is defined as the combination of all the strengths, attributes, and resources available to the built asset to manage and reduce adverse impacts of climatic events and strengthen its resilience.*

Cascading effects: A cascading effect of climate impacts can take place when multiple effects resulting from climate change occur simultaneously. This combination of effects can generate further unexpected impacts which haven't been factored into a climate change risk assessment. *For example, flood and storm events occurring simultaneously could create storm surges which could drastically increase the severity of damage to a built asset*[3].

Chronic hazard: Climatic impacts which gradually build up over a long period of time such as sea level rise, overall temperature increase or changes in precipitation patterns.

Climate adaptation: Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change.[4]

Climate projection: Simulated response of the climate system to a scenario of future emissions or concentrations of greenhouse gases (GHGs) and aerosols and changes in land use, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario used, which is in turn based on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realised[5].

Climate resilience: The capacity to anticipate, prepare for and respond to hazardous events or trends related to climate. *In the built environment, it is the ability of buildings, landscapes, and infrastructures to adapt to – and reduce the impacts of – climate-related events, such as flooding or overheating*[6].

Climate-related financial risks: A set of potential risks that may result from climate change and that could potentially impact the safety and soundness of individual financial institutions and have broader financial stability implications for the banking system. These risks are typically classified as physical and transition risks[7].

Climate scenario: A plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that have been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models[8].

Consequence: A result of a particular action or situation, often one that is bad or not convenient.[9] I*n the built environment, consequence is defined as the adverse effects arising from a defined climatic event (hazard) to the built asset in the short, medium or longer term. This should take into account the Exposure, Vulnerability and Capacity of the built asset*[10, 11, 12].

Exposure: The fact of experiencing something or being affected by it because of being in a particular situation or place. *In the built environment, exposure is defined as the fact of the built asset being in a particular situation or place and therefore subject to a potential loss.*

Impact: The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather/climate events), exposure, and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure[13].

Physical hazard: A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage[14]. *In the built environment, a hazard is defined as climatic events that are acute or chronic which, in certain circumstances, could lead to adverse impacts to a built asset.*

Probability: The level of possibility of something happening[15]. *In the built environment, probability is defined as the likelihood over a given time period that adverse effects to the built asset will arise.*

Risk: The potential for adverse consequences[16], determined probabilistically as a function of hazard, exposure, vulnerability and capacity. *In the built environment, risk is defined as the potential loss including destroyed or damaged assets within a defined zone of influence which could occur in a specific period of time, which can be determined as a function of consequence and probability.*

Stranded asset: An asset which loses economic value well ahead of its anticipated useful life, whether that is a result of changes in legislation, market forces, disruptive innovation, societal norms, or environmental shocks[17].

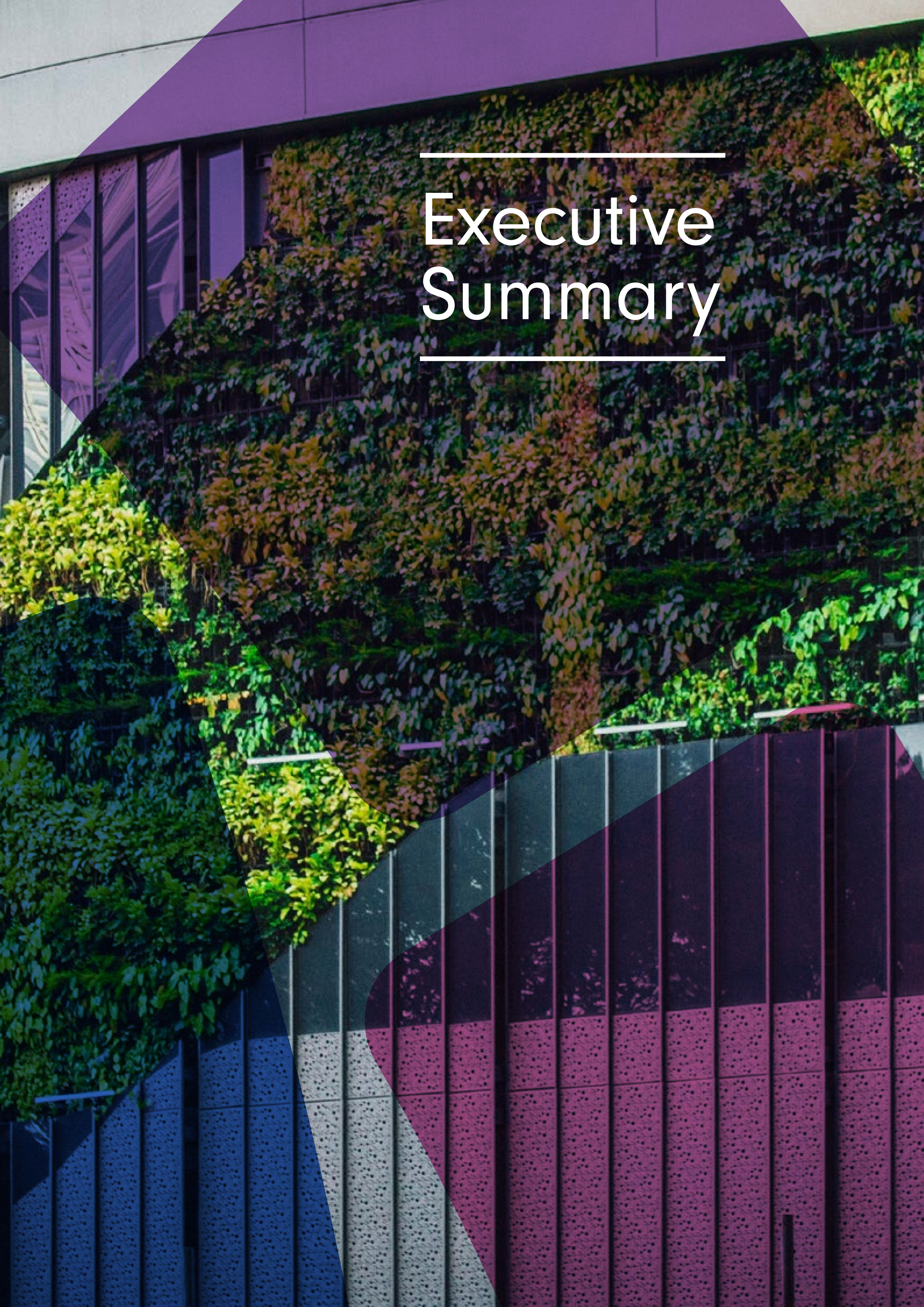
The Taskforce on Climate-Related Financial Disclosures (TCFD): A Task Force created by the Financial Stability Board (FSB) to improve and increase reporting of climate-related financial information.[18]

Transition risk: The risk associated with transitioning to a lower-carbon economy. This may entail extensive policy, legal, technology, and market changes to address mitigation and adaptation requirements related to climate change. Depending on the nature, speed, and focus of these changes, transition risks may pose varying levels of financial and reputational risk to organisations[19].

Uncertainty: A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour[20].

Vulnerability: The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.[21] In the built environment, vulnerability is defined as the susceptibility of the built asset to the adverse impacts of the climatic event (hazard).

Executive Summary



Extreme weather events resulting from climate change have intensified over the last seven years, posing significant challenges to the resilience of the built environment. Climate-induced physical hazards can affect both tangible built assets and their business supply chains, resulting in impacts across the entire investment cycle, such as increases in insurance premiums and higher incidences of stranded assets. To ensure that climate-related risks are effectively considered and priced into financial and organisational governance decisions, physical hazard risk assessments can be utilised to understand the risks a built asset faces across its lifetime.

Mandatory disclosure of climate-related risks is due to come into force from April 2022 for large organisations and financial institutions within the United Kingdom, aligned with the Task Force on Climate-Related Financial Disclosures' (TCFD) recommendations. If successful, this requirement is likely to expand to include smaller organisations by 2025. For asset owning organisations, alongside reporting transition risks from reducing greenhouse gas emissions, this will include a requirement to consider, measure, and report their risks arising from physical climate-related risks.

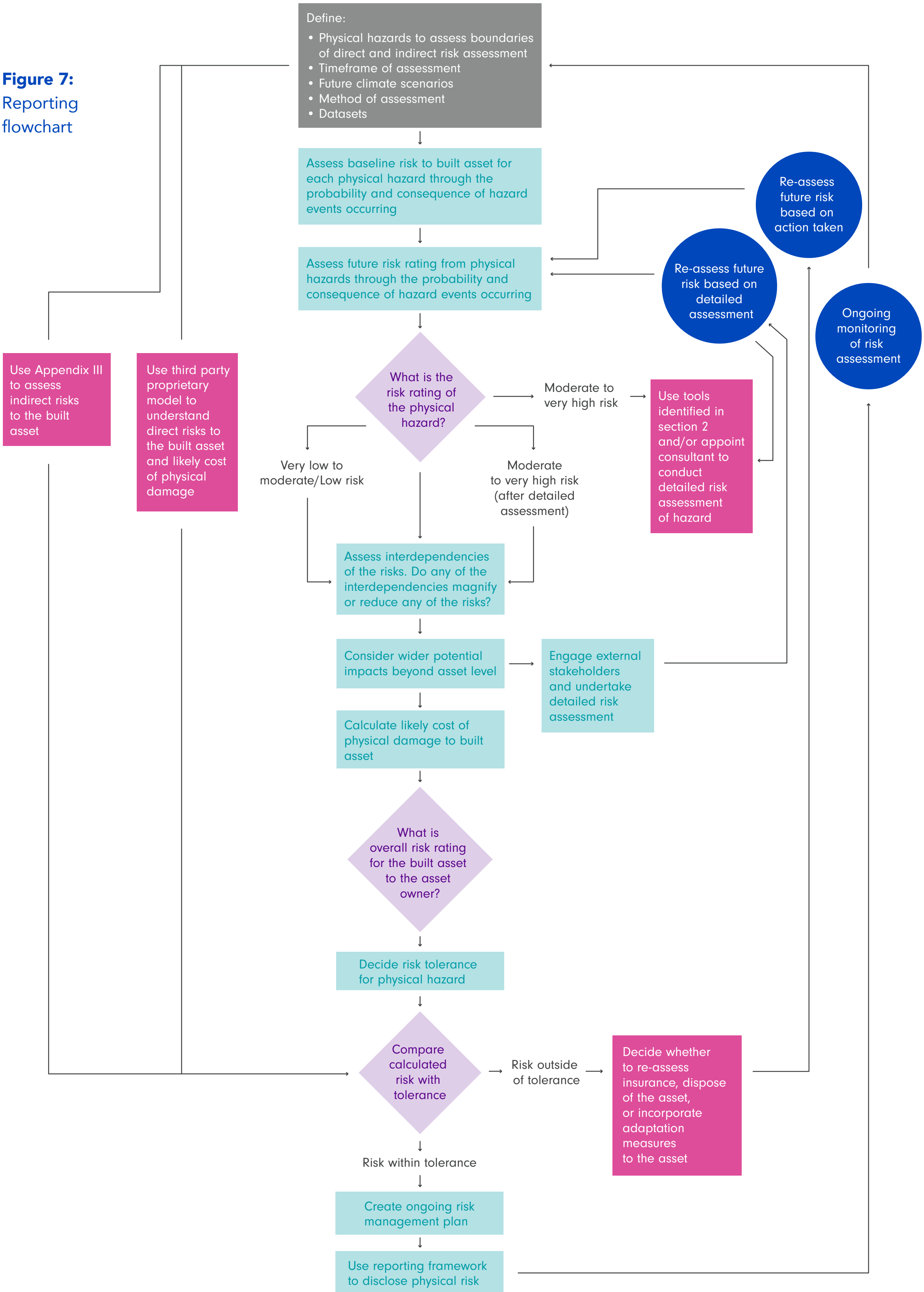
Whilst TCFD recommendations are moving the industry towards greater standardisation on physical risk disclosure, they lack the granularity necessary to explicitly guide organisations through this process at asset level. As a result, there is currently a lack of consensus within industry regarding measurement and disclosure methodologies.

This report provides guidance on understanding the physical risk assessment process and presents a methodology for measuring climate-related physical risks at the built asset scale, aligned with the TCFD recommendations. It includes information to consider and decisions to make prior to starting a physical risk assessment, how to assess baseline and future risks from physical hazards, how to assess an overall risk rating for a built asset and how to disclose physical risk. This process is illustrated in the reporting framework overleaf.

