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Managing the impacts of climate change: risk management responses

Contents

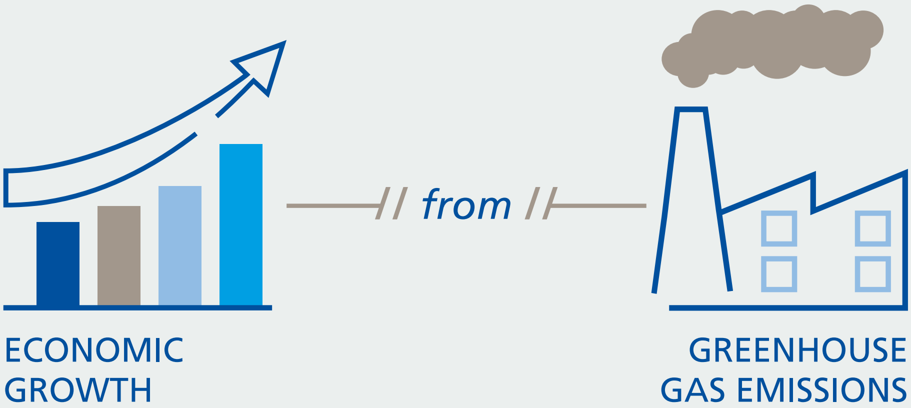
Acronyms

2 C	2 degrees Celsius
B2B	business to business
BCP	business continuity plan
CCS technology	carbon, capture and storage technology
CCUS	carbon capture, utilization and storage
COP	conference of parties
ERP	emergency response plan
ESG	environmental, social and governance
ETS	emission trading systems
EV	electric vehicles
FSB	Financial Stability Board
GHG	greenhouse gas
HLEG	high-level expert group
HSE	health, safety and environment
IAE	International Energy Agency
INDCs	independent nationally determined reduction commitments
IPCC	Intergovernmental Panel on Climate Change
PV	photovoltaic
RCP	representative concentration pathways
TCFD	Taskforce on Climate-related Financial Disclosures
TRP	total risk profiling
UNFCCC	United Nations Framework Convention on Climate Change

Executive summary

The Paris Agreement has set a goal to limit mean global warming to well below 2 degrees Celsius. If warming were to be allowed beyond this limit, scientific consensus suggests devastating climate change impacts. **The challenge is to act now**, to transform the global economy and largely decouple global economic growth from greenhouse gas emissions.

The challenge is to act now to **decouple**...



This report examines two scenarios: One scenario is based on the failure to act on climate change, resulting in a steady rise in temperature and rising physical risk. The other scenario assumes that effective measures are taken to reduce carbon emissions, in line with keeping the rise in global temperature below 2 degrees Celsius (2 C) relative to pre-industrial levels by 2100. This is consistent with the main aim of the COP 21 Paris Agreement, but carries a number of transition risks with it.

Broadly speaking, risk management responses to climate change risks fall into two categories; adaptation to the largely physical consequences of climate change and mitigation of greenhouse gas (GHG) emissions and its associated transition risks (see page 7 for a definition).

Whilst many solutions for the highly interconnected risks from climate change will need to be sought at a multistakeholder level, there are specific actions businesses can take and tools they can use. Zurich recommends developing and acting upon a climate resilience adaptation strategy. This strategy should: identify the broad business and strategic risks; develop a granular view of the risks involved including, for example, individual locations; develop a mitigation strategy involving insurance and resilience. Meanwhile, building an enterprise GHG emission mitigation strategy and framework, especially in carbon-intensive industries, will help to actively manage the downside and capitalize on the upside of climate change. Boards play a pivotal role in this process.

There are a number of risk management tools and practices at companies' disposal. They include risk management framework approach (see Figure 6 on page 23), applying Zurich's total risk profiling (TRP) approach from a climate change perspective to better assess hazard level, exposure and controls (see Section 4.3.4 on page 25) and other best practices.

For example, as part of Zurich's flood resilience program, the Post Event Review Capability (PERC) provides research and independent reviews of large flood events. It seeks to answer questions related to aspects of flood resilience, flood risk management and catastrophe intervention. It looks at what has worked well (identifying best practice) and opportunities for further improvements. Through this work, we have identified a set of risk management recommendations which we believe can apply to a wide range of climate and weather-related perils.

The world needs to create **societies, economies** and **infrastructure** that are **resilient** to the physical impacts of climate change

Additionally, we believe a five-step approach: assess and identify; explore and investigate; implement, appoint; collaborate can together frame the risk management response to a wide range of physical climate-related perils. The five-step response to water scarcity, rising temperatures, flooding and windstorm are listed in the table found in Section 5.3.

