INTERGOVERNMENTAL PANEL ON climate change

The concept of risk in the IPCC Sixth Assessment Report: a summary of cross-Working Group discussions

Guidance for IPCC authors

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Prepared by

Andy Reisinger	**Mark Howden**	**Carolina Vera**
Mathias Garschagen	**Margot Hurlbert**	**Sylvia Kreibiehl**
Katharine J. Mach	**Katja Mintenbeck**	**Brian O'Neill**
Minal Pathak	**Roque Pedace**	**Hans-Otto Pörtner**
Elvira Poloczanska	**Maisa Rojas Corradi**	**Jana Sillmann**
Maarten van Aalst	**David Viner**	**Richard Jones**
Alexander C. Ruane		**Rosh Ranasinghe**

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1. Purpose

The concept of risk is a key aspect of how the IPCC assesses and communicates to decision-makers the potential adverse impacts of, and response options to, climate change.

The use of the concept of risk has not been fully consistent across Working Groups or between assessment cycles, given that the concept itself and its use by IPCC has continued to evolve. Since the Special Report on Global Warming of 1.5ºC, cross-Working Group efforts have been put in place to develop a consistent risk framing throughout the subsequent products of IPCCs Sixth Assessment Cycle (AR6).

The purpose of this guidance note is to promote a more consistent and transparent application of the concept of risk across Working Groups in the sixth assessment cycle and to provide the foundation for its use and possible further evolution in future assessment cycles.

This guidance note seeks to maximise consistency among Working Groups while recognising differences in how the concept of risk is used across scientific disciplines and relevant literature. Consistent use of the concept of risk is intended to provide a more robust, clear and transparent basis for communicating climate change-related risks and risk management options to decision-makers working in a wide range of institutional and policy settings.

The scope of this guidance is relatively narrow. This document merely seeks to clarify how the term 'risk' should be used *where and when* authors consider it appropriate to use this concept *within* their assessment – it does *not* propose an overarching risk-centred framework for assessment of climate change impacts and responses in IPCC reports in order not to preclude consideration of beneficial consequences from impacts or responses.

2. Annotated definition

During the preparation of the three Special Reports of the sixth assessment cycle, the definition of risk was revised (see online glossary) by a group of authors and IPCC Bureau members to better reflect its various uses and contexts, and to clarify issues that have led to differing interpretations and applications across Working Groups and in different reports.

The revised definitions for "risk" and "risk management", used in the Special Report on Climate Change and Land and Special Report on the Ocean and Cryosphere in a Changing Climate, and intended to be used in the Working Groups' contributions to the AR6, are as follows:

Risk

The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential *impacts of* climate change as well as human *responses to* climate change. Relevant adverse consequences include those on lives, livelihoods, health and wellbeing, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species.

- In the context of climate change impacts, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards. Hazards, exposure and vulnerability may each be subject to uncertainty in terms of magnitude and likelihood of occurrence, and each may change over time and space due to socio-economic changes and human decision-making (see also *risk management, adaptation, mitigation*).
- In the context of climate change responses, risks result from the potential for such responses not achieving the intended objective(s), or from potential trade-offs with, or negative side-effects on, other societal objectives, such as the Sustainable Development Goals (see also *risk trade-off*). Risks can arise for example from uncertainty in implementation, effectiveness or outcomes of climate policy, climate-related investments, technology development or adoption, and system transitions.

Risk management

Plans, actions, strategies or policies to reduce the likelihood and/or magnitude of adverse potential consequences, based on assessed or perceived risks (see also *risk assessment, risk perception, risk transfer*).

The revised definition of risk clarifies and refines previous definitions in the following respects:

a) The 'core' definition of risk is "**the potential for adverse consequences**".