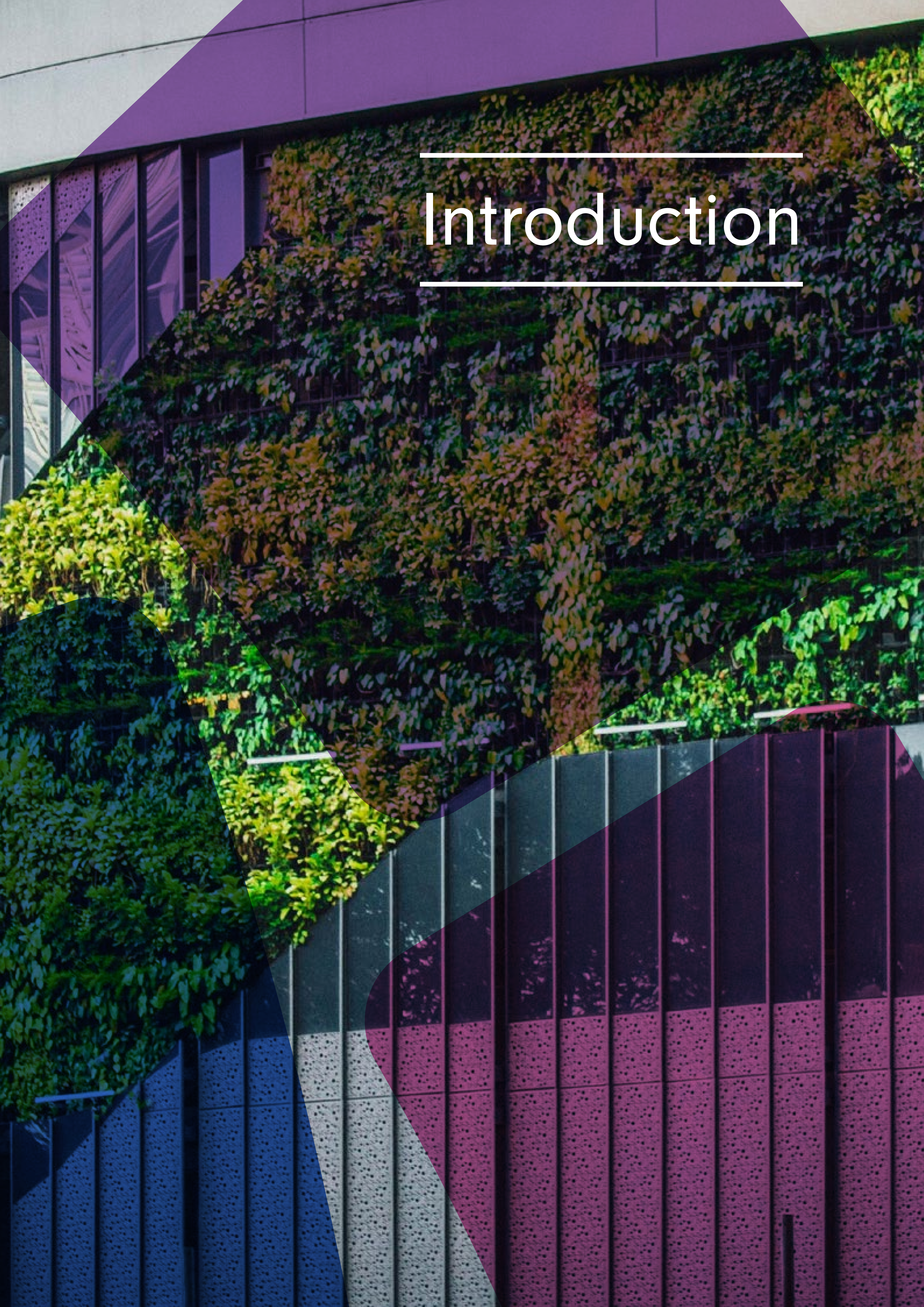
To support organisations facilitating their own analysis, a reporting framework is also provided which can be used to support the preparation of TCFD disclosure reports. The guidance provided within this report will result in an overview of the risks an asset may face and provides organisations starting their physical risk disclosure journey with an opportunity to get ahead of the curve before disclosure becomes mandatory.

By providing a methodology for the built environment, it is hoped that this report and framework will address the current lack of consensus on physical risk disclosure methodologies and increase the amount of climate-related physical risk assessments at built asset level.

Figure 7:
Reporting flowchart



Introduction



Threats from Climate Change are Increasing

Across the asset investment cycle, risks are increasing as a result of intensifying climate hazards.

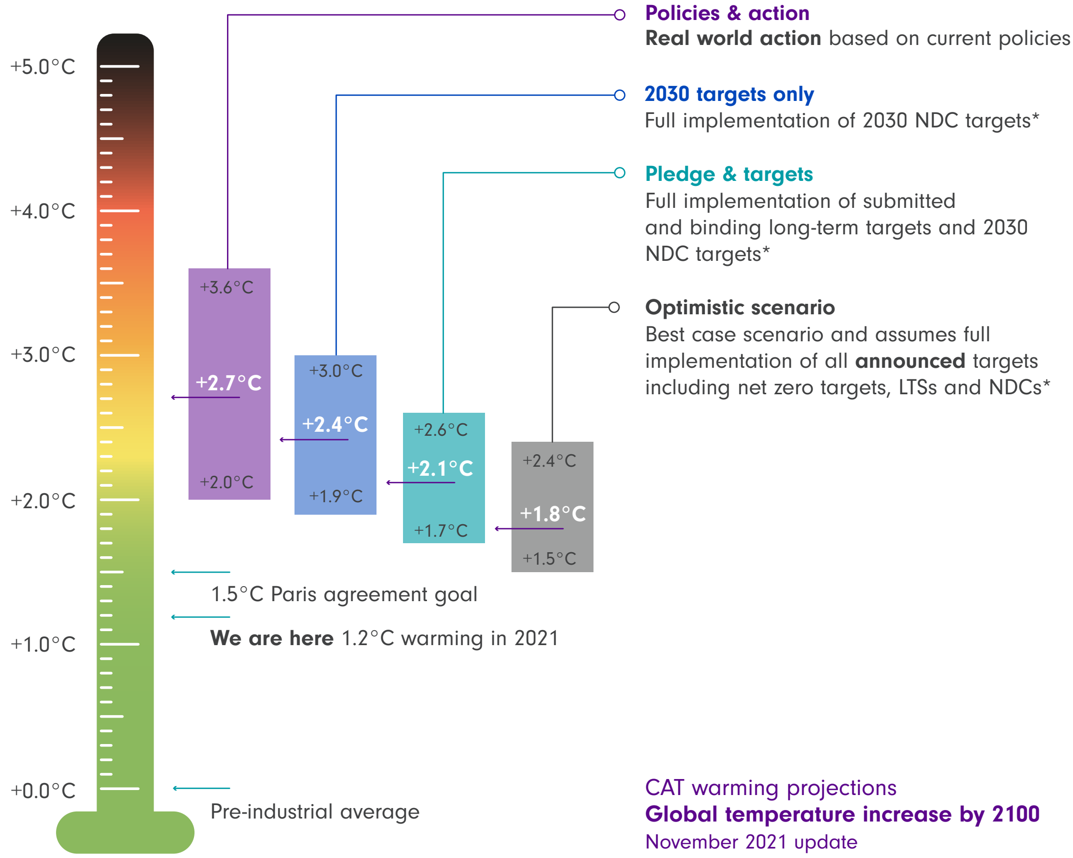
The past seven years have been the warmest since pre-industrial levels, with sea level rise accelerating globally, along with the frequency and intensity of extreme weather events. Exceptional heatwaves have been accompanied by sweeping wildfires across the United States, Canada, and the Mediterranean, whilst months' worth of rain fell in a few hours across China and parts of Europe, leading to catastrophic flooding.[22] Over the last 60 years, the average temperature of the UK has risen by 0.8°C and rainfall by 7.3%.[23]

In October 2021, the Intergovernmental Panel on Climate Change (IPCC) released their sixth assessment report on the physical science basis of climate change. The report defined the human influence on global climate change as now 'unequivocal' and outlined how observed changes in weather and climate extremes in every region of the globe had intensified since the last IPCC report was published in 2014.

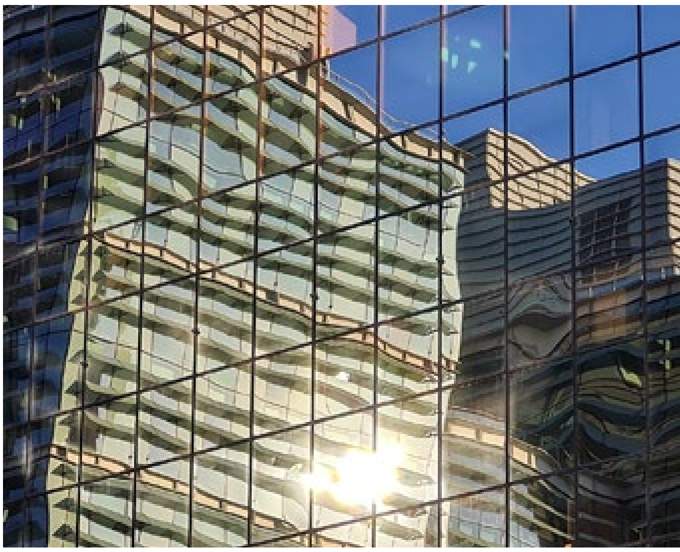
The findings of the Climate Change Committee's (CCC) Third Independent Assessment of UK Climate Risk (CCRA3) detailed this intensity further.[24] The report noted how the gap between the level of risk we face and the level of adaptation underway has widened since the last assessment in 2017. Crucially, the CCRA3 recognises that swift action to adapt to the physical impacts of climate change will be much cheaper in the long term than inaction against these risks.

The Climate Action Tracker (CAT) estimates global end-of-century warming based on the existing policies, actions, pledges, and targets made by each country (Figure 1).[25] As demonstrated in Figure 1, the CAT estimates that following COP26 in November 2021, real world action is set to deliver a 2.7°C rise. Even if ambitious pledges and targets are met, it is expected that we will see a global temperature increase of 2.1°C, far exceeding the commitments of the Paris Climate Agreement.

Figure 1:
Climate action tracker thermometer

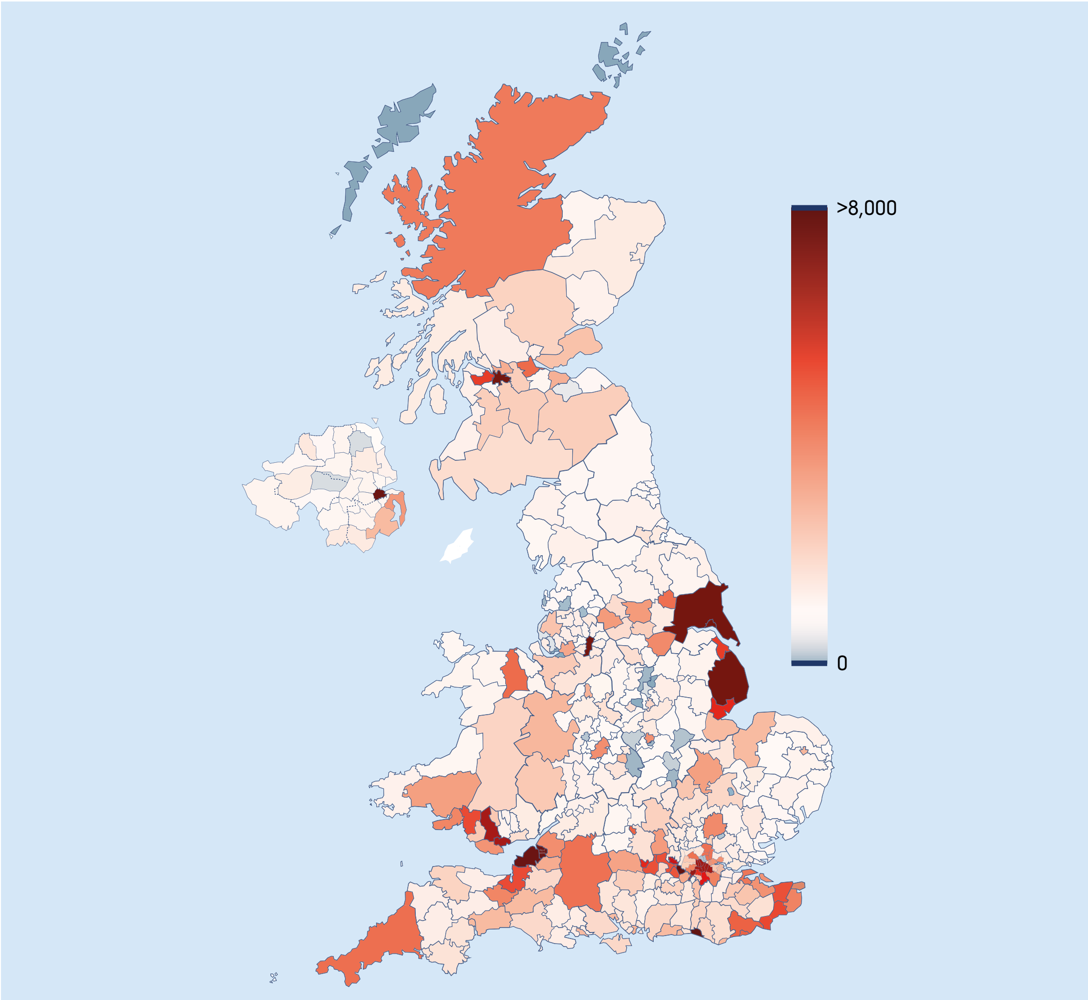


With every degree of warming, the likelihood increases for destructive climate impacts and extreme weather events. For the built environment, this poses challenges across the entire investment cycle, such as increases in insurance premiums, accelerated depreciation of assets, higher incidences of stranded assets, and considerably greater capital costs in the future. Intensifying climate hazards therefore pose physical risks to both tangible assets and business supply chains, threatening their financial viability.[26]



* If 2030 NDC targets are weaker than projected emissions levels under policies & action, CAT use levels from policy & action.

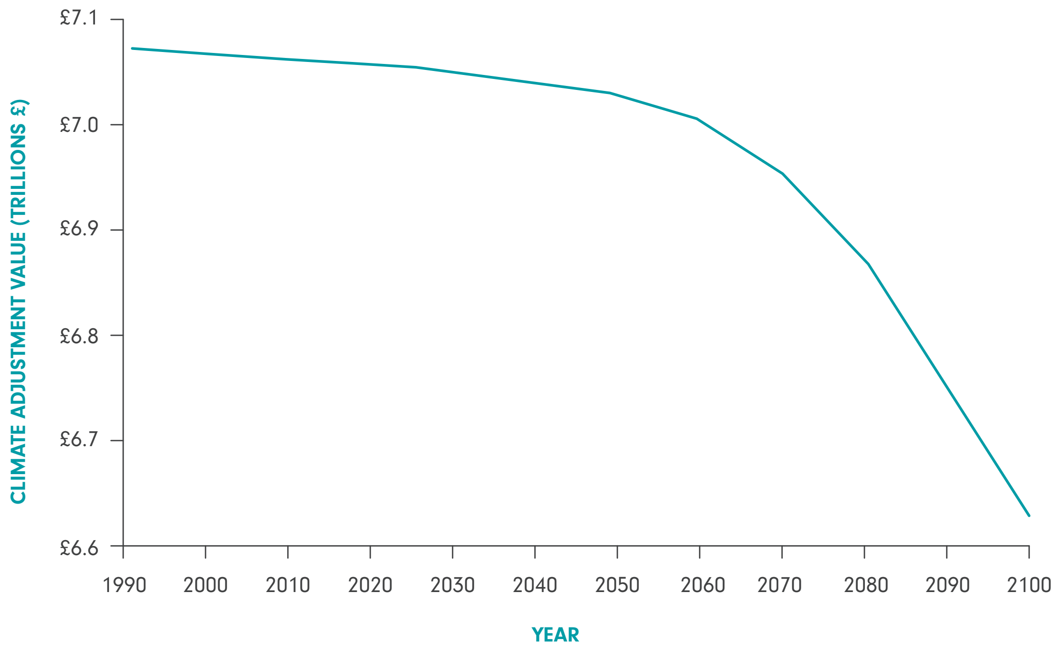
Figure 2: Number of high-risk properties per county by 2050



In the UK, modelling using RCP8.5 as a baseline has found over 500,000 residential and commercial properties to be at high-risk by 2050 (Figure 2).[27] At such risk, affordable insurance may be lost and the value of these properties will decrease. These adjustments in value, brought on by climate risk, are estimated to cost £525billion by 2100 (Figure 3). If disclosure on climate-related risks and their use by investors, creditors, and underwriters is enhanced, then the risk of such large, abrupt corrections in asset values is reduced.[28]

RCP8.5 is one of four Representative Concentration Pathways (RCPs), a set of future climate scenarios. The four RCPs represent low (RCP2.6) to high (RCP8.5) concentrations of greenhouse gas emissions in the atmosphere by 2100, making RCP8.5 the worst-case scenario out of the four. RCP8.5 approximately aligns with a global warming level range of 3.3°C–5.7°C in 2100. More information on climate scenarios can be found in section 1.10.