It should be clear by now that, whether climate change is sufficiently addressed or not, society faces greater risks ahead. The question is: Will they be mainly based on rising temperatures or the attempts to contain climate change? To help navigate this uncertainty, Zurich developed a scorecard that attempts to measure progress and commitment in critical areas, and to detect changes in direction around climate change. While good progress has been made, our scorecard tells us this is still falling short of what is needed to sustainably transition the global economy and societies to a 2 C scenario.

It is to be hoped that technological breakthroughs, such as in carbon capture or electricity storage, can significantly alter the profile of climate change and the commensurate risks and opportunities that present themselves. If not, the longer it takes to adequately tackle global warming, the greater the efforts and disruption will be needed in the decades ahead to counter the rise in extreme weather events.

The aim of this report has been to set out the potential future trajectories of climate change and our advice to businesses and policymaker on risk management response. However, we acknowledge that some readers will appreciate further background on what the physical impacts from climate change may look like, including regional profiling. This information can therefore be found in the report's appendix, in Section 5.

PART 1

Introduction

"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level."

Intergovernmental Panel on Climate Change (IPCC), 2007

2°C

Climate change is one of the most complex risks facing society as a result of its interconnectivity.

The Paris Agreement has set a goal to limit mean global warming to well below 2 degrees Celsius (2 C). If warming were to be allowed beyond this limit, scientific consensus suggests devastating climate change impacts.

If further impacts from a warming climate are to be avoided, the global economy needs to be transformed over the coming decades to reduce greenhouse gas (GHG) emissions. If not, then a further buildup of GHGs in the atmosphere, will lead to a rise of average temperatures beyond 2 C. Over time this will have increasing and, in some cases episodic changes in physical impacts including changes to severe weather event patterns, frequency and impact. In turn this is likely to dramatically change regional economic prospects, not only from the physical impacts, but potentially also from transition risks.

Whilst the most severe physical changes of climate change are likely to take decades to manifest, they are largely irreversible in the long term. So, **the challenge is to act now**, to transform the global economy and largely decouple global economic growth from GHG emissions. At the same time, due to the lag effects of GHGs in the atmosphere, the world will need to continue to adapt to the physical effects of climate change for decades to come. The challenge here is to create societies, economies and infrastructure resilient to the physical impacts of climate change.