- The word "**potential**" makes clear that uncertainty, or more broadly, incomplete knowledge (as defined in IPCC), is a key element of the concept of risk. This uncertainty does not necessarily have to be quantified, but authors need to provide some sense of the nature and degree of uncertainty to allow a meaningful risk assessment and risk management responses to be undertaken (see also Section 3).
- In IPCC use, risk refers only to negative ("**adverse**") consequences; the potential for positive outcomes should be described using other terminology (such as 'opportunity' or 'potential benefit/co-benefit'). Note this is a definitional choice; some scientific and technical disciplines (e.g. finance) treat risk as value-neutral while in others (and also in most non-technical uses of the word) it refers only to negative (adverse) consequences. Authors should take care to check the use of the concept of risk in primary literature to ensure consistency with the IPCC definition, and will need to be transparent about this definitional choice when communicating IPCC findings back to decision-makers in communities that may use the word 'risk' for both positive and negative outcomes.
- Several climate change impacts or responses to climate change hold the potential for both beneficial and adverse consequences, and thus present both a risk and an opportunity. This could depend on the nature of the affected system, magnitude of change, and values and objectives of different actors. IPCC authors therefore need to check and, where necessary, describe carefully the context and assumptions under which and for whom a specific impact of or response to climate change would represent predominantly an adverse consequence and thus the label 'risk' is appropriate. This is particularly true when considering not only the assessment but also management of risk.

b) Risk in IPCC use applies only to "**human or ecological systems**".

- The concept of risk should ***not*** be used to describe outcomes within physical systems only. For example, the term "flood risk" should not be used if it only describes changes in the frequency and intensity of flood events; it would need to be linked explicitly to the consequences of such events for human or ecological systems (see "dos and don'ts" in Section 4 and "Examples" in the Appendix, including the distinction between 'physical risk' and 'transition risk' found in literature on finance).
- "**recognising the diversity of values and objectives**" emphasises that different individuals will evaluate the potential consequences for human and ecological systems from different points of view. Some judgments will reflect values that are held by many, but some values may be held only by a subset of a population; i.e. risk can apply to material as well as cultural, aesthetic and spiritual aspects of human or ecological systems, and to ecological systems that do not have any explicit human value. The third sentence of the definition gives examples of this.

c) Risk applies to both ***impacts of*** and ***responses to*** climate change.

- This is a significant evolution and clarification compared with earlier assessments, which have tended to be dominated by risk related to climate change impacts, at least for headline messages. The way in which risk is understood and expressed differs between those two broad domains; the two sub-bullets in the risk definition further clarify its use in those two domains.
- In some instances, it may not be self-evident whether an outcome is related to a climate change impact or a response to climate change. E.g. adverse health outcomes in populations that migrate because of climate change could be considered a risk related to climate change impacts or to a climate change response. What lens is useful will depend on the available literature and context:
    - If the assessment provides detailed information on how this risk depends on the severity of impacts that drive migration and local adaptation options that could limit migration pressures, it may make sense to frame this as a risk related to climate change impacts.
    - If the assessment focuses more on ways in which adverse health outcomes can be reduced within migrating populations, including the role of receiving environments and the decisions made by migrants, this risk could be framed as associated with a climate change response.
    - Note this may not have to be an either/or decision: as long as authors provide transparent and useful information about the key drivers of adverse consequences, their uncertainty and potential changes over time, it may not be necessary to explicitly cast a specific risk as related to either climate change impacts or a response to climate change.

d) Use of '**risk**' in the context of climate change impacts

- This sub-definition is based on earlier definitions centred on the interaction between hazard, vulnerability and exposure (building on the IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation).
- The current definition of 'risk' related to climate change impacts has retained the notion of 'hazard' to describe the climatic driver of a risk. This is consistent with the definition of

'hazard' (see online glossary) also being focused on the potential for negative consequences. Referring to a climatic event or trend as 'hazard' thus relies on an assessment of the potential consequences of this climatic change, not only an assessment of the observed or projected change in a climate variable on its own.

- For this reason, Working Group I has developed the more general concept of 'climatic impact driver' to provide information about "natural or human-induced climate events or trends that may have an impact (detrimental or beneficial) on an element of society or ecosystems" (see online glossary). This allows a broader and more value-neutral characterisation of climatic changes by Working Group I that may be relevant for understanding potential impacts, without prejudging whether specific climatic changes lead to adverse, neutral or beneficial consequences. These consequences will depend on the affected system and associated values and are assessed typically by Working Group II.
- This definition recognises the "dynamic" nature of risk; that is, each of the three elements (hazard, vulnerability and exposure) is subject to change over time due to climatic changes or socio-economic change; depending on the specific variable and time frame, these changes can be natural, unintended or deliberate (for example through risk management).
- The use of the term 'risk' in physical science literature is not always fully consistent with the definition of risk by IPCC. For example, event attribution studies often refer to the 'fraction of attributable risk' when assessing the changing probability or magnitude of a climatic impact driver only. Authors should be explicit about whether attribution statements refer only to climatic impact drivers or to attribution of risk, which also depends on the changing exposure and vulnerability of a given system.
- The notion of uncertainty applies to each of the three elements, i.e. not only the magnitude and frequency of hazards but also the exposure and vulnerability to any given hazard. If a study or conclusion assumes no change or no uncertainty in one of those dimensions (i.e. risk due to flooding considering only changes in flood frequency and magnitude, but not societal conditions) it should be stated explicitly since not only the magnitude but even direction of change in risk could depend on past or future socio-economic developments (see also Appendix).