Figure 3: Climate adjusted value by 2100



As well as impacts to built assets, physical climate risks also present significant risks to human health and wellbeing. This can cause impacts ranging from decreased employee productivity and lower customer retention to injury, illness, and risk to life[29].

Physical Risk Disclosure is Maturing

Failure to recognise and incorporate climate-related physical risks into decision-making is considered a threat to socioeconomic security. For organisations, this could include the success of business models and impact the stability of the global financial system more broadly.[30] It is therefore essential that organisations can understand the climate risks they face, the process of how to measure and report these risks, and the financial implications they may bring.

In October 2021, the UK Government announced that physical risk disclosure including qualitative scenario analysis would become mandatory for large organisations and financial institutions from April 2022, to ensure that the effects of climate change are routinely considered within investment decisions. This disclosure is required to be aligned with the Task Force on Climate-Related Financial Disclosures' (TCFD) recommendations. Equally, an increasing number of investors and lenders are recognising the materiality of climate-related financial risks across their portfolios, proactively demanding more and more information and transparency to judge these risks effectively.[31] As the TCFD's recommendations become mandatory, this necessity intensifies.

Tools and guidance to help measure and report physical risks to built assets:

- BREEAM In Use rating system by BRE.
- C40 Cities Climate Change Risk Assessment Guidance.
- City Resilience Index by Rockefeller Foundation and Arup.
- EU Sustainable Financial Disclosure Regulation.
- EU Taxonomy for sustainable activities and the EU Taxonomy Compass.
- Green Star rating system by GBCA.
- GRESB Real Estate Assessment and GRESB Infrastructure Assessment.
- Urban Land Institute Risk Assessment Process.
- EN ISO 14091:2021 Adaptation to Climate Change – Guidelines on Vulnerability, Impacts and Risk Assessment.
- The MSCI Climate Value-at-Risk assessment: This tool allows for analysis of the risks and also offers support for reporting (particularly when aligning with TCFD).
- Planetrics' Climate Risk Model: This tool can be used to model and price climate risk at both portfolio and asset level and supports the development of risk management strategies (in line with TCFD recommendations).

Understanding the materiality of physical risks to assets and organisations, through clear and agreed means of measuring and reporting on them, can reassure financial stakeholders, increase investor confidence, will generate higher asset valuations, enable access to preferential insurance premiums, and ultimately deliver industry-wide climate resilience. Failure to effectively measure and disclose (and subsequently act) on climate risks will increase the cost of insurance and the likelihood of defaults, driving property value declines and unwanted market corrections.

There is a clear need to report on and effectively price-in the costs of climate risks, however, barriers remain. Translating climate risk exposure into quantitative financial materiality is challenging because standardised metrics have not yet been developed, however this is changing (see Future Trends below). A recent TCFD briefing paper for the property and construction sector cited the need for greater 'harmonisation' of existing frameworks and tools, in order for the sector to effectively align with TCFD requirements.[32] Equally, obtaining the granularity of data required for meaningful calculations can be a complex process. In addition, climate risk modelling and scenario planning is abstract by nature, which challenges conventional corporate methods of strategising and presents decision-makers with a series of possible futures.[33]

Aligning with TCFD's recommendations for risk measurement and reporting is a positive first step towards overcoming these barriers. Whilst the TCFD moves towards greater standardisation and consensus of measurement and reporting techniques, it lacks the granularity necessary to explicitly guide organisations through this process at asset level. Regarding built assets, guidance and tools for climate risk reporting is increasing, as are proprietary analysis tools that can provide organisations with scenario-driven assessments of climate change risks.

There are, however, individual shortfalls and caveats associated with the use of all tools, and many of them must be paid for. Therefore, users should be cautious and considered in their utilisation of them, interrogating the results to ensure they are valid and align with real-world knowledge and/or comparative examples.

At present, organisations rarely disclose detailed, forward-looking and consistent risk assessments, and most research in this area to date has focused on transition as opposed to physical risks.[34] In addition, assessments of physical risk are most often undertaken at portfolio rather than asset level. Crucially, at either scale there persists a lack of consensus within industry regarding disclosure methodologies.

Delivering on UKGBC's ambition for all built assets to be climate resilient by 2030 is reliant upon an adequate understanding of what it is to be 'resilient' at the asset level. Organisations will therefore need to know what the physical risks are before they can effectively undertake comprehensive adaptation planning and action.

TASK FORCE ON CLIMATE-RELATED FINANCIAL DISCLOSURE (TCFD)

The TCFD was created after a request from the G20 to the Financial Stability Board (FSB) to take account of climate-related impacts on global financial activities. The TCFD framework broadly outlines approaches for measuring and disclosing the transition and physical risks from climate change to investors, lenders, insurers, and other key financial stakeholders.[35] The TCFD recommendations are grouped into four main areas: **Governance**; **Strategy**; **Risk Management**; and **Metrics & Targets** (Figure 4).

Figure 4: Core elements of the TCFD recommendations

GOVERNANCE	STRATEGY	RISK MANAGEMENT	METRICS & TARGETS
Disclose the organization's governance around climate-related risk and opportunities.	Disclose the actual and potential impacts of climate-related risks and opportunities on the organisation's businesses, strategies, and financial planning where such information is material.	Disclose how the organisation identifies, assesses, and manages climate-related risks.	Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such information is material.
Recommended disclosures	**Recommended disclosures**	**Recommended disclosures**	**Recommended disclosures**
• Describe the board's oversight of climate-related risks and opportunities. • Describe management's role in assessing and managing climate-related risks and opportunities.	• Describe the climate-related risks and opportunities the organisation has identified over the short, medium, and long term. • Describe the impact of climate-related risks and opportunities on the organisation's businesses, strategy, and financial planning. • Describe the resilience of the organisation's strategy taking into account considerations different scenarios, including a 2°C or lower scenario.	• Disclose the organisation's processes for identifying and assessing climate-related risks. • Describe the organisation's processes for managing climate-related risks. • Describe how processes for identifying, assessing, and managing climate-related risks are integrated into the organisation's overall risk management.	• Disclose the metrics used by the organisation to assess climate-related risks and opportunities in line with its strategy and risk management process. • Disclose Scope 1, Scope 2, and, if appropriate, Scope 3 greenhouse gas (GHG) emissions, and the related risks. • Describe the targets used by the organisation to manage climate-related risks and opportunities and performance against targets.

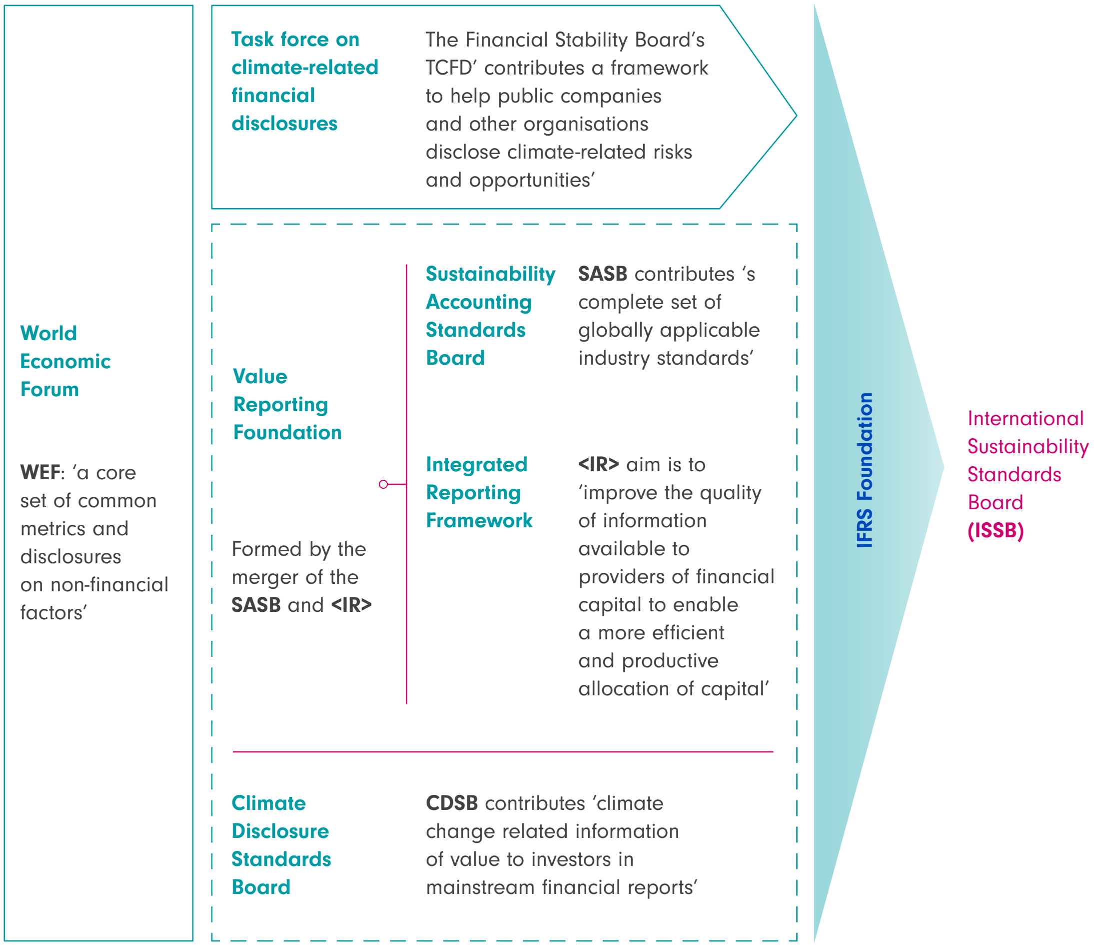
Future Trends of Measuring & Reporting Physical Risk

Crucially, many current tools lack the capacity to include resilience measures within them, or to assess future climate scenarios. As this area continues to develop, organisations will need to incorporate them within their measurement and reporting exercises. The Reporting Framework outlined here provides a foundation to build upon, integrating new tools and technologies within the steps it defines as and when they become available.

Beyond methods, the regulatory landscape within which climate-related financial disclosures sit will also evolve. For example, the International Financial Reporting Standards (IFRS) Foundation Trustees have announced several actions aimed at providing global financial markets with high-quality disclosures on climate and other sustainability issues. The establishment of an International Sustainability Standards Board (ISSB) will develop a comprehensive global baseline of high-quality sustainability disclosure standards to meet investors' information needs.

The ISSB will consolidate the current Climate Disclosure Standards Board (CDSB) and the Value Reporting Foundation (VRF), whilst building on the work of TCFD. Companies that have already adopted or aligned with the TCFD's recommendations will therefore be well positioned to use these as a bridge to the adoption of the new international standards (Figure 5). This Reporting Framework therefore helps organisations to align with both existing and forthcoming regulations, providing much-needed granularity at asset level to assist organisations with their alignment.

Figure 5: Shaping the ISSB



Purpose of this report

The purpose is to increase the amount, quality, and consistency of built asset level climate-related physical risk assessment and reporting.

It aims to provide organisations and individuals with the knowledge and tools to undertake self-analysis of physical risks at the asset level. The detail provided within this report will support physical risk assessments of individual built assets, which may be undertaken in the place of, or in conjunction with, broader portfolio assessments.

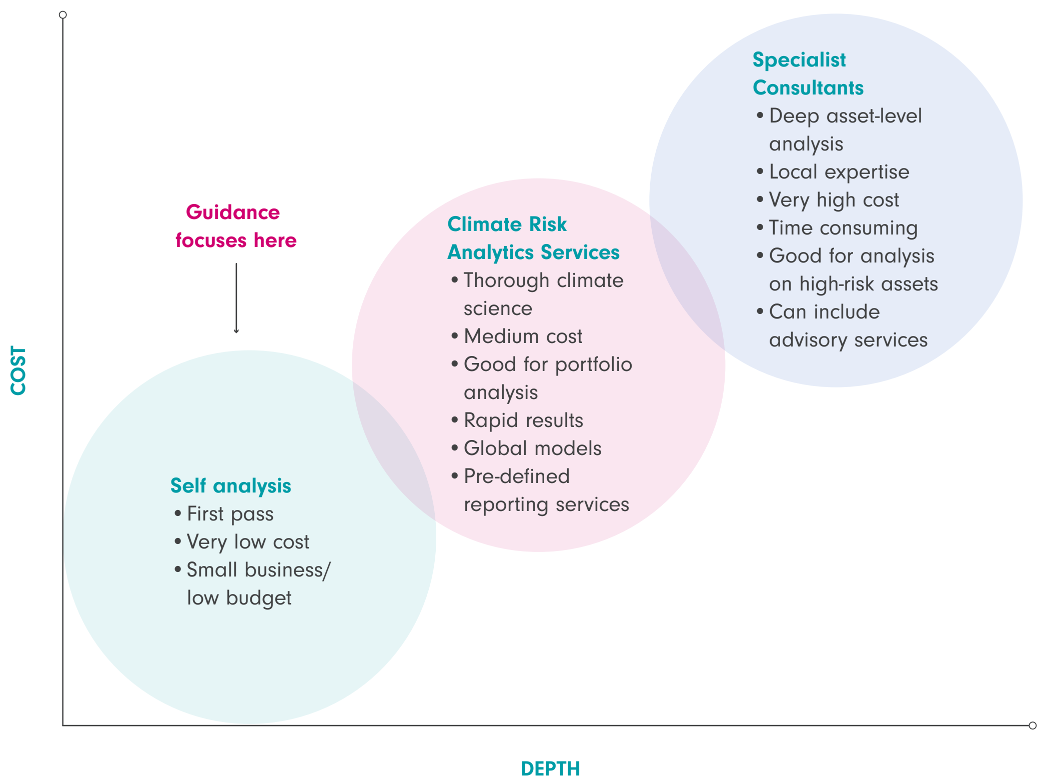
The guidance provided within this report will result in an overview of these risks and will be less detailed than a professional assessment undertaken by climate risk service providers.