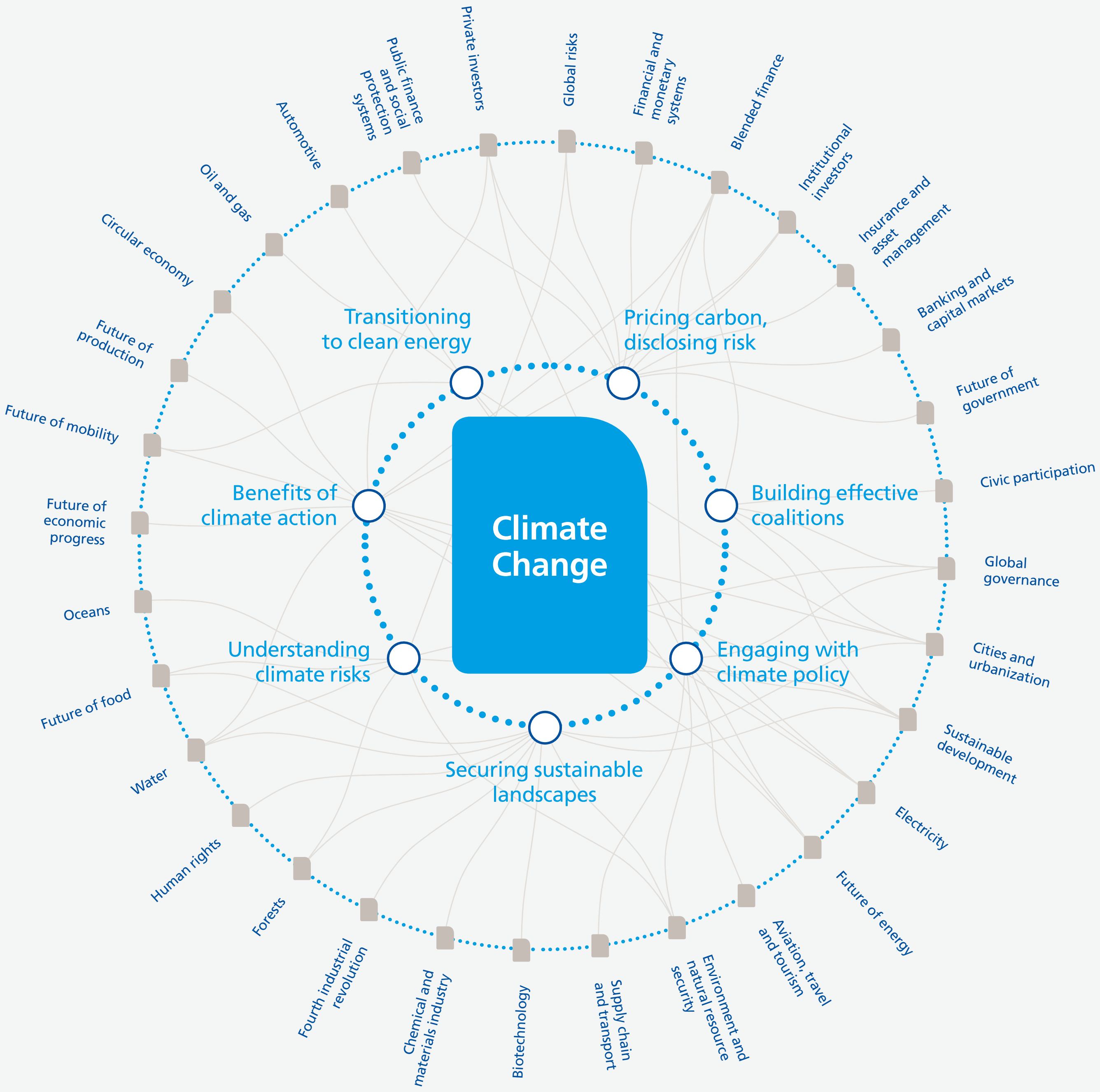


Figure 1 Climate risk interconnectivity.
Source: World Economic Forum, Global Transformation Maps.

In contrast to the physical risks, the transition risks, which are largely technology and policy-driven, will potentially lead to economic and societal impacts on a much shorter time frame. However, other transition risks will relate to changes in risk and opportunities for individual businesses, industries and in economies in some cases lead to re-valuation of financial assets. A clear understanding of the goals of transition and the unintended consequences of even the most well-meaning policies, will help focus and mitigate transition risks.

At Zurich, we want to help our customers and communities become more resilient to these risks. Through our insurance and risk management expertise, we can help to enhance resilience and prevent, or minimize, damage and harm. That is the purpose of this document – to provide a set of risk management tools, approaches and best practices which can help businesses and policymakers best respond to our assessment of the potential future pathways for climate change. Whilst climate change brings its own unique challenges, many of the approaches suggested stretch across perils and can even be applied from other types of risk entirely.

These efforts with customers form part of our commitment to being a responsible and sustainable company.

> Whilst the most severe physical changes of climate change are likely to take decades to manifest, they are largely irreversible in the long term. So, the challenge is to act now, to transform the global economy and largely decouple global economic growth from GHG emissions.

Physical risk as defined by the Financial Stability Board's Taskforce on Climate-related Financial Disclosures (FSB's TCFD)

Physical risks resulting from climate change can be event-driven (acute) or longer-term shifts (chronic) in climate patterns. Physical risks may have financial implications for companies, such as direct damage to assets and indirect impacts from supply chain disruption. Companies' financial performance may also be affected by changes in water availability, sourcing and quality; food security; and extreme temperature changes affecting their premises, operations, supply chain, transport needs and employee safety.

Transitional risk as defined by FSB's TCFD

These risks result from the extensive policy, legal, technology and market changes required to address mitigation and adaptation related to climate change.

PART 2

A history of collective efforts to address climate change: the case for action

The global community has achieved some good progress in battling climate change over the last 20 years, but there is more to do:

1997 Adoption of the Kyoto Protocol (the world's first GHG reduction treaty)

2013 Release of the second part of the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report known as AR5 (1,000 IPCC scientists agree on the science of climate change)

2014 IPCC's Working Group II reports on the impacts, adaptation and vulnerability related to climate change (raising awareness of the potential impacts of climate change)