e) Use of '**risk**' in the context of responses to climate change

- This sub-definition is new, presenting a significantly strengthened element of the concept of risk. It builds on the way that risk has been used in previous Working Group III assessments, but which has not made it into IPCC headline messages in the same way as risks relating to climate change impacts.
- The 'hazard-exposure-vulnerability' concept does not generally apply here because climatic drivers may play no direct, material role in the risk being described (see Appendix for examples such as liability risk, financial risk, technological risk).
- In this context, adverse consequences can arise from the potential for:
    - a response to climate change failing to achieve its intended outcome; or
    - the intended action creating an adverse outcome elsewhere.

  Note this concept of risk applies to both adaptation and mitigation responses. For adaptation responses, it is closely related to the concept of maladaptation.
- Consistent with the general definition of risk, what matters is the *potential* for adverse consequences, not the actual realisation. Where we are *certain* that an adverse

consequence will occur (e.g. increasing air conditioning *will* increase electricity demand), this should be referred to as trade-off, not as risk.

- A situation may be described appropriately as "risk" in an IPCC assessment even though the primary literature does not use the risk concept (e.g. in some disciplines, the concept of risk is used only if all elements can be quantified), or conversely, the primary literature may refer to risk but it would not be appropriate to use the term in the IPCC assessment (e.g. in some disciplines, risk is used for both positive and negative consequences). Authors need to take care to translate findings from the primary literature into the IPCC 'risk' terminology, but equally need to take care when communicating IPCC findings back to decision-makers to ensure that any differences in the definition and use of "risk" are made transparent to avoid misunderstandings. See Appendix for examples.

3. Characterising uncertainty in risk assessments

The IPCC definition takes an inclusive approach to the situations where the concept of risk can be applied (recognising the diversity of values and hence what consequences might be considered "adverse" by at least some people). The definition does not require the adverse consequence or the degree of uncertainty or likelihood of those consequences to be quantified. However, to be useful for risk management, authors will need to adopt some rigour – not every potential for adverse consequences deserves to be described as 'risk'. The future is always uncertain; context and comparability matter. (For example, leaving your house undoubtedly has the *potential* to lead to adverse consequences on any given day, but in most normal circumstances we would not therefore say that leaving your house presents a 'risk' that needs to be managed. However, in some contexts, e.g. during a pandemic, such a statement may be much more appropriate and relevant to decision-making.)

Risk management relies on an ability by decision-makers to weigh up alternative courses of action, and to balance a range of potentially adverse consequences, since no action is entirely free of the potential for adverse consequences. Such balancing inevitably relies on individual or collective value judgements, including whether risks are viewed as manageable, intolerable or existential.

A critical contribution from IPCC assessments to inform decision-making lies in a careful and transparent characterisation of risks, considering both the *adverse consequence* and its *potential*:

- What is the magnitude, reversibility, distributional effects, etc. of the adverse consequence?
- How confident are we in our understanding of those aspects?
- How much do those consequences depend on socio-economic trends or other assumptions?
- How well do we understand the *potential* for such events/outcomes to occur, and how much does this potential depend on climate change, policy design or socio-economic variables?
- Can we quantify the probability of occurrence? If not, can we characterise the *potential* in some other way that helps stakeholders decide whether to take this potential seriously, and how it compares with potential adverse consequences from alternative courses of action?

These considerations apply not just to risks related to climate change impacts but equally to risks related to responses to climate change, including adaptation and mitigation technologies, investments, practices and behaviours, and policies.

Careful use of the IPCC-calibrated uncertainty and confidence language will be important to transparently and clearly describe what we know and do not know both about the adverse consequences themselves should they be realised, and the potential for them to be realised.