The suitability of this approach will vary depending on organisational priorities and asset value and may wish to be combined with other approaches such as engaging specialist consultants or climate risk analytics services. It may be beneficial for organisations to undertake an initial risk assessment using the methodology presented within this report to further understand requirements needed from a specialist provider. Organisations should consider the level of detail required for individual assets carefully and adopt the most applicable solution (see figure 6). For example:

- Small businesses starting their physical risk disclosure journey may wish to start with self-analysis as a low-cost option,
- Larger organisations may wish to use climate risk analytics services to understand risks using more accurate climate science models,
- Businesses with high-value assets within their portfolio may directly appoint specialist consultants for individual risks they face.

This report will enable greater harmonisation of existing frameworks and tools so that the property and construction sector can effectively align with TCFD requirements. The focus is on making the TCFD recommendations on "Risk Management" and "Metrics and Targets" practicable at an asset level. The Reporting Flowchart (Figure 7) and Reporting Framework (Appendix I) have been designed to align with these recommendations and their relevance is cited throughout. Whilst the focus is on these elements of the TCFD, suggestions will also be provided for alignment with the "Governance" and "Strategy" recommendations. The reporting framework provided as Appendix I of this report can be used by organisations within their annual report to disclose the physical risk to their built assets.

Figure 6: Framing of the report recommendations



Target Audience

The reporting framework and supporting information is primarily intended to be used by those that will be required to disclose their physical climate risks using the TCFD recommendations. This includes asset owners, insurers, investors, lenders, and other financial stakeholders.

However, the content of the report will also be useful for anyone aiming to increase their understanding on physical risk disclosure. This includes developers, engineers, architects, landscape architects, contractors, landscape contractors, planners, professional bodies, national and local policy makers, and environmental non-governmental organisations (NGOs).

Methodology and future updates

Initial desk-based research, incorporating a literature review and semi-structured interviews, identified critical gaps regarding the measurement and reporting of physical risks at asset level, in both theory and practice. With gaps identified, a Task Group was established and then worked collaboratively through a series of workshops to consider how to overcome the gaps. Together, the Task Group worked to define the scope of the report, the necessary contents, overall structure, and the design of both the Reporting Framework and Reporting Flowchart. The Task Group also acted as a sounding board for the first full draft of the report.

A Peer Review Group was also established to review a finalised version of the report, ensuring its overall rigour and evaluating the functionality of both the Reporting Flowchart and Reporting Framework. The full list of contributing individuals and organisations can be found in Appendix III.

UKGBC will update this work in line with emerging policy and best practice methodologies. The Reporting Framework will be updated as the industry guidance and physical risk related policy moves forward.

Using the Framework and Report

The remainder of this report serves as a how-to guide for organisations to self-report their physical risks to built assets from climate change. A reporting framework is provided in Appendix I which aligns with the TCFD recommendations. The following chapter acts as a reference guide for the framework, providing advice and examples on how to complete each section. The glossary should be referred to for key terms and definitions, and how to apply these to the built environment.

How to Measure and Report Physical Risks to Built Assets

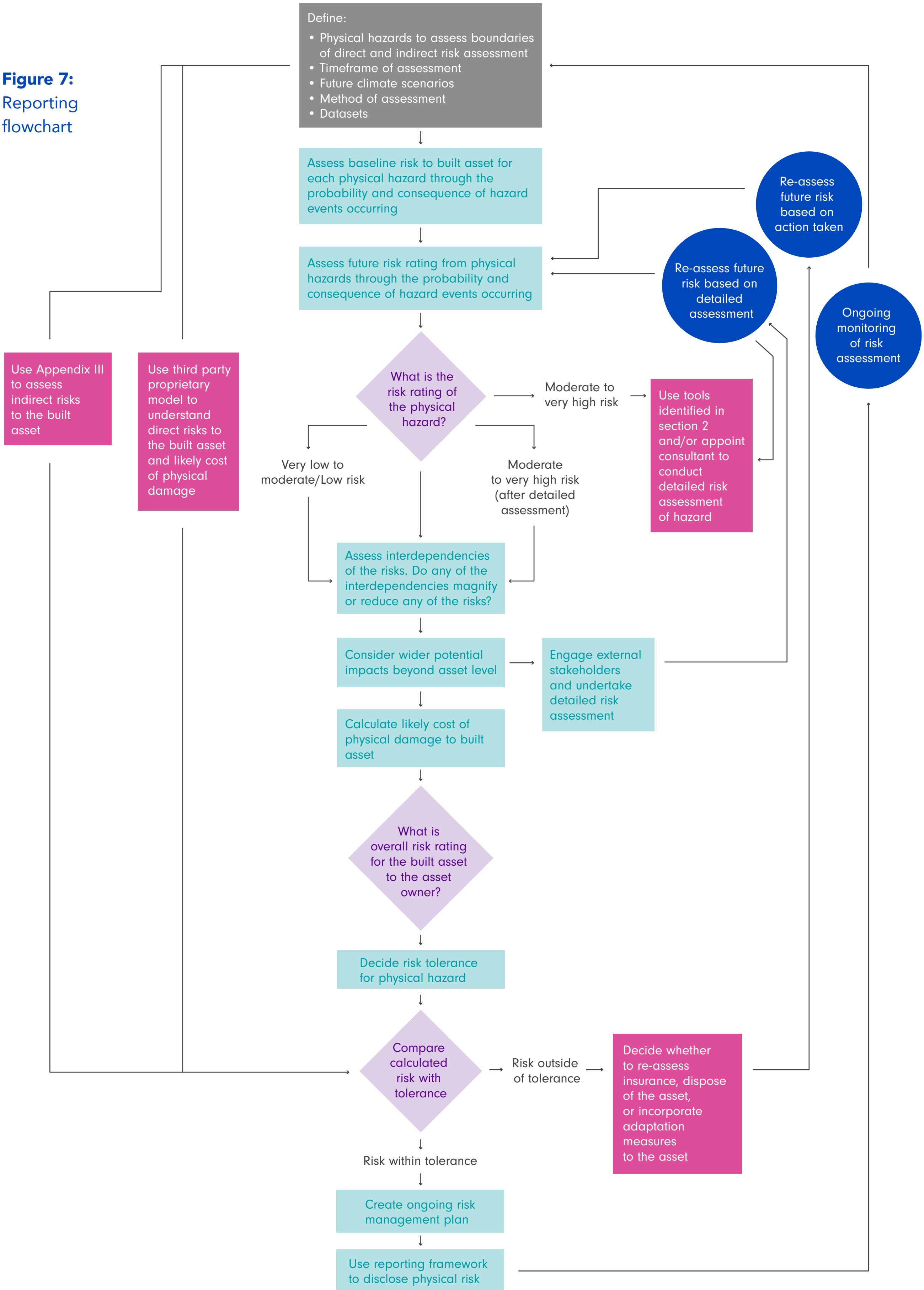
This chapter provides guidance on how the reporting framework provided in Appendix I should be completed, giving background information and examples for each section.

This chapter should be read in conjunction with the reporting template and is divided into the following sections to match the framework layout:

- Framework Section 1: Initial Information.
- Framework Sections 2 and 3: Assessing Baseline and Future Risk from Physical Hazards.
- Framework Section 4: Assessing Overall Risk Rating.
- Framework Section 5: Using the Framework to Disclose Physical Risk.

The reporting flowchart (Figure 7) provides an overview of the process required to measure and report physical risks at the built asset level.

Figure 7:
Reporting flowchart



FRAMEWORK SECTION 1

Initial Information

What Section 1 Covers

Section 1 of the Reporting Framework sets out the initial information to consider and decisions to make before starting the physical risk assessment. It is intended to link to TCFD recommendations 3a and 4a to support the disclosure of the processes and metrics used by organisations to identify and assess climate-related physical risks.

Why this is Important

Transparent disclosure of the methodology, assumptions, key inputs, and choices made will support the comparability of results across different processes used by organisations. In turn, this allows analysts and investors to evaluate differences in disclosures, supporting better-informed risk and capital allocation decisions.

How to Complete Framework Section 1

1.1 Name of Asset

The name of the asset should be recorded for asset identification purposes. This should match the registered address of the asset where possible.

1.2 Date of Assessment

This section records the date the risk assessment was carried out for the asset. If this is over a longer period, the date recorded should align with the final day of the assessment.

Recording the date of an assessment allows the asset owner to refer to previous decisions made based on the data available at the time. It serves as a timestamp for any datasets and tools used, which may be updated in the future. It is also important for the ongoing risk management process and for deciding future risk assessment dates.

1.3 Asset Type

This could include asset types such as residential, commercial, public/civic assets, or infrastructure elements (e.g. roads, railways, bridges, pipelines). If assessing for a new development, the planned use class could be stated here in lieu of detailed information.

1.4 Asset Location

Where possible, a postcode should be provided to ensure the location is specific enough for detailed risk assessment.

Location is an important consideration when judging the asset's exposure to physical hazards, for example adjacency to coastal areas or rivers could increase probability of a flood event occurring.

1.5 Expected Duration of Asset Life

The asset's expected duration of life is a key consideration when starting the risk assessment process as it directly impacts the relevant timeframes of assessment. If an asset is impacted by a physical hazard before it reaches the end of its anticipated useful life span, the financial implications for the organisation may be considerably larger than for an asset which has reached the end of its useful life.

In this section record the anticipated duration of asset life and key dates for the consideration of refurbishment, demolition and redevelopment. For example, for an asset built in 2011 with a 60-year life span may consider the following key dates:

- Refurbishment considerations made every 15 years: 2026, 2041, 2056, 2071.
- Demolition or redevelopment considered for end of life: 2071.

1.6 Timeline of Interest

As risks and opportunities occurring from climate-related impacts will change over time, it is recommended that risk assessments are conducted on short-, medium- and long-term horizons to align with TCFD guidance. The Task Force recommends that time frames are defined according to the life of their assets, the profile of the climate-related risk they face, and the sectors and geographies in which they operate.[36]

For built assets, this could link to the asset's designed life span to ensure physical risk is considered in key decisions around refurbishment, demolition, and redevelopment. Some organisations may wish to consider longer timescales to incorporate land value within their physical risk assessment.

For organisations uncertain of timescales to use in their risk assessment, the following are recommended:

- Short term: within the current decade (2020s).
- Medium term: within the next three decades (2030s–2050s).
- Long term: within the second half of this century (2050s–2100).

1.7 Boundaries of Risk Assessment

Physical hazard events can generate risks that will directly affect built assets (direct risks) but also impact wider systems beyond the asset, causing secondary effects (indirect risks). For example, a flood event could cause damage to a building envelope and contents requiring extensive repair and clean up (direct), but it could also damage nearby electrical infrastructure causing an interruption to the asset's electricity supply (indirect).

As many direct and indirect risks extend beyond the footprint of the built asset it can be useful to determine the boundary of the risk assessment at the outset. It is recommended that direct risks are considered within the asset's red line boundary and indirect risks are considered within a wider Zone of Influence. This Zone of Influence could change depending on the physical hazard being assessed, but generally should be large enough to consider the wider systems that the asset relies on such as utilities, transport, and social infrastructure.

1.8 Indirect Risks

Once the boundaries of risk assessment have been determined, the indirect risks relevant to the asset type and its location can be identified. A list of suggested (though not exhaustive) indirect risks to consider relating to the built environment has been provided in Appendix II.

The level of detail for direct and indirect risk assessments may also change depending on an organisations' chosen methodology. A quantitative risk assessment based on numerical hazard projections may provide a more robust analysis of direct risks to an asset. A qualitative review of indirect risks to an asset's essential supporting services may identify key areas to investigate further or incorporate into future risk assessments.

1.9 Physical Hazards

The identification of which physical hazards to assess will depend on the asset's vulnerability and exposure to each hazard type. Some physical hazards may only arise at longer timescales, so it is recommended that where data is available, an initial high-level assessment of all physical hazards included within the reporting framework is undertaken. If a physical hazard has not been assessed, the reasoning and assumptions behind this decision should be recorded to ensure transparency.

The effects of climate change manifest in several physical hazards which can have multiple effects on the built environment. Not all climate-related hazards will be relevant when assessing risk to built assets. Key physical hazards for the UK built environment have been identified in bold in Table 1, though other hazards may be relevant depending on asset location and adjacency to geographical features such as rivers or coastal areas.