2015 Adoption of the Paris Agreement at the conference of parties (COP) 21:

- 195 nations agree to combat the impact of climate change and invest in a low-carbon, resilient and sustainable future
- Alignment of independent nationally determined reduction commitments (INDCs) to the energy trilemma (low-cost, low-carbon and secure energy)
- "Tragedy of the Commons" speech held by the governor of the Bank of England on the risks faced by the global economy as result of climate change
- Setting up of the Taskforce for Climate Related Financial Disclosures (TCFD) by the Financial Stability Board (FSB)

2016 Setting up of the G20's Green Finance Study Group under China's presidency of the international forum (co-chaired by China and UK. UN Environment acts as secretariat)

2017 TCFD presents framework recommendations (impetus for policy making and financial market transparency)

2018 The European Union's (EU) High-Level Expert Group (HLEG) on Sustainable Finance publishes an action plan including:

- Taxonomy on environmental, social and governance (ESG) 'green' finance proposed to be delivered in 2019
- Further definitions for investors to drive the transition to low-carbon energy

Despite all of this good work, our analysis suggests that collective failure is currently more likely than decisive action. If governments and companies fail to act decisively, mean global temperature will continue to rise steadily to well above 2 C.

The path toward low-carbon economic policy requires decisions such as carbon pricing or taxation, or policies favoring low-carbon technology. Such technologies include renewable energy, grid-scale storage, electric vehicles (EV), low-carbon hydrogen for transportation and heating, and enable technologies such as carbon capture, use and storage are put in place and accelerated, which could create transition risks.

To understand this and the risk management options, we assess two archetypal scenarios. Despite scenario analysis being agnostic to considerations of probability i.e., all possible futures are equally likely, we consider that given the history of climate change policy, a failure to act either in time, or in an effective manner, is more likely than transition to a two-degree compliant world (see Section 3.3).

PART 3
Setting the scenarios

Risks and opportunities linked to both physical and transition risk have to be understood and we use the FSB's TCFD framework to help us understand that analysis, using scenarios as a way to explore different possible futures and options to respond. To guide this process, which easily gets very complex, we have devised a simplified framework that is built around two scenarios positioned at opposite ends and with opposite projected effects of climate change.

One scenario is based on the failure to act on climate change, resulting in a steady rise in temperature and rising physical risk. The other scenario assumes that effective measures are taken to reduce carbon emissions, in line with keeping the rise in global temperature below 2 C relative to pre-industrial levels by 2100. This is consistent with the main aim of the COP 21 Paris Agreement, but carries a number of transition risks with it.

In reality, the next decade will be characterized by profound uncertainty around climate change policies, new technology and the behaviors they drive and, as a result, what direction is most likely. To help navigate this uncertainty, this report includes a scorecard of key indicators, reviewed in Section 3.3, that attempts to measure progress and commitments made in critical areas, and detect changes in direction.

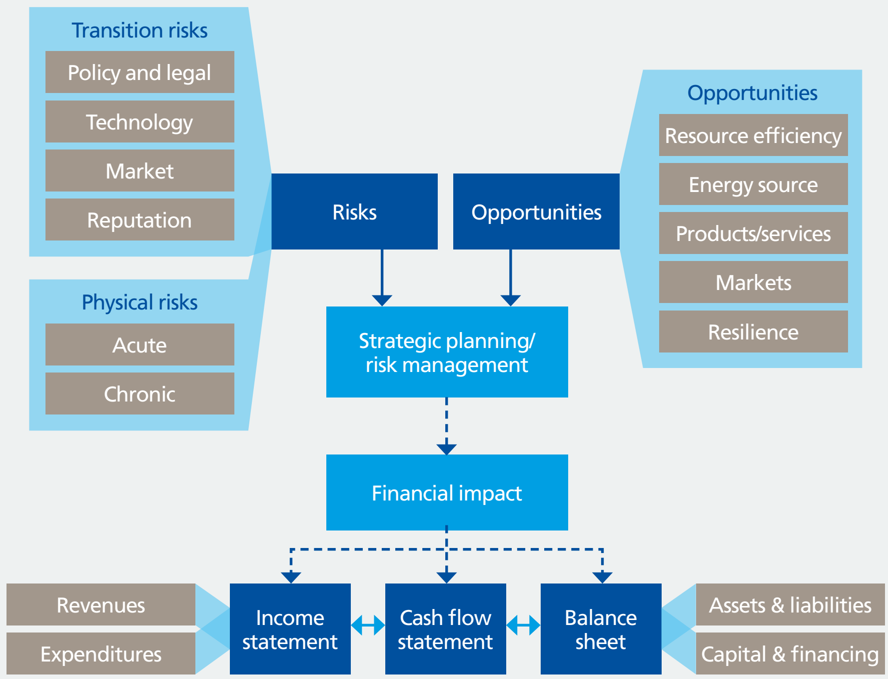


Figure 2 Risks and opportunities as a result of climate change.
Source: FSB's TCFD, www.fsb-tcfd.org