Note that confidence language is relevant to the different drivers and elements of risk (e.g. the probability of a certain amount of change in a key hazard, or the confidence in the consequences of a certain physical event on a species or ecosystem), but it will also apply in aggregate form to the magnitude of the assessed risk itself (e.g. confidence that risk to system X is high at warming of Y degrees). The level of confidence in the overall risk will depend on how the risk is stated. It will be related to, but not determined by, confidence in the individual components.

For example, the confidence in a statement such as "Risks to system X become high at Y degrees of warming" in most cases will not be higher than the confidence that Y degrees of warming would result in quantifiable changes to the climate variables that drive this risk (e.g. seasonal rainfall in a specific region). By contrast, the confidence in a statement such as "Further warming will increase risks to system X" may be high even if confidence in the projected amount of change is only medium.

Evolving practice and explicit guidance for producing 'burning embers' diagrams offer additional criteria and metrics that may help authors identify and quantify risks for complex systems and transparently report their confidence in their assessment. The concept of risk is the foundation of the so-called 'reasons for concern', which are focused on high-level, severely adverse consequences. The reasons for concern in turn offer a framework and explicit criteria for determining some 'key' climate-related risks.

IPCC generally assesses the 'additional' risk due to climate change impacts or responses, not the total risk to a system that may be related to resource exploitation, pollution, habitat fragmentation, inequality, etc. However, the risk from climate change may depend on the current and future non-climatic stresses. Authors need to be clear about their assumptions about non-climate stressors.

4. Some DOs and DON'Ts

Do:

- **use risk where you are explicitly considering potential adverse consequences and the uncertainty relating to those consequences.** The more clearly you can characterise the adverse consequence (in terms of magnitude, scale, distribution, reversibility, etc.) and the nature of uncertainty, by providing the respective narrative, the more useful the risk concept will be. Note that uncertainty could lie in climate hazards, exposure, vulnerability/sensitivity, economics, human behaviour, technology, etc. Recognise that each of those can change over time, either naturally, unintended or as a deliberate change. If you assume no change in a relevant component of risk, state this explicitly to ensure your risk assessment is transparent.
- **use risk to improve the ability for decision-makers to understand and manage risk.** Understanding and managing risk means making decisions about whether the potential for adverse outcomes is acceptable, whether/how it could be reduced, or whether alternative paths of action might result in lesser or different potential adverse consequences.

Don't:

- **use risk as a simple substitute for probability/chance.** For example, a statement such as "climate change increases the risk of wildfire" may simply mean that climate change increases the probability of wildfires. If that is the case, stick with probability language.
- **use risk to describe physical hazards.** In IPCC use, risk refers to consequences for human or ecological systems. Don't use risk terminology if you are only describing a change in frequency and/or magnitude of physical hazards (e.g. don't say "climate change increases flood risk" if your assessment is only looking at changes in flood frequency and/or magnitude and not at the consequences for specified human or ecological systems). In such a case, refer explicitly to changes in frequency and/or magnitude of hazards.
- **use risk as generic term for 'anything bad that may happen in future'.** Not every negative consequence that may occur in future deserves to be described as 'risk', because every future change has the 'potential' for adverse consequences. What adverse consequences are usefully presented as 'risk' will depend on the context of the assessment. For example, presenting the risk from a specific action may be highly subjective, but comparing risks under alternative courses of action may provide useful support for decision-making.
- **use 'hazard' as a generic term for climatic events or trends that may not have adverse consequences for all elements of an affected system.** The term 'climatic impact driver' may instead be used in climate science assessments to refer to climatic events or trends in general terms without prejudging whether their consequences are universally adverse or beneficial. The term 'hazard' is only appropriate if the consequence of a climate event or trend is determined to be adverse for a specific element of the affected system.

Terminology: "the risk of …" vs "the risk from …"

There are some common uses of the word 'risk'; some are more likely to be consistent with the concept of risk as defined in the IPCC than others. However, context matters: some expressions work in some specific contexts but not in others. Check carefully and if unsure, discuss with colleagues, including authors of this guidance document.