Table 1: Classification of climate-related hazards

	Temperature-related	Wind-related	Water-related	Solid mass-related
Chronic hazards *(slow-onset)*	Changing temperature (air, freshwater, marine water)	**Changing wind patterns**	**Changing precipitation patterns and types (rain, hail, snow/ice)**	**Coastal erosion**
	Heat stress		Precipitation and/or hydrological variability	Soil degradation
	Temperature variability		Ocean acidification	**Soil erosion**
	Permafrost thawing		**Saline intrusion***	Solifluction**
			Sea level rise	
			Water stress	
Acute hazards *(extreme)*	**Heat wave**	Cyclone, hurricane, typhoon	**Drought**	Avalanche
	Cold/frost wave	Storm (including blizzards, dust and sand storms)	**Heavy precipitation (rain, hail, snow/ice)**	Landslide
	Wildfire	Tornado	**Flood (coastal, fluvial, pluvial, ground water)**	**Subsidence**
			Glacial lake outburst	

(Adapted from the EU taxonomy technical report[37])

1.10 Climate Scenarios

Climate scenarios are projections of how the climate might change in future depending on the societal choices made, policies committed to and resulting GHG emissions remaining in the atmosphere. They allow us to explore multiple possible futures, the assumptions they depend upon, and the courses of action that could bring them about[38]. Climate scenarios are created using Global Climate Models which use mathematical equations to replicate the physics of the Earth's systems. Different levels of GHG emissions are added into the model to output various scenarios of the Earth's climate.

* Saline intrusion is the movement of saline water into freshwater.
** Solifluction is the flow of water-saturated soil down a steep slope.

Climate scenario analysis is a useful tool for assessing a range of potential implications of climate-related risks and opportunities. It can also be used to inform stakeholders about how an organisation is positioning itself considering these risks.

Provided below is an overview of current physical climate scenarios organisations may consider when beginning their risk assessment.

Climate-change related risks include inherent uncertainties which can cause challenges for decision makers. Common sources of uncertainty for climate-related risks include[39]:

- Future emissions trajectories: the magnitude and rate of future climate change is heavily dependent on future global policies and actions.
- Current modelling limitations: it is not possible to model all Earth systems and socio-economic processes.
- Natural variability: global temperatures not only depend on greenhouse gas emissions, but are also dependent on variability within the global climate system (i.e. future volcanic eruptions).

It is important to consider uncertainty within the risk assessment process as the resulting decisions may have long-term effects and impacts. Assessments which include allowance for uncertainty will result in a more robust decision-making process and limit the risk of incorporating inadequate, inappropriate, or vulnerability-increasing responses to climate-related risks. The TCFD recommends that a range of climate scenarios are used within a physical risk assessment to analyse the difference in potential future scenarios.

Alignment with Global Warming Levels

The most common of climate scenarios are the levels of global warming that may occur by the end-of-century, based on the pre-industrial average. These were used in the Paris Climate Agreement at COP21, in 2015, which pledged to:

> "Holding the increase in the global average temperature to **well below 2°C** above pre-industrial levels and pursuing efforts to **limit the temperature increase to 1.5°C** above pre-industrial levels."

Global warming levels are often used for transition risk modelling so it may be useful for organisations to use temperature aligned scenarios across their physical and transition analysis. Global warming levels are the most commonly used metric across multiple industries for the communication of climate risks and scenarios chosen.

Representative Concentration Pathways (RCPs)

The RCPs were developed by the IPCC to describe climate scenarios with different levels of greenhouse gases (GHGs) that may occur in the future. As GHG emissions increase, the amount of energy trapped within the Earth's climate increases. The difference between the incoming and outgoing energy is called radiative forcing (measured in Watts per metre squared). Each RCP scenario describes the amount of radiative forcing occurring in 2100 based on the concentration of GHGs in the atmosphere – for example RCP2.6 describes a scenario where 2.6W/m² of radiative forcing occurs in 2100. The four pathways are RCP2.6 (best case), RCP4.5, RCP6.0 and RCP8.5 (worst case).

Shared Socioeconomic Pathways (SSPs)

In 2016, the Shared Socioeconomic Pathways were developed by the IPCC to explore how the global economy and society may evolve over the next 80 years and were included in the most recent sixth assessment report on the physical science basis of climate change[40]. The SSPs look beyond GHG emissions and describe futures based on global socio-economic challenges for mitigation and adaptation to climate change. The five scenarios used within the IPCC AR6 report are:

- SSP1: Sustainability – Taking the Green Road (low challenges to mitigation and adaptation).
- SSP2: Middle of the Road (medium challenges to mitigation and adaptation).
- SSP3: Regional Rivalry – A Rocky Road (high challenges to mitigation and adaptation).
- SSP4: Inequality – A Road Divided (low challenges to mitigation, high challenges to adaptation).
- SSP5: Fossil-fuelled Development – Taking the Highway (High challenges to mitigation, low challenges to adaptation).

The UK-SSPs project[41] has developed UK specific SSPs and provides a number of products which can be used for organisational risk assessment including a database of quantified socioeconomic projections.

Scenario Alignment

Table 2 shows the relationship between the RCPs, SSPs and the Global Warming Levels. If an organisation chooses to use either RCP or SSP scenarios within their risk assessment, it may be useful to refer to the broader temperature alignment in communications with stakeholders.

The SSP scenarios provided in Table 2 depict the socioeconomic pathway and corresponding radiative forcing projections. For example, SSP2-4.5 describes SSP2 (middle of the road) and an expected radiative forcing of 4.5 W/m².

Table 2: Climate scenario global warming level alignment (adapted from IPCC AR6 Summary for Policymakers Table SPM.1)[42]

2013 RCP Scenario (IPCC AR5)	2021 SSP Equivalent Scenario (IPCC AR6)	Global warming level range*
–	SSP1–1.9 (New)	1.0–1.8°C
RCP 2.6	SSP1–2.6	1.3–2.4°C
RCP 4.5	SSP2–4.5	2.1–3.5°C
RCP 6.0	–	–
–	SSP3–7.0 (New)	2.8–4.6°C
RCP 8.5	SSP5–8.5	3.3–5.7

Guidance on Scenario Selection

Different scenarios may be appropriate depending on the asset's exposure and vulnerability to a certain physical hazard. The TCFD recommends that organisations assess a range of scenarios to capture a wide range of assumptions about uncertain futures.

It is also important to use the same climate scenarios throughout the risk assessment and across multiple assets (if applicable) to aid comparison of data. To ensure transparent disclosure, the chosen scenario should be included within the physical risk disclosure alongside any assumptions made or limitations found.

For organisations uncertain on scenario selection, we recommend that at least two scenarios are selected that align with a 2°C and 4°C futures (RCP2.6 and RCP8.5)[43]. For best practice, analysis using the four RCP scenarios (RCP2.6, RCP4.5, RCP6.0 and RCP8.5) should be used to provide a broad range of possible risk futures and address uncertainty. Whilst it has been noted that RCP8.5 represents an improbable future scenario based on its reliance on global fossil fuel consumption[44], and a temperature alignment range of 3.3–5.7°C, it can still provide a useful worst-case scenario for organisations to use within risk assessments.

Further information and guidance on which climate scenarios to use can be found in the TCFD's Guidance on Scenario Analysis for Non-Financial Companies[45]. When determining the climate scenarios to use in the risk assessment it is important to consider the following[46]:

- Scenarios and models use a variety of methodologies and assumptions in their creation–are your scenarios reputable, robust and created through a validated scientific process?
- What are the key limitations and assumptions contained in your scenarios?

- What are the likelihoods of your scenarios? Are they likely based on current policies and actions or improbable?
- What uncertainties are included within your scenario?
- Understand how to use scenarios appropriately: they provide plausible futures, not predictions, and they cannot yet address acute shocks or interdependencies between hazards.

1.11 Datasets and Tools

The datasets and tools used for identifying baseline and future risk should be recorded to ensure a transparent assessment process.

Provided below is a non-exhaustive selection of tools that may be used for the initial risk assessment. Further hazard specific tools are also provided in section 2.7 if you would like to carry out a more detailed assessment.

Met Office Historical Data

The Met Office's UK Climate Averages[47] can be used to determine baseline climatic conditions for an asset within the UK. Tables, graphs and maps of average climate variables can be identified using 1961–1990, 1971–2000 and 1981–2010 periods. The climate variables available will depend on the historical records kept at the relevant climate station, but the majority will provide the following variables: maximum temperature (°C), minimum temperature (°C), air frost (days), sunshine (hours), rainfall (mm), days of rainfall ≥ 1mm, monthly mean wind speed at 10m (knots).

UK Climate Projections 2018 (UKCP18)

The UKCP18 dataset is the most up to date assessment of how the UK climate may change in the future. The UKCP18 key results spreadsheet provides probabilistic projections and sea level projections for all countries, administrative regions and river basin regions in the UK. The spreadsheet provides details of changes in mean annual temperature, mean summer precipitation, mean summer temperature, mean winter precipitation, and mean winter temperature compared with a 1981–2000 baseline. A variety of time horizons and climate scenarios can be chosen.

Other variables, including maximum and minimum temperatures, and future probabilistic projections can be accessed through the UKCP18 User Interface which allows datasets, graphs and maps to be downloaded for various scenarios.

If an asset lies within Bristol, Belfast, Glasgow, Kirklees, Leeds, London City or Exeter, the Met Office have also produced City Packs which provide headline results of future climatic data for 2030, 2050 and 2080 based on the UKCP18 probabilistic projections.

UK Climate Risk Indicators

The UK Climate Resilience Programme developed the Climate Risk Indicators mapping tool using the UKCP18 dataset. A variety of variables within climate, temperatures extremes, heating and cooling, transport, agriculture, wildfire, and water can be investigated at a range of scales including regional, county, district, and local authority boundaries.

Global Tools and Datasets

Global models can be useful for consistent assessments across geographies which may be beneficial for organisations with regionally or globally diverse assets. However, the resolution and precision of data can be reduced at the global scale so it is unlikely that asset-scale information will be available.

Tools such as the XDI (Cross Dependency Initiative)* can quantify multi-hazard exposure, asset resilience and cost-benefit analysis for climate adaptation. The following global tools could be utilised to inform a risk assessment of physical hazards:

- KNMI Climate Atlas
- IPCC AR6 WG1 interactive atlas
- World Bank Climate Knowledge Portal
- GFDRR ThinkHazard! tool
- EasyXDI*
- GRESB Climate Risk Platform*
- MSCI Climate Value-at-Risk*

FRAMEWORK SECTIONS 2 AND 3

Assessing Baseline and Future Risk from Physical Hazards

What Sections 2 and 3 Cover

Once the initial decisions regarding the risk assessment have been made and reported in Framework Section 1, the climate scenarios, datasets and the chosen timeline can be used to begin the risk assessment. This section of the report covers Framework Sections 2 and 3, which provide guidance on assessing the baseline risk and future risk to built assets from physical hazards.

The definition tables provided within this section should be used to reach conclusions on how likely a physical hazard event is to occur, the consequences of its occurrence and the resulting risk of its occurrence. These results should be filled out in Table 2 of the Reporting Framework, starting with an assessment of baseline risk, and completing assessments for the short-, medium- and long-term horizons.

Why this is important

Physical risk assessments are used to identify the hazards, assess the risks of hazard occurrence and to provide useful data for financial decision-making processes. The physical hazards arising from climate change and an asset's exposure and vulnerability to these hazards must be considered simultaneously in order to assess the risks and potential impacts to a built asset.

How to Complete Sections 2 and 3

2.1 Previous Physical Risk Assessments

Record any previous risk assessments of physical hazard impacts to the asset. Include details of the date of assessment, methodologies used and priority risks identified. The information derived from the previous assessment should be used when assessing the consequence of the risks (section 2.4).

2.2 Historic Impacts

Providing records of historical impacts can identify key asset-level risks to consider when assessing probability and consequence of occurrence. For any historic impacts found, the date of occurrence, the impact it had to the asset, and any adaptation measures that were incorporated should be recorded and considered when assessing the likelihood of impact (section 2.4). Evidence for reviewing impact to the asset could include any direct financial impacts, such as insurance records.

2.3 Describing Inherent Vulnerabilities and Resilience Measures

Assessing risks at the asset level can be challenging due to the need to consider its vulnerability (how susceptible it may be to adverse climatic hazards) and resilience (how the asset can adapt to and reduce impacts of climatic hazards). These factors should be considered and recorded before assessing the probability and consequence of risks occurring.

Examples of vulnerability could include:

- An asset containing a basement is more vulnerable to flood events,
- An asset located in a city centre location which increases exposure to the Urban Heat Island effect,
- An asset located adjacent to forests or moorlands which could increase exposure to wildfires.

Examples of resilience measures could include:

- Flood defences built upstream of an asset,
- Asset having redundant infrastructure, for example back up power generators,
- Asset being designed to higher temperature thresholds and passive thermal comfort measures introduced.

2.4 Assessing the Likelihood of Impacts

The datasets and tools provided in Framework Section 1.11 should be used to review baseline and future climatic conditions to assist in the assessment of probability. Baseline and future risks are assessed using same methodology, however different tools and datasets are used to assess probability of occurrence. The baseline risk assessment uses averaged historical climatic data to understand current risks, and the future risk assessment uses future climate scenarios to project possible climate futures.

Climatic variables can be used as a proxy for the probability of an event occurring. For example:

- Baseline and future projected maximum gust strength could be reviewed to assess the intensity of projected storm events in current and future time horizons; or
- For an urban asset adjacent to high levels of impermeable paving, projected rainfall levels could be used to assess the probability of a surface water flood event occurring.

It is important to be aware of the limitations of each tool and where supplementary information may be required for more detailed risk assessments.

Table 3 provides definitions of each classification of probability and provides examples for how this could relate to a built asset.

Table 3: Classification of probability

Classification	Definition
High likelihood	The hazard event appears very likely in the short term and almost inevitable over the long term.
Likely	It is probable that an event an event is not inevitable, but possible in the short term and probable over the long term.
Low likelihood	Circumstances are under which an event could occur. However, it is by no means certain that even over a longer period such an event would take place and is less likely in the shorter term.
Unlikely	Circumstances are such that it is improbable that an event would occur even in the very long term.

2.5 Assessing the Consequence of Impact

Table 4 provides definitions of each classification of consequence and examples for how this could relate to a built asset. To determine the consequence, first consider the vulnerability/sensitivity and exposure of the built asset to the specific climatic event (hazard). The more vulnerable/sensitive or exposed the built asset is to a hazard, such as high winds, the more severe the consequence will be, such as, structural failure.