3.1 Failure to act: too little action too late

In the failure to act scenario, governments and companies do too little, too late to tackle climate change, with temperature rising steadily to well above 2 C relative to pre-industrial levels. Climate change models[1] show that this leads to rising physical risk, with increased likelihood of extreme weather events such as flooding, storms and drought, and an indirect impact on health and resources such as water availability and crop yield.

Regional changes in precipitation are likely, with dry regions projected to get dryer and vice versa, and with increased risk of wildfires and crop failure. The risk of unobserved and potentially catastrophic events also rises if tipping points for abrupt and irreversible climate changes are reached. An example would be the melting of Arctic permafrost – leading to massive release of methane gas, rapid warming, more melting, more methane, etc. in an uncontrollable cycle. Alternatively, changes in ocean salinity due to melting sea and land ice could impede on oceans' current circulation e.g., the Gulf Stream, with significant climate impacts such as cooling of the Europe's northwestern maritime regions.

While there is a large degree of uncertainty around the timing and impact of overall physical risk, some effects are less sensitive to modelling assumptions. These include rising sea levels, warming of oceans, disproportional warming of the Artic regions, and the occurrence of more frequent and longer lasting heat waves.

Over the near to medium term, physical risk is mainly likely to remain influenced by multidecade climate systems such the climate patterns El Niño and La Niña, even in a failure to act scenario. Current climate models indicate that physical climate change risk begins to rise more materially beyond the next couple of decades. Regional variations will be large, however, and low-lying island and coastal areas are likely to see risk from sea-level change earlier on. Risk from extremes of heat (drought and wild-fires) and cold (frost damage) as well as coastal (storm surge) flooding are also projected to increase relatively early, especially if adaptation measures are not enacted. Indeed, some change has already happened.

Transition risk will be limited in the failure to act scenario, as policies to reduce carbon emissions fail to be implemented on a global scale, though they can still be material in specific regions.

Fossil fuels remain the dominant component of the energy mix and efforts to establish a global price on carbon fail. Measures to encourage renewable energy investment are patchy, and there is a failure to adapt energy systems to large scale and integrated use of renewables.

Risk premia (insurance premiums) for insurable weather-related peril regions currently reflect the outputs of natural catastrophe models as well as other economic and market factors. As such they reflect the current situation rather than the future risks implicit in climate models. Similarly, broader asset prices (buildings, equities, etc.) are currently also unlikely to fully capture climate change-related risk. Over time, we anticipate prices for exposed assets to adjust in response to changes in severe weather impacts, as these events begin to be factored into risk premia. This may very well drive volatility in financial markets over the coming decade, as climate change becomes increasingly likely in this scenario. Vulnerability of supply chains to physical risk will also become more acute over time, and a failure of governments and companies to fully adapt and protect against this is likely contribute to more frequent and impactful business disruptions.

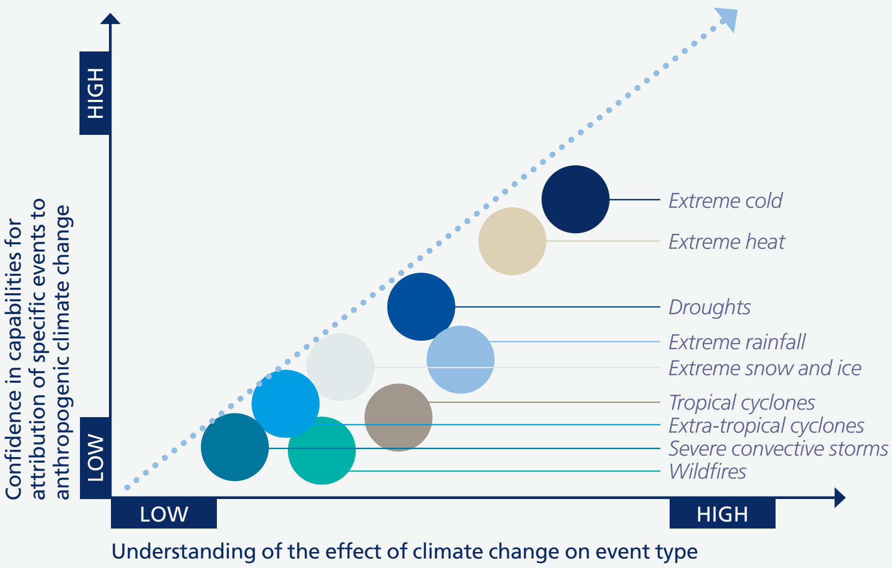


Figure 3 Dealing with uncertainty in predicting climate change impacts

Source: National Academies of Sciences, Engineering, and Medicine. 2016. "Attribution of Extreme Weather Events in the Context of Climate Change." Washington, DC.