The following phrases may be appropriate:

- "**The risk from …**": this is likely correct if it refers to a specific driver of risk for a specified human or ecological system. For example, "climate change increases the risk *from* wildfires *to* human settlements", or "price-based policies increase the risk *from* market responses *to* poor people". Be clear what the affected system/value is and how it will be affected.
- "**Risk related to …**": this is similar to "risk from …". It should describe the driver(s) for adverse consequences for a specific human or ecological system (e.g. "risks *related to* large-scale land-based mitigation" should cover how and to what extent land-based mitigation has the potential to produce adverse consequences to human or ecological systems).
- "**Risk(s) to …**": this should refer to the human or ecological system that would experience the adverse outcome (e.g. "climate change increases risks to coral reef systems", or "reliance on large-scale BECCS increases risks to food security"). Check that you have characterised the magnitude and/or likelihood of the adverse outcome in some way to make such statements useful for decision-making.

- "**… is/are at risk**": such statements should refer to the human or ecological system that would experience the adverse outcome. To be useful for decision-making, the focus should be on describing *why and how* the system will potentially experience an adverse outcome (e.g. "food systems are *at risk* due to direct impacts of climate change on production, as well as pressure on water from multiple uses and pressure on land from land-based mitigation responses").

Avoid the following phrases:

- "**The risk of …**": The expression "climate change increases the risk of…" often is merely a statement about changing probability of an adverse outcome. Even if such a statement refers to changes in both frequency and magnitude of a physical hazard (e.g. flooding), this is still not a statement about risk, because risks refer to human or ecological systems. If your key point is the change in *probability* of an adverse outcome, or a change in the frequency and magnitude of a hazard, say so explicitly rather than using the concept of risk.
- "**Potential risks …**": The *potential* for adverse consequences is inherent in the concept of risk already. Statements such as "climate change entails *potential risks* to XXX" is therefore doubling up and implies that you are not sure whether a risk even exists, which suggests that a proper assessment has not been done.

Potential exceptions exist to any of the above 'rules'. For example, the statement "the risks *of* a changing climate [increase with the rate and magnitude of change]" might be appropriate even though phrases that contain "the risk of …" are generally not recommended. It would be helpful if authors scan their drafts as they near submission stage and discuss potentially problematic formulations with colleagues to reduce and ideally eliminate inconsistent uses of the concept of risk.

Appendix: Examples of application in different contexts

Statements about risk can be made in a qualitative, directional way (e.g. "X increases risks to Y") or can aim to provide quantitative categorisation (e.g. "warming of X degrees results in high risks to Y and very high risks to Z").

Statements that have a quantitative categorisation (e.g. "high" or "very high" risk) need to provide a traceable description of what this means (e.g. "high risk means at least X million people exposed to seasonal water shortages in excess of historical variability over a given period"). In many cases, it will not be possible or meaningful to quantify the level of risk precisely (in terms of number of people, economic damages, probability of events occurring); in these situations it is particularly important that authors provide as much information as possible to allow readers of the assessment to understand and clearly trace what judgements were made to arrive at the different levels of risk.

For example, risks related to singular events in most cases cannot provide quantified probabilities; or in some cases, the number of people affected may be quantified but the degree to which they are affected may be based on a more qualitative judgement. Criteria developed to assess 'reasons for concern' and 'burning embers' can assist in identifying key risks and reporting confidence levels.

a) Flood risk

The risk from flooding to human and ecological systems is caused by the flood hazard (the frequency and/or magnitude of flood events), the exposure of the system affected (e.g. topography, or infrastructure in the area potentially affected by flooding) and the vulnerability of the system (e.g. design and maintenance of infrastructure, existence of early warning systems).

Statements about changes in the frequency and/or magnitude of flood events on their own should not be characterised as changes in flood risk, since this covers only the climate-related hazard part. Whether and how much the actual risk, i.e. adverse consequences for human and ecological systems will increase in future (or have changed in the past), will depend also on changes in the exposure and vulnerability of such systems. For example, the damage from flooding could be reduced, even if the frequency of flooding increases, if measures are taken that reduce the exposure and/or vulnerability of affected systems (noting river management in many parts of the world has reduced flood risk).

It would be correct to say that increasing flood frequency increases risks to human systems – but *whether and how much* the actual risk will increase with climate change by a given date will inevitably depend on concurrent socio-economic changes including proactive risk management decisions such as protection or managed retreat.

b) Food security

Climate-related risk to food security arises from multiple drivers that include both climate change impacts, responses to climate change and other stressors.