When assessing the vulnerability and exposure, it is also important to consider the capacity of the built asset to reduce the impacts of the climatic event. For example, a built asset that houses a generator in the basement and is adjacent to a major river may be relatively vulnerable and exposed to flooding. However, if flood defences are present, this will increase the capacity of the built asset to reduce the impact of a flooding event, thereby reducing the vulnerability/sensitivity and exposure of the built asset to flooding (the hazard).

Risk tolerance ranges are a measure of how much risk asset owners, organisations and investors are willing to accept in relation to their built assets. These ranges can be used as a key measure when making risk-based decisions. Consideration of an asset’s risk tolerance to the physical hazard should be undertaken when deciding the consequence of the hazard.

Table 4: Classification of consequence

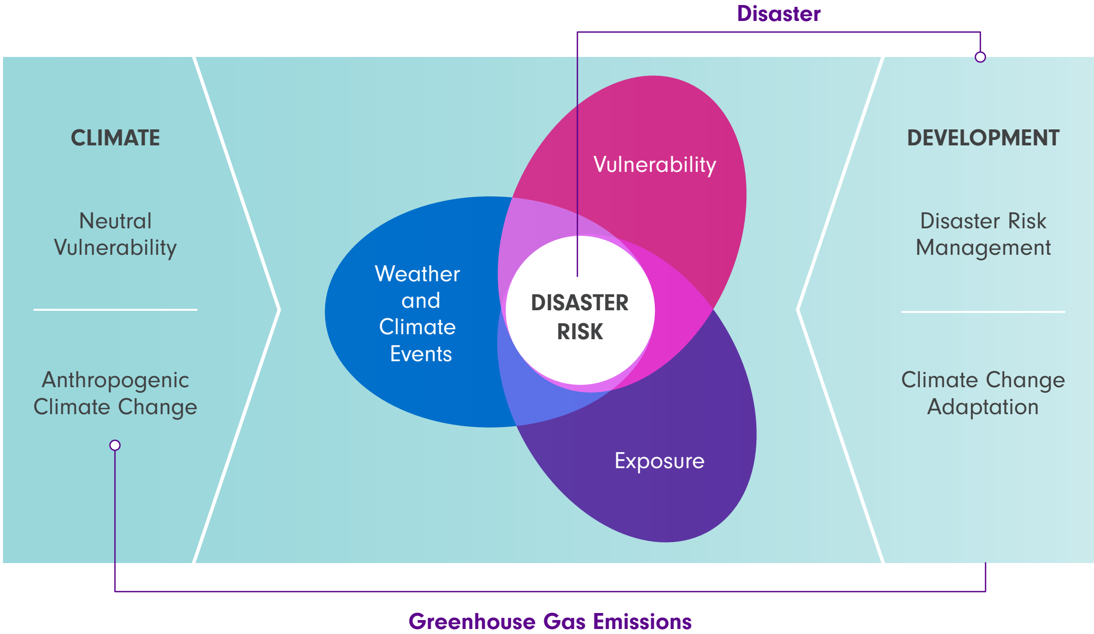
Classification	Definition	Examples
Severe	• Impact to the built asset likely to result in catastrophic damage to buildings/property. • Built asset has substantial exposure to a potential loss. No or negligible effort to strengthen resilience of built asset. • Damage to buildings/structures or services or the environment rendering asset unsafe to occupy. • Asset is stranded. Demolition and full re-build of asset required or total write off of asset value. • Business interruption or direct damage resulting in total financial loss. • Asset becomes uninsurable. • ££££	• Extreme winds resulting in total structural failure or foundation damage resulting in instability. • Extreme flooding resulting in total structural failure. • Damage to essential infrastructure that is considered uneconomical to repair.
Medium	• Impact to the built asset likely to result in high levels of damage to buildings/property, substantial re-build or substantial reduction in asset value. • Built asset has substantial exposure to a potential loss. Limited effort to strengthen resilience of built asset. • Damage to key buildings/structures/services or the environment rendering asset unsafe to occupy. • Business interruption or direct damage resulting in substantial financial loss or expenditure to resolve. • Insurance premiums on asset rises substantially. • £££	• Extreme winds causing full roof replacement. • Extreme flooding resulting in partial (e.g. ground floor) refurbishment. • Gas infrastructure damage to built asset.
Mild	• Impact to the built asset likely to result in low levels of damage to business/property. • Built asset has some exposure to a potential loss. Efforts have been made to strengthen resilience of built asset. • Damage to buildings/structures/services rendering limited areas of the building unsafe to occupy or unsafe on a short-term basis. • Damage to vulnerable buildings/structures/services or the environment. • Limited business interruption or direct damage resulting in limited financial loss or expenditure to resolve. • ££	• Extreme winds causing broken windows. • Extreme flooding resulting in short-term access issues. • Loss of plants in a landscaping scheme.

Classification	Definition	Examples
Minor	• Impact to the built asset likely to result in no or very low levels of damage to business/property. • Built asset has negligible exposure to a potential loss. Efforts have been made to strengthen resilience of built asset. • Damage to buildings/structures/services or the environment rendering limited areas of the building unsafe to occupy or unsafe on a very short-term basis. • Damage to vulnerable buildings/structures services or the environment. • No or limited business interruption that may result in no or negligible financial loss or expenditure to resolve. • £	• Extreme winds causing wind-blown debris requiring housekeeping. • Extreme flooding resulting in water driven debris requiring housekeeping.

2.6 Assessing Risk Rating

The TCFD indicate the essential building blocks for a comprehensive risk assessment as hazards, exposure, vulnerability, risk, and impacts[48].

Figure 8: Relationship between hazard, exposure and vulnerability



Adapted from the IPCC's Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation[49]

Table 5 shows the consequence and probability table that is included within the reporting framework. For each physical hazard, the resulting risk is found by locating the probability (likelihood) of the hazard occurring and its consequence. For example, a risk that is likely to occur but would only have mild consequences would be deemed moderate/low risk. Table 6 provides descriptions of each level of risk and the recommended actions required.

Where a high-level assessment has identified moderate to high risks for any physical hazards, we recommend undertaking a detailed risk assessment at the built asset level (see page 43 for further information).

Table 5: Definition of risk

		Consequence			
		Severe	**Medium**	**Mild**	**Minor**
Probability	**High likelihood**	Very high risk	High risk	Moderate risk	Moderate/low risk
	Likely	High risk	Moderate risk	Moderate/low risk	Low risk
	Low likelihood	Moderate risk	Moderate/low risk	Low risk	Very low risk
	Unlikely	Moderate/low risk	Low risk	Very low risk	Very low risk

Table 6: Description of the classified risks and likely action required

Very high risk	Catastrophic impacts to the built asset are highly likely to occur from an identified hazard, OR, these impacts have already occurred. Realisation of the risk is likely to result in substantial liability. Urgent assessment (if not undertaken already) is required to clarify the risk and to determine the potential liability, likely followed by implementation of adaptation measures for the built asset.
High risk	Substantial impacts to the built asset is likely or highly likely to occur from an identified hazard. Realisation of the risk is likely to present a substantial liability. Urgent assessment (if not undertaken already) is required to clarify the risk and to determine the potential liability. Implementation of adaptation measures for the built asset may be necessary in the short term and likely over the longer term.
Moderate risk	It is possible that impacts could arise to the built asset from an identified hazard. However, it is either relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that the harm would be relatively mild. Assessment (if not already undertaken) is normally required to clarify the risk and to determine the potential liability. Some implementation of adaptation measures may be required in the longer term.
Low risk	It is possible that impacts could arise to the built asset from an identified hazard, but it is likely that this impact, if realised, would at worst be relatively mild. Further assessment is not normally required and, although possible, it is unlikely that adaptation measures will be required.
Very low risk	There is a low possibility that harm could arise to a receptor. In the event of such harm being realised it is not likely to be severe. Further assessment is not normally required and, although possible, it is unlikely that adaptation measures will be required.

2.7 Assumptions and Limitations

Any limitations of the datasets and tool used, or assumptions made when undertaking the risk assessment should be documented. Recording this information ensures a transparent assessment of risks and can help future risk assessors determine the reasons behind decisions made.

Impacts to assets and detailed analysis strategies

This page highlights the main physical hazards that the UK built environment is facing, various assessment methodologies and tools that can be used to provide detailed, asset specific risk assessments and who to engage to provide these assessments.

Heat Stress and Extreme Heat Waves

What are the potential impacts to the built environment?

High temperatures can cause heat stress to building structures, fixtures and fittings which can lead to expansion and buckling. Technology assets such as data centre equipment can also be highly impacted. External building services can also be affected leading to inefficiencies, reduced life spans and damage. Asset owners may see increased energy costs for areas that require air conditioning, or a reduction in asset life span if a building becomes unsuitable for occupants.

Externally, subsidence can occur due to soil shrinkage and maintenance costs for landscaping can increase. In extreme cases, heat stress can cause an increase in flora and fauna death.

Depending on the design of the asset, high external temperatures can cause uncomfortable internal conditions for building occupants leading to decreased sleep and increased stress in residential settings and loss of productivity in commercial settings. Vulnerable occupants such as children, the elderly or those with pre-existing health conditions are at increased risk of illness from high temperatures. Over the summer of 2020, an extra 2,556 deaths were recorded in England and Wales due to three heatwave events[50].

Assets located within cities and urban environments may be more vulnerable to heat stress due to the Urban Heat Island Effect. Additionally, assets with high glazing percentages and high levels of insulation may be more vulnerable to increased internal temperatures. This issue is likely to increase as winter energy efficiency targets continue to improve.

What tools and models can be used to provide detailed analysis?

CIBSE's TM52 & TM59 methodologies can be used to assess overheating risk for human health. Additionally, KS16: How to Manage Overheating in Buildings provides practical advice for building owners, managers and users on improving summertime comfort in buildings.

Cooling Degree Days can be used to calculate the number of days where average temperature exceeds a base temperature and additional cooling may be requested by occupants.

Who to engage for detailed analysis?
Mechanical engineers and building physicists can undertake thermal modelling calculations of internal temperatures for both current and future climate scenarios.

Structural and civil engineers can advise on buckling due to high temperatures.

Low Temperatures

What are the potential impacts to the built environment?
Whilst winter temperatures are likely to become warmer and wetter, climate change increases the variability of lower temperature events such as blizzards and frost events. Low temperatures can cause cold related stresses to built assets such as freezing pipes or the weathering of porous building materials through processes such as frost heave.

What tools and models can be used to provide detailed analysis?
Heating Degree Days can be used to calculate the energy demand required to heat a built asset, relative to a baseline external temperature.

Flooding and Sea Level Rise

What are the potential impacts to the built environment?
Surface water (pluvial) flooding can occur after periods of heavy rainfall. Risk of surface water flooding often increases in urban areas where non-permeable surfaces like concrete reduce the ability of rainfall to drain away. River (fluvial) flooding can occur when water levels in rivers, lakes or streams overflow. Assets located adjacent to these types of water bodies are most exposed to fluvial flooding. Sea level rise increases risk of coastal flooding during high tides and storms and can also affect tidal rivers. Coastal erosion is more likely to occur due to sea level rise as waves are able to extend further up and along beaches and cliffs.

Flood water can ingress into built assets and cause damage to the building envelope, structure, building services equipment, fittings and furnishings and contents. In extreme situations, flood events can result in total structural failure. Porous building materials can also retain water and cause further damp and decay issues. Buildings can be left unusable until maintenance is carried out, leading to the temporary displacement of occupants.

Major damage to essential supporting infrastructure can occur, such as transportation services, energy or water infrastructure, causing indirect risks to asset owners. For example, this could include road closures which can impede emergency vehicles from reaching victims of flooding. Flood events can also cause sewers to overflow and drinking water to become contaminated.

Flood events can also cause considerable financial impacts such as the cost of cleaning and repair, an increase in insurance premiums, or asset relocation in extreme situations.

What tools and models can be used to provide detailed analysis?
The Environment Agency (EA)'s flood map for planning[51] provides an easy-to-use mapping tool for assessing likelihood of flooding in an area. The Scottish Environment Protection Agency (SEPA) and the Department for Infrastructure (NI) also produce flood maps for assets located in Scotland or Northern Ireland respectively.

Table 7: The Environment Agency's Flood Zone Definition Table[52]

Flood Zone	Definition
Zone 1 (Low Probability)	Land having a less than 1 in 1,000 annual probability of river or sea flooding. (Shown as 'clear' on the Flood Map – all land outside Zones 2 and 3)
Zone 2 (Medium Probability)	Land having between a 1 in 100 and 1 in 1,000 annual probability of river flooding; or land having between a 1 in 200 and 1 in 1,000 annual probability of sea flooding. (Land shown in light blue on the Flood Map)
Zone 3a (High Probability)	Land having a 1 in 100 or greater annual probability of river flooding; or Land having a 1 in 200 or greater annual probability of sea flooding.(Land shown in dark blue on the Flood Map)
Zone 3b (The Functional Floodplain)	This zone comprises land where water has to flow or be stored in times of flood. Local planning authorities should identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency. (Not separately distinguished from Zone 3a on the Flood Map)

The Environment Agency's long term flood risk checking service[53] can advise on the risk of flooding from nearby rivers, the sea, surface water, reservoirs and some ground water. The EA has defined four levels of risk as follows:

- **High:** each year, the area has a chance of flooding of greater than 1 in 30 (3.3%).
- **Medium:** each year, the area has a chance of flooding of between 1 in 100 (1%) and 1 in 30 (3.3%).
- **Low:** each year, the area has a chance of flooding of between 1 in 1000 (0.1%) and 1 in 100 (1%).
- **Very low:** each year, the area has a chance of flooding of less than 1 in 1000 (0.1%).

Climate Central's Coastal Risk Screening Tool[54] can be used to identify areas threatened by sea level rise and coastal flooding.

Who to engage for detailed analysis?
Flood risk specialists can be engaged to undertake site specific hydraulic modelling, including the impact that climate change will have on flood risk.