Over the last decades, the understanding of climate modelling has vastly increased. However, the complexity and interconnectivity of the systems involved still limits how detailed predictions of climate change affect observable weather. This is the science of 'extreme event attribution,' trying to understand how climate change is impacting the likelihood, or severity of any one severe weather event. Generally speaking, the larger the spatial scale and the longer the time period, the more confidence we have in defining the response to climate change. Droughts, heat waves and heat stress are therefore possibly the best understood and predictable of all extremes, while severe local storms, tornadoes, etc. are the least predictable. Aligning the timeframes of climate models (with impacts over decades) with natural catastrophe modelling (with an annual impact) that are extensively used in the insurance industry for accumulation modelling, will be an important breakthrough in understanding how the physical risks of climate change will develop.

As the nature of extreme weather events changes, policy will increasingly focus on adapting to climate change. Adaptation measures are more likely in high density and developed areas where potential losses are large, amplifying regional variations in vulnerability and risk premia. We also anticipate financial regulation to adjust, to increase the resilience of the financial system to climate change-related events. This could expose vulnerabilities if companies do not foresee and plan for this.

Regional variation in physical risk is expected to be large. Emerging markets with limited resources will generally be more exposed to climate change than developed markets, reflecting higher physical exposure and less capacity and resources for adaptation and protection. There are exceptions to this broad generalization. The current prioritization of the environment on the political agenda and its ability to undertake large-scale projects makes China, for example, less vulnerable than many other growth markets. The value of assets that are exposed to extreme weather events will also be higher in wealthier and more developed regions, raising the potential for disruptive losses, particularly if measures to increase resilience are initially delayed, or if tipping points are reached.

In a failure to act scenario, adaptation and protection measures will present opportunities as investment needs will be sizable, particularly in infrastructure, but also to secure water and energy supplies from climate extremes, and to protect coastal zones and build resilience around food supplies.

3.2 Two-degree compliant world: change ahead

At the other end of the spectrum is a two-degree compliant world, where measures are taken to

[1] IPCC's representative concentration pathway (RCP) 8.5 scenario forecasts a mean temperature increase of 3.7 C and a sea increase of 0.63 m by 2080-2100

make progress toward a low-carbon economy, with the temperature rise from pre-industrial levels kept at or below 2 C by 2100. Over the longer run, physical risk is contained relative to the failure to act scenario, though not eliminated, and some regions will be more exposed than others, including low-lying coastal areas and islands.

In the near to medium term, however, climate change- related risk will be higher in this scenario. They will be dominated by transition risk, as far-reaching changes to the global energy system are needed to reduce the carbon footprint, and every part of the global economy will be affected. Independently of the precise pathway to reach a two-degree compliant world, the transition will be disruptive, as significant asset price moves are required to shift resources to the renewable sector on a global scale. The transition will be particularly costly if action is initially delayed, so timing is critical when assessing transition risk.

It is well established that cost-effective solutions such as energy efficiency and switching to low-carbon, low-cost and energy-secure systems will urgently need to be prioritized, to leave the door open for a two-degree world. Over time, comprehensive reform of global energy systems with adjustments to grid-scale storage, supply and demand management through smart grids and distributed power generation will be required to facilitate decarbonization of electricity generation and manage intermittency in renewable power generation. Transportation and domestic/commercial heating are other key emitters, and dramatic changes will need to take place in these areas, including around penetration of EVs and the use of electrical heat pumps. New sources of low carbon hydrogen will be needed for transportation e.g., hydrogen fuel cells and power generation requiring new technologies at scale e.g., carbon capture, use and storage (CCUS) to offset carbon emissions in sectors which are difficult to decarbonize, including aviation, heavy transportation, iron and steel, glass, cement, petrochemicals and agrochemicals. Nuclear power will also remain an important source of baseload energy in a 2 C scenario.