In the context of climate change impacts, these include climate hazards (e.g. drought, temperature extremes, humidity), indirect climate-related impacts (e.g. pest outbreaks triggered by ecosystem responses to weather patterns), exposure of people (e.g. how many people depend on a particular crop) and vulnerability or adaptability (how able are affected people to substitute other sources of food, which may be related to financial access and markets).

In the context of responses to climate change, drivers of risk include the demand for land from climate change responses (both adaptation and mitigation), the role of markets (e.g. price spikes related to biofuel demand in other countries), governance (how are conflicts about access to land and water resolved) and human behaviour more generally (e.g. trade barriers, dietary preferences).

Given the multitude of drivers, it will be difficult for any statement to describe “the” risk to food security. To be useful, most statements will have to be relative to some factors remaining unchanged, and to focus on the effect of specific changes (e.g. the risk arising from changes in temperature extremes on food security, for a scenario with no change in food or land demand; or the risk arising from increased demand for land from biomass production, for a scenario with no change in climate). Such assumptions are important for analytical robustness and to clearly identify the role of, for example, different technologies or practices to affect risk under otherwise similar socio-economic scenarios. Nonetheless, it will be important to state any such assumptions clearly because in the real world, all factors are likely to change over time, and hence the actual, systemic risk to food security will always be a superposition of individual but interacting (e.g. compound or cascading) risks.

Socio-economic and behavioural factors and trends, including technologies, institutions and governance, are clearly important in assessing risks, even if the focus of an assessment is on the role of changing climate variables in changing risk. Authors should be careful with statements about risk at a future time if underlying studies assume present-day socio-economic conditions, because such an assumption would be clearly counterfactual. Clear statements about the assumed socio-economic conditions, and whether they are assumed to change over time concurrent with climate, will be important to provide transparency. Studies that focus only on the role of climate change are important but should not be used exclusively to support high-level summary statements of risk where changes in socio-economic conditions clearly have a major influence.

c) Risk in the investment and finance literature

Investment and finance literature and practice makes very frequent use of the concept of risk, and risks may arise from potential climate change impacts and/or responses to climate change (including the lack of a response to climate change).

The way that the risk concept is used in the finance and investment literature is often but not always consistent with the IPCC definition. A key difference is that use of the term 'risk' in finance and investment is not necessarily confined to negative outcomes only, but simply describes the potential for actual consequences to be different from (better or worse) their expected value. Also, some parts of the literature use risk only where potential consequences can be quantified up front but not where consequences depend on qualitative judgements or deep uncertainties.

Authors should scrutinise the use of the concept of risk in the primary literature before using the same risk terminology in their own assessment; equally authors should take care to translate findings back to stakeholders to avoid misinterpretations of IPCC findings.

The investment and finance literature and practitioner community broadly distinguish between 'physical risk' and 'transition risk'. The term 'physical risk' is closely related to risks arising from climate change impacts and climate-related hazards, while the term 'transition risk' typically refers to risks associated with transition to a low carbon economy.

Physical Risk

In much of the business and financial literature, the term 'physical risk' relates to those derived from the hazard × exposure × vulnerability framework, but the focus of this literature is often exclusively on changes in the hazard rather than exposure or vulnerability. Physical risks involve risks from climate change including risk to facilities and infrastructure, impact on operations, water and raw material availability and supply chain disruptions.

Literature on physical risks sometimes separates acute short-term events or chronic long-term changes in weather and climate. Physical risks have direct financial consequences for organisations where those risks are realised, as well as up-front insurance and investment related costs. How physical risks change over time through the dynamic relationship of the three core components of risk (hazard, exposure, vulnerability) is poorly understood and has yet to be dealt with in a coherent, consistent and widespread manner. Authors should be careful not to simply import the term 'physical risk' if a study considered only changes in hazard but not concurrent exposure or vulnerability, as this would be inconsistent with the IPCC definition of risk.

Transition risk

Climate change risk is still perceived by many organisations as long-term in nature and perceived to fall outside the temporal dimensions of decision-making processes, yet many of the potential consequences from a changing climate as well as the transition to a net zero carbon economy will occur, and are occurring, within the typical lifespan of businesses. Transition risks typically refer to risks associated with transition to a low carbon economy.