Reduced Water Availability

What are the potential impacts to the built environment?
Drought occurs when demand for water outstrips the supply, usually caused by long periods of low rainfall, though this can also

be exacerbated by high temperatures.[55] Soil shrinkage resulting from drought can increase the risk of damage to underground infrastructure such as burst water pipes or damage to gas lines and increase the risk of subsidence.

Overall availability of water is reduced which can lead to insufficient drinking water for building occupants and dehydration, or a risk to operations and revenue for any organisations that use water in operational processes such as the food industry. Sanitation is also impacted due to reduced water for sanitary appliances such as taps, toilets and showers. In extreme cases, reduced water availability can lead to building closure.

What tools and models can be used to provide detailed analysis?

The modelling and assessment of reduced water availability within the built environment is still immature within the UK.

The WWF Water Risk Filter[56] is a free tool which assesses physical, regulatory and reputational risk arising from projected water quantity and quality datasets. Risk levels for 2020, 2030 and 2050 time horizons are provided.

The SPEI Global Drought Monitor[57] can be used to review current and historical drought conditions in a certain region on a monthly time resolution.

The WRI Aqueduct Water Risk Atlas[58] provides overall water risk values for baseline and future scenarios over annual and monthly resolutions.

Who to engage for detailed analysis?

Geotechnical engineers can provide asset-level analysis of ground conditions.

Storm Events including High Winds

What are the potential impacts to the built environment?

Storm events present greater chances of structural damage to built assets and ingress of water from driving rain. Impacts can be significant ranging from risk to life, total structural failure or foundation damage to damaged fixings and facade elements and comfort of occupants.

What tools and models can be used to provide detailed analysis?

The BRE's Wind Microclimate Around Buildings (DG 520) provides guidance on the general principles of wind flow around buildings and techniques for mitigating unacceptable wind speeds, largely for pedestrian wind comfort.

Who to engage for detailed analysis?

Wind and microclimate experts can be engaged for more detailed wind studies including the use of Computational Fluid Dynamics (CFD) or wind tunnel testing.

Wildfires

What are the potential impacts to the built environment?

Risk of wildfire may seem unlikely within the UK, however, 130,370 wildfire incidents were recorded in England over the period

2009–2017[59] and future projections show a significant increase in the number of summer wildfire events[60].

Many wildfire events occur in rural settings making rural assets more exposed to wildfire risk.

Impacts from wildfire can be severe ranging from loss of life and total loss of property to damage of individual components and contents. Indirect risks from wildfire incidents also include serious interruptions to local infrastructure systems which may affect the operation of built assets.

What tools and models can be used to provide detailed analysis?

Assessment of wildfire risk is still within its infancy within the UK, however the UK Fire Severity Index can be used to assess how severe a fire could become if one were to start.

FRAMEWORK SECTION 4

Assessing Overall Risk Rating

What Section 4 Covers

Once the baseline and future risks have been assessed for each physical hazard, the results can be used to assess an overall risk rating for the asset. This section provides guidance on how to identify the most significant risks to address, consider the interdependencies of risks, review the cost of potential impacts, and decide on adaptation measures to take where applicable.

Why this is important

An overall view of risks to the asset, which incorporates cost of impact and appraises the interaction of risks, can be used to understand which risks need addressing most urgently and can provide useful information for the wider business strategy and financial planning (see section 5).

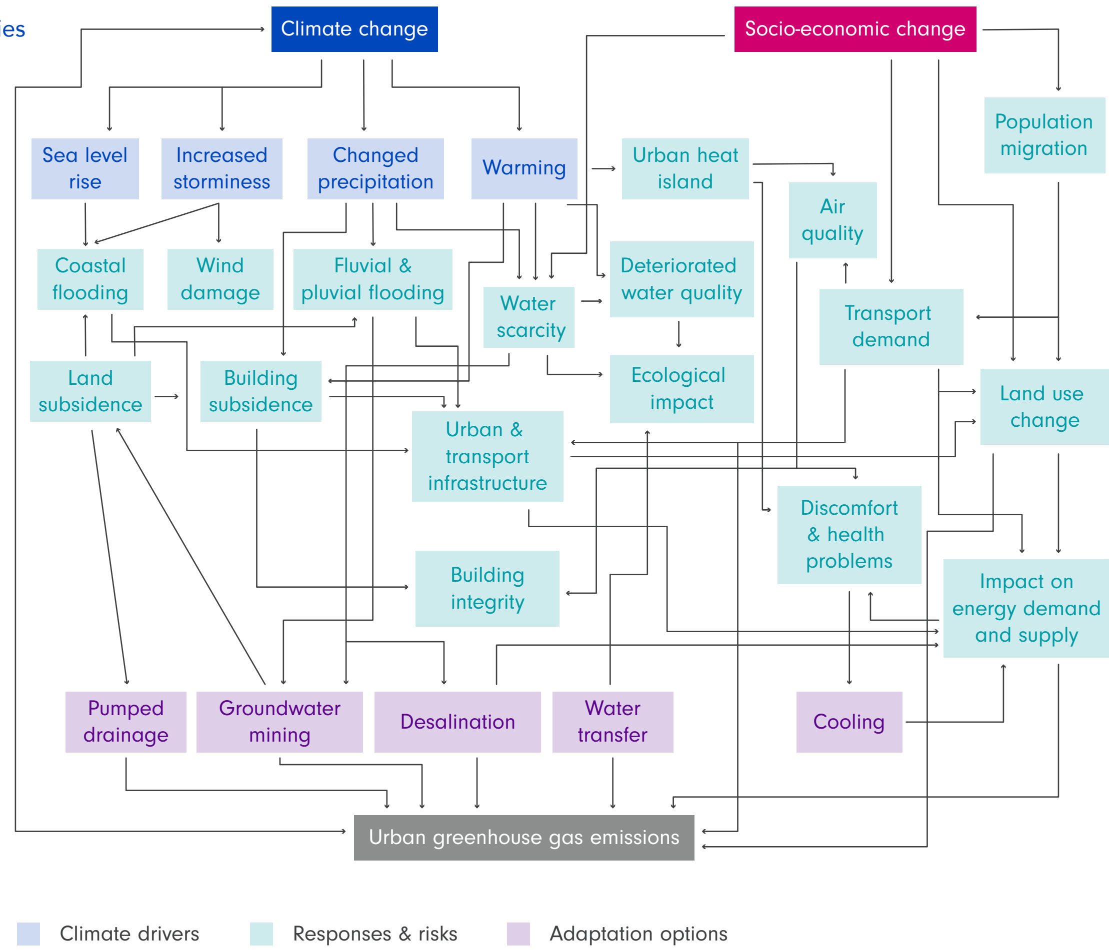
How to Complete Section 4

4.1 Interdependencies Analysis

Many hazards are interdependent, which may result in cumulative effects and cascading impacts that can substantially alter the magnitude or consequence of the hazard and, therefore, the risk (Figure 9). Recognition of these interdependencies and how climate change may alter or amplify these interdependencies should be recognised within the risk assessment.

For example, combined surface water and river flooding events could create high risks of flooding that individually pose a low risk. This higher risk may then cascade to, for example, impacting power supply within the built asset and/or accessibility to the built asset. If interdependencies are not considered, then miscalculation of risks may occur leading to missed opportunities for adaptation or potential for maladaptation.

Figure 9:
Interdependencies Matrix[61]



4.2 Cost Impact

Climate change is expected to financially impact assets in various ways, including:

- Impacts to the fair value of assets due to exposure to physical risks.
- Access to capital from climate risk or opportunities[66].
- Reduced revenue and higher costs from negative impacts on workforce (e.g., health, safety, absenteeism).
- Write-offs, early retirement, or risk of stranded existing assets (e.g., damage to property and assets in "high-risk" locations).
- Increased operating costs (e.g., inadequate water supply for hydroelectric plants or increased asset running costs from heating and cooling).
- Increased maintenance requirements due to more rapid degradation of materials.
- Increased capital costs (e.g., damage to facilities or adaptation measures required).

- Reduced revenues from lower sales/ output – Increased insurance premiums and potential for reduced availability of insurance on assets in "high-risk" locations.[63]
- Reduced insurance premiums from the adoption of adaptation measures.

Calculations of likely cost of impact should be undertaken for each physical hazard, though the level of detail may differ depending on where organisations are in their physical disclosure journey. This could vary from:

- Using the descriptions of consequence (Table 4) to identify level of expected cost (£, ££, £££, ££££, £££££).
- Undertaking a high-level analysis of cost impact and recording projected ranges of costs.
- Undertaking a detailed cost of damage calculation and recording projected costs.
- Using a third-party proprietary model analysis which includes calculation of the likely cost of physical damage.

4.3 Overall Risk Rating

Each physical hazard will now have a baseline risk rating and future risk rating, and the interdependencies of the risks and cost impacts should have been reviewed. Taking all four items into account, an overall risk rating can be given to the asset from each physical hazard.

For example, an asset which has a moderate baseline risk, and high future risk of fluvial flooding has a number of interdependent risks such as sea level rise and/or storm and wind events. The combination of these risks would result in a very high cost impact to the asset owners and therefore the overall risk rating has been deemed very high risk.

Description of physical hazard	Description of the risks to the built assests	Baseline			Future	Interdependencies of risks	Cost impact	Overall risk rating
		Probability of risk occuring	Consequence of risk occurring of physical hazard	Baseline Risk Rating	Baseline Risk Rating			
Fluvial flood	Damage to structure and contents, building out of use (relocation of occupants)	Low likelihood	Severe	Moderate risk	High risk	Fluvial flood combined with sea level rise/ storm and wind events increases severity	££££	Very high risk

4.4 Adaptation Measures

The risks posed to the asset from each physical hazard should be reviewed to identify urgent, short, and long-term actions required to manage climate-related risks.

As per Table 6, physical risks to the asset classified as moderate, high, or very high signal that adaptation measures should be adopted on the following timescales:

- Very High: Urgent implementation of adaptation measures for the built asset.
- High: Implementation of adaptation measures may be necessary in the short term and likely over the longer term.
- Moderate: Some implementation of adaptation measures may be required in the longer term.

Providing individual adaptation measures to adopt is beyond the scope of this report, but it is recommended that consultants are engaged to identify cost effective adaptation measures that address multiple risks where possible.

FRAMEWORK SECTION 5

Using the Framework to Disclose Physical Risk

What Section 5 Covers

Once Framework Section 4 has been completed and the overall risk rating of the asset has been assessed, this information can be incorporated within overarching business strategies and financial planning (linking to TCFD recommendations 2a, 2b, 2c). Decisions about the future of the asset can then be made, for example, to determine whether a re-assessment of insurance is required, whether adaptation measures can be effectively incorporated, or (in worst case scenarios) whether an asset needs to be disposed of.

Why this is important

By establishing risk ratings, identifying priority areas, and understanding risk tolerances, organisations are better placed to develop comprehensive and ongoing risk action and management plans.

How to Complete Section 5

5.1 Materiality of Risks

The cornerstone of most disclosure standards is a determination of materiality. In its 2017 report, the TCFD did not define materiality but rather deferred to existing reporting standards and legal requirements, stating that "organizations should determine materiality for climate-related issues consistent with how they determine the materiality of other information included in their annual financial filings".[64]

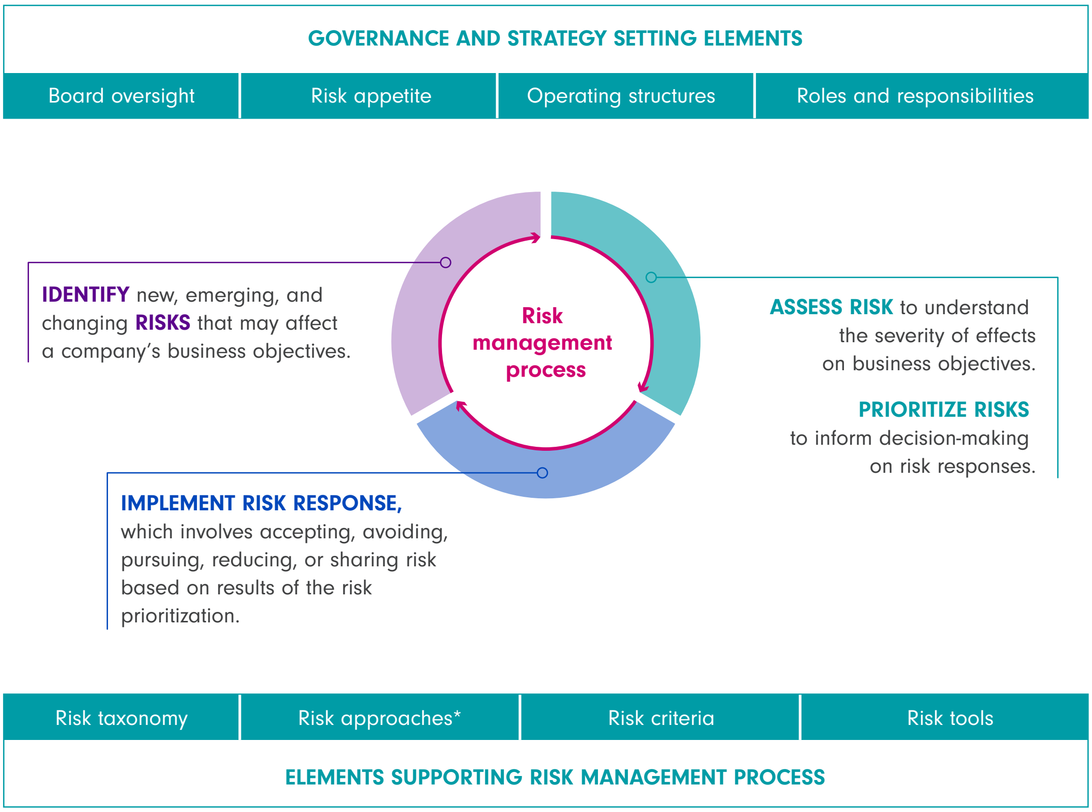
To help investors understand the context in which materiality determinations are made, companies could consider whether the following disclosure is helpful:

- Reporting the basis of their materiality assessment of climate-related risks, including the materiality threshold applied and over what period of time, to allow investors and other stakeholders to understand a company's approach in determining materiality and non-materiality.
- Disclosing whether climate-related risks could be material in the future. In such cases, a company might disclose climate-related information outside financial filings to facilitate the incorporation of such information into financial filings once climate-related issues are determined to be material.
- Companies should be cognisant that materiality is not a static concept. It is evolving over time in terms of what primary users view as material to their decisions; who beyond primary users might be an audience for the disclosure; and what type of information is desired.[65]

5.2 Ongoing Risk Management Plan

The TCFD's 2020 Status Report found that companies' disclosure of their risk management process is much lower than their disclosure of most other recommended disclosures. Risk management is essential in supporting organisations to both retain and create value. Disclosing risk management processes demonstrates how an organisation thinks about and acts upon its most significant risks in order to protect value and achieve its strategic objectives. Systematic risk management involves the identification, assessment, and evaluation of risks, which are then responded to (managed) and reported on (Figure 10).[64]

Figure 10: Risk management processes and key elements



Risk exposure and management processes must be reviewed and updated periodically. A strategy should therefore be put in place to update risk assessment and implement adaptation measures if certain climate thresholds are met.