A global price on carbon will have to be established, and we expect this to be disruptive. The World Bank Group indicates that a price of USD 80-120 per ton of CO2 emissions is required to achieve a 2 C path. To put this in context, only around 15 percent of global emissions are priced today, with an average price of only around 20 USD per ton of CO2 emissions. Fossil fuel subsidies, which currently amount to around USD 250 billion annually, will need to be removed, or at least harmonized across different power generation technologies to encourage the development of low-carbon, low-cost and secure energy supplies. Companies that fail to adjust to a higher price of carbon, by adopting and investing in energy efficient technologies, will be at risk. Regional variations in carbon pricing schemes are also likely, which could be disruptive for some regions.

Global mean annual temperature change compared to 1980-1999 (°C)

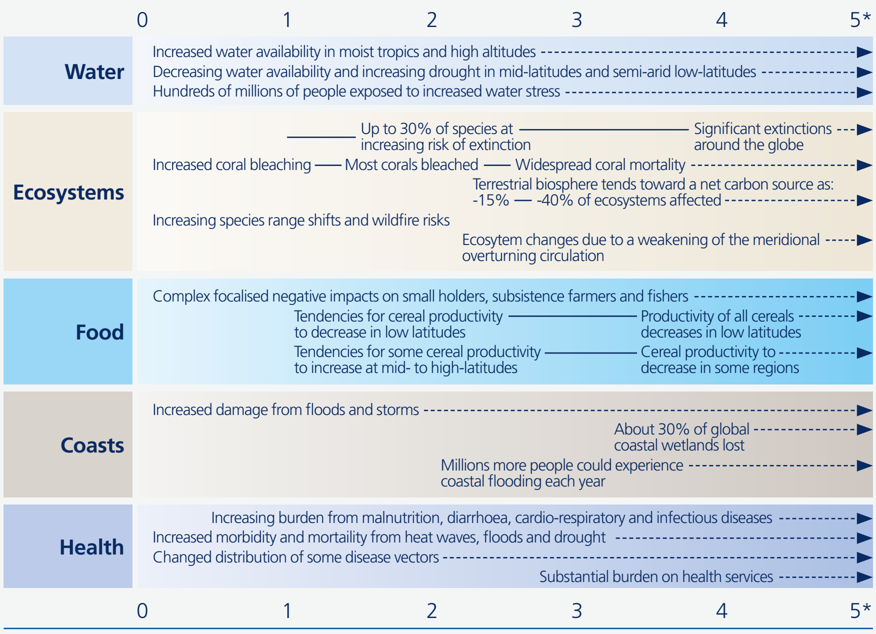


Figure 4 Heading toward global warming exceeding 2 C, resilience and adaptation will become critical in many areas.

Source: IPCC, 2007: "Climate Change 2007: Synthesis Report." Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Depending on policy decisions, some fossil fuel reserves, in particular coal, may eventually become stranded and undeveloped in a two-degree compliant world, with assets suffering from premature and unanticipated write-downs as a result of policy actions and unfavorable demand conditions. However, global population growth and economic development will continue to drive demand for some carbon-intensive sectors, notably oil and gas, and related petrochemical and agrochemical sectors, even in a two-degree compliant world. This presents a complex economic puzzle where depending on demand and the price elasticity of oil and gas, we might anticipate fluctuations in the price of fossil fuels, potentially delaying the necessary transition of the energy sector in some geographies and increasing transition risk for them at a later stage.

While transitioning to a low-carbon economy will be disruptive, there will be potentially positive effects on the broader macroeconomic environment, as it will create opportunities across the global economy. Successfully tackling climate change is likely to represent such a major leap that it could conceivably put it on a par with other historical technological transformations. Were this to materialize, companies and sectors that fail to invest in new low-cost and low-carbon technology and adapt their business models will stand to lose.

While these potentially fundamental changes will pan out over the longer term, near-term opportunities will also be sizable. Countries have to develop a coherent energy policy around renewable energy, to allow for an accelerated expansion of renewables in power and heat. This requires large-scale investment to increase storage capacity and integrate green energy into the grid system, creating opportunities for investors and companies. Estimates by the UN's Framework Convention on Climate Change (UNFCCC) and the International Energy Agency (IEA) imply that cumulative investment finance of more than USD 90 trillion will be required over the next 15 years (equivalent to 115 percent of annual global GDP), with roughly half of that amount needed for the energy sector alone, dwarfing the adaptation investments that are likely to be seen over the same time horizon in a failure to act scenario.