Transitioning to a lower-carbon economy can 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 organizations. The nature and magnitude of risks will depend upon how rapidly organisations develop resilience attributes (awareness, objectiveness, diversity and flexibility). Transition risks could include Policy; Legal; Technology; Market; Liability risk; and Reputational. Transition risks, if realised, can result in stranded assets, loss of markets, reduced returns on investment and financial penalties. A key issue is the stranding of assets that may not provide the expected financial returns and may end up as large financial liabilities.

Additional risk categories relating to business, finance and investments

Within the broad (and not always precisely defined) concepts of physical and transition risk, the following risk-related terms appear frequently in finance and investment literature. Apart from the specific issues identified above, these terms are broadly consistent with the IPCC definition of risk related to responses to climate change (which includes the lack of a response to climate change).

Risk related to an **asset losing its value:** the potential for loss of investment in infrastructure (dams, highways) including mortgages and mortgage-backed security in damaged real estate and assets.

Risk related to losing some or all of the principal of an investment (or **invested capital**): this risk arises due to the possibility of harm to people and damage to communities and infrastructure as a result of climate change impacts (drought, flood, hurricanes, typhoons) and inability of repayment.

Solvency risk: the risk from reduction in credit ratings due to potential adverse consequences of climate change or climate policy, resulting in higher financing costs for investors, countries and municipalities. This includes **liquidity risk** or the risk of not being able to access funds – for example, when constructing assets such as coal-fired power plants within a changing climate policy landscape, suffering cost overruns such that no further funds are accessible, but the plant is only half complete. Another example is suffering a downgraded credit rating due to exposure to climate change, retention of carbon-intensive assets, or failure to account for climate change, including regulatory response to climate change resulting in an increase in the cost of capital (See Policy Risk).

Risk of lower than expected return on investment: responses to climate change, including changing customer preferences, changing climate change regulations that lower investment returns (coal fired and natural gas power production plants within rising carbon prices, but also withdrawal of subsidies for renewables), and new climate innovations that render older carbon intense technology obsolete, give rise to risk surrounding investment in stranded or obsolete assets and technologies (See Transition risks).

Liability risk: lack of response to climate change creates risk of liability for failure to accurately assess risk of climate change to company infrastructure and business lines, failure to assess and plan for climate change impacts before decision-making, and failure to protect people from impacts of climate change when a duty of care or other legal obligation exists.

Technology risk: the term ‘technology risk’ generally refers to situations where reliance on a particular technology to achieve an outcome creates the potential for adverse consequences if the technology fails to be developed or deployed (for example, the potential for temperature limits to be exceeded if bioenergy with carbon capture and storage (BECCS) isnot developed and deployed at large scales), or adverse side effects associated with using this technology (for example, risks to food security from large-scale deployment of BECCS). Adverse consequences can include lower than expected returns on investment, failure to achieve sectoral or national policy objectives, and risk related to exceedance of temperature limits or increased exposure or vulnerability to climate impacts.

Multidimensional technology assessment is preferable whenever possible, because technology generally does not change in isolation but alongside wider socio-economic, cultural, behavioural, institutional and policy changes. Assessing the risk associated with a specific technology, but with all other socio-economic conditions held constant, may be analytically useful but of limited practical relevance over longer time frames.

Policy risk: changes in policy or regulations in response to climate change could result in the loss of value of assets e.g. climate policy creating stranded assets due to emissions pricing or regulatory changes. Climate policies that provide positive incentives for certain energy sectors can also result in investment risks by making other energy sources less competitive, or once subsidies or other incentives are withdrawn (see Risk of lower than expected return on investment). Similar risks can arise from policies directed at adaptation goals, such as changes to land-use zoning, water prices or water withdrawal rights.

Market risk: changes in relative prices from increased prices of CO_2 and other greenhouse gas emissions could reduce financial returns and hence increase risks to investors.

Residual risk: in some corporate and finance literature, the term 'residual risk' refers to adverse consequences that cannot be quantified in probabilistic terms. This is different from how the term 'residual risk' is generally used in IPCC, where it means the risk remaining after adaptation and risk reduction efforts (see glossary for the IPCC Special Report on the Oceans and the Cryosphere). Authors should take care to check the meaning of the term 'residual risk' where it is used in primary literature and avoid copying the term if it refers to quantifiable vs non-quantifiable risk to avoid confusion.