Within their disclosures, organisations should:

- Outline explicitly how risks will be managed.
- Define priority risks and how they are to be addressed.
- Define the timeframe for risk management (we recommend that risk management plans are updated on a minimum 5-year timescale as outlined in the EU Taxonomy).
- Provide details of internal governance processes on physical risk disclosure (TCFD 1a).
- Provide details of the management's role in assessing and managing climate-related risks and opportunities (TCFD 1b).
- Describe how the risk assessment is integrated into the organisation's overall risk management plan (TCFD 3c).

* Risk approaches include approaches used for identifying and assessing risks.

5.3 Setting Quantified Targets for Physical Risk Reduction

TCFD recommendation 4c requires organisations to describe the targets used to manage climate-related risks and opportunities and performance against targets. For physical risk disclosure of assets, examples of this could include:

- Reduce percentage of asset value exposed to acute and chronic physical climate-related risks to 50% by 2050, or
- Ensure at least 60% of flood-exposed assets have risk mitigation in place in line with the 2060 projected 100-year floodplain.

Any targets set by organisations should:

- Define whether they are absolute or intensity-based.
- State the timeframe over which it applies.
- Define a base year over which progress is measured.
- Set key performance indicators to assess progress.

Investors will want to know how any targets relate to the organisation's strategy and wider governance. As well, the ability to track progress and understand historical changes in performance will be key for attracting investment.

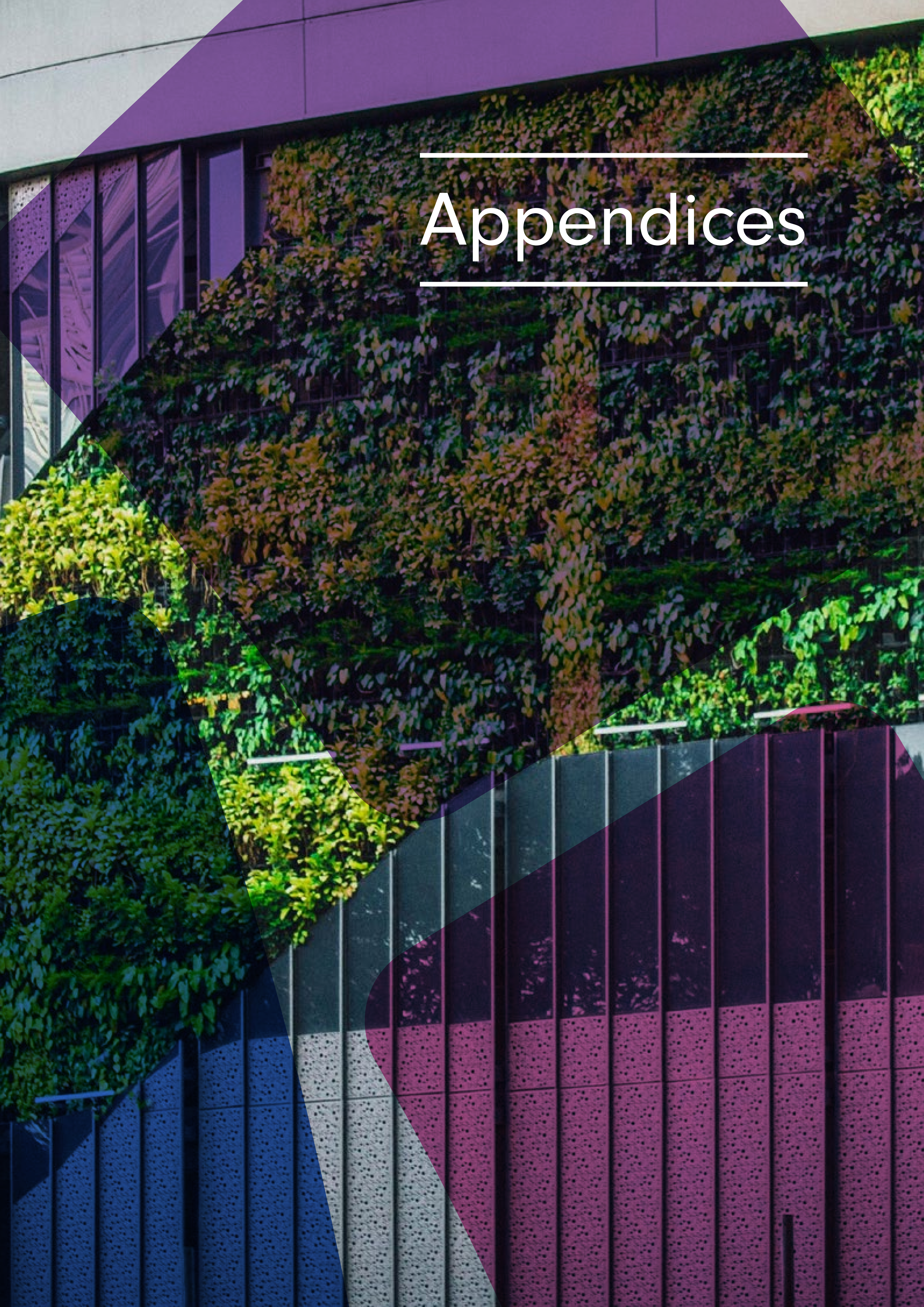
5.4 Using the Reporting Framework for TCFD Disclosure

According to the TCFD, 'effective disclosures' must:

- Be presented in sufficient detail for users to assess exposure to climate-related risks and understand the approach to managing/addressing them.
- Take into account different timeframes and their varying impacts.
- Provide a thorough overview of exposure to climate-related risks.
- Be written with the intention of communicating financial information.
- Offer a balance of both quantitative and qualitative information
- Explain any changes in disclosures and approaches.

In working through Steps 1 to 5 of the Reporting Framework, organisations will ensure that all necessary information is gathered to support such 'effective disclosures'.

Appendices



APPENDIX I

Reporting Framework

A Framework for Measuring and Reporting of Climate-related Physical Risks to Built Assets

UK GBC

How to use this framework

The purpose of this framework is to guide organisations through the process of measuring the physical risk to built assets from climate change in accordance with the Taskforce on Climate-related Financial Disclosures (TCFD) recommendations. The result of this exercise is to compile a risk register of climate-related hazards for an individual built asset (Table 2).

Each section should be completed in order, referring back to the detail provided within the accompanying report A Framework for Measuring and Reporting of Climate-realted Physical Risks to Built Assets. The numbers to the left of each question identify the relevant section of the report. The sections will guide users through initial information and decisions required to be made, how to assess your baseline risks from climate change, how to assess your future risks from climate change and how to assess an overall risk rating for your asset. Finally, details are given regarding the ongoing risk management plan and organisational targets around physical risk.

Section 1: Initial Information

1.1	Name of asset	
1.2	Date of assessment	
1.3	Asset type	
1.4	Asset location	
1.5	Expected duration of asset life	
1.6	Define timeline of interest for risk assessment:	
	Short-term:	
	Medium-term:	
	Long-term:	
1.7	Define boundaries of risk assessment:	
	Boundary for direct risks	
	Boundary for indirect risks	
1.8	Identify any indirect risks to consider	
1.9	Identify physical hazards to be assessed in **Table 2**.	
	Have you excluded any physical hazards from the risk assessment? If yes, record reasons behind this decision.	
1.10	Identify chosen climate scenarios	
1.11	Identify datasets and tools to be used	
	Baseline assessment	
	Future assessment	

Section 2: Assessing Baseline Risk from Physical Hazards

2.1	Has a physical risk assessment been undertaken for the asset previously? If yes, provide details here.	
2.2	Has the asset been impacted by any physical hazards historically? If yes, provide details in **Table 1** below.	

Table 1 - Historical impact from physical hazards

Description of physical hazard	g precipitation patterns	oil erosion & subsidence.			
Date of occurance					
Impact to asset					
Adaptation measures incorporated as a result of impact					

2.3	Describe how any inherent vulnerabilities or resilience the asset has to this physical hazard has been incorporated into the assessment of consequence.	
	For this section, consider each physical hazard in turn and provide answers in the baseline section of **Table 2** below.	
2.4	Assess the likelihood of the physical hazard occuring in the current time period (probability).	
2.5	Assess the impact of the physical hazard occuring in the current time period (consequence).	
2.6	Use **Figure 1** to assess the overall risk to the built asset from the physical hazard	

Figure 1

		Consequence			
		Severe	Medium	Mild	Minor
Probability	High Likelihood	Very high risk	High risk	Moderate risk	Moderate / low risk
	Likely	High risk	Moderate risk	Moderate / low risk	Low risk
	Low Likelihood	Moderate risk	Moderate / low risk	Low risk	Very low risk
	Unlikely	Moderate / low risk	Low risk	Very low risk	Very low risk

2.7	Describe any assumptions made or limitations of the methodology used.	

Section 3: Assessing Future Risk from Physical Hazards

For this section, consider each physical hazard in turn and provide answers in the short, medium and long term sections of **Table 2** below.

2.3	Assess the likelihood of the physical hazard occuring in the short, medium and long term (probability).	
2.4	Assess the impact of the physical hazard occurring (consequence).	
2.6	Use Figure 1 to assess the future risk to the built asset from the physical hazard.	
2.7	Describe any assumptions made or limitations of the methodology used.	

Section 4: Assessing Overall Risk Rating

4.1	Consider the interdependencies of the risks. Do any of the interdependencies magnify or reduce any of the risks?
4.2	Consider the cost impact of the risks.
4.3	Determine the overall risk rating for the asset from the physical hazard.
4.4	Decide which adaptation measures will be adopted to reduce risk (recommended for moderate, high and very high risks).

Table 2

		Baseline			Future											
						Short Term		Medium term		Long term						
Description of physical hazard	Description of the risks to the built asset	Probability of risk occuring	Consequence of risk occuring	Baseline Risk Rating	Chosen Climate Scenario	Probability of risk occuring	Consequence of risk occuring	Probability of risk occuring	Consequence of risk occuring	Probability of risk occuring	Consequence of risk occuring	Future Risk Rating	Interdependencies of risks	Cost Impact	Overall Risk Rating	If moderate to high risk, what adaptation measures will be adopted to reduce risk?
Heat stress					RCP2.6											
					RCP4.5											
					RCP6.0											
					RCP8.5											
Extreme precipitation					RCP2.6											
					RCP4.5											
					RCP6.0											
					RCP8.5											
Extreme cold temperature					RCP2.6											
					RCP4.5											
					RCP6.0											
					RCP8.5											
Storm and wind events					RCP2.6											
					RCP4.5											
					RCP6.0											
					RCP8.5											
Water scarcity					RCP2.6											
					RCP4.5											
					RCP6.0											
					RCP8.5											
Wildfire					RCP2.6											
					RCP4.5											
					RCP6.0											
					RCP8.5											
Fluvial flood					RCP2.6											
					RCP4.5											
					RCP6.0											
					RCP8.5											
Pluvial flood					RCP2.6											
					RCP4.5											
					RCP6.0											
					RCP8.5											
Sea level rise					RCP2.6											
					RCP4.5											
					RCP6.0											
					RCP8.5											
Mass movement					RCP2.6											
					RCP4.5											
					RCP6.0											
					RCP8.5											

Section 5: Using the Framework to Disclose Physical Risk

5.1	Describe the organisation's ongoing risk management plan including board oversight, management's role in assessing and managing climate-related risks and opportunities, and timeframe for the ongoing risk management plan.	
5.2	Describe any quantified targets set by the organisation for physical risk reduction.	

APPENDIX II

Indirect Risks for Consideration

Utilities services

- Water
- Gas
- Electricity
- Communications
- Sewage systems

Local infrastructure

- Major roads
- Railways
- Underground/metro systems
- Airports
- Harbours

Social infrastructure

- Healthcare
- Education services
- Public services

Local Population

- Risk of reduced accessibility
- Risk to life
- Risk to health
- Risk of reduced comfort

Local Environment

- Biodiversity loss
- Chemical changes
- Insect infestation

Business Operations

- Loss of revenue
- Loss of productivity
- Reputational risk
- Impact on market risk
- Changes in insurance premiums
- Increased competition for resources
- Disruption of supply chains

APPENDIX III

Acknowledgements

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Editors

UKGBC – Alastair Mant, Brooke Penman, Kai Liebetanz

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Arup – Andy Sheppard and Anna Tuddenham
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BuroHappold – Alison Nicholson
Carbon Laces – Madhuban Kumar
CBRE – Ed Blackburn and Rachael McGinley
Currie & Brown – Elizabeth Greenhill
Dan Carson Sustainability – Dan Carson
Hoare Lea – Robert Winch
JLL – Phoebe Lewis and Connor Monk
London Climate Change Partnership – Kristen Guida
Lendlease – Brett Ormrod
Mott MacDonald – Maria Pooley
Perkins&Will – Asif Din
RPS – Anna Velkov
RPS/West Berkshire Council – Emily Ashton-Jelley
Stanhope Plc – Alice Reid, Nils Rage and Adam Smith

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QUESTIONS & FEEDBACK

We welcome input from any interested stakeholders from across the building value chain on the content of this guidance and any future revisions.

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