3.3 Tracking climate risk indicators

It should be clear by now that, whether climate change is sufficiently addressed or not, society faces greater risks ahead. The question is: Will they be mainly based on rising temperatures or the attempts to contain climate change? To help navigate this uncertainty. We have developed a scorecard that attempts to measure progress and commitment in critical areas, and to detect changes in direction around climate change.

The scorecard takes as a starting point the insight that far reaching change is needed to achieve a two-degree compliant world. Rapid progress is required around policy and technology and sentiment and behaviors have to change. The scorecard attempts to measures developments in each of these fields, using quantitative data and drawing on a range of climate change scenarios constructed by the IPCC and the IEA, among others. The following requirements are, in our view, critical to leave the door open for the 2 C scenario:

Policy measures: National and regional legislation to enforce binding climate change commitments; a global price on carbon; a phasing out of fossil fuels; transformation of global energy system to support large-scale use of renewable energy.

Technology and emissions: A rapid rise in the share of renewable energy in the energy mix; progress on energy storage, renewable power and EVs; achievements of near-term targets for CO2 emissions, global energy demand and energy efficiency; tangible progress on carbon-capture technology.

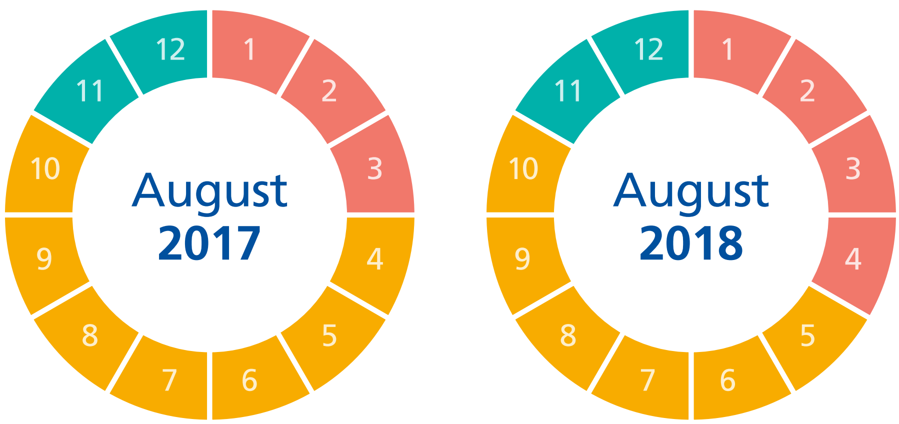
Sentiment and behavior: Increased public and private investment in climate change research and clean energy; favorable corporate action and positioning; social trends driving actions to tackle climate change.

What we observe, and which was clear from Chapter 2, good progress has been made in most of these areas. Action is, however, still falling short of what is needed to sustainably transition the global economy and societies to a 2 C scenario. Carbon pricing remains patchy and ineffective, and the national commitments agreed in the Paris Agreement have not yet been reflected in legislation. In our view, good progress in some other areas, in particular around clean technology, is not sufficient to offset this. Based on this, we assess that the likelihood of being on a 2 C trajectory is relatively low, given slow progress in the two critical areas of carbon pricing and legislative change, and insufficient progress on energy efficiency measures more broadly. Consequently, and unless action is materially stepped up, from a risk perspective, w e would expect physical risk to increase over time, while near-term transition risk is likely to be patchy, and relatively low in comparison.

Tracking the scorecard indicators over the past year also shows that energy demand and CO2 emissions have in fact accelerated, mainly as a result of a relatively modest cyclical rebound in global economic growth. Energy efficiency gains have not been strong enough to offset this, which emphasizes that further progress is urgently required. Carbon pricing schemes have taken some important steps forward, with reforms to the emissions trading system (ETS) in the EU and announcements of the initial details of the ETS planned in China. Despite this, progress is simply too slow, with only around 15 percent of CO2 emissions priced or taxed. Finally, we also observe that momentum around regulation and media attention to climate change appear to have slipped, after having peaked at around the time of the Paris Agreement. The latest data therefore reinforce our view that progress is still not consistent with a 2 C trajectory.

It is to be hoped that technological breakthroughs, such as in carbon capture or electricity storage, can significantly alter the profile of climate change and the commensurate risks and opportunities that present themselves. If not, the longer it takes to adequately tackle global warming, the greater the efforts and disruption will be needed in the decades ahead to counter the rise in extreme weather events.

Scorecard: Slow progress in critical areas



1. Carbon pricing
2. Corporate action and positioning
3. CCS technology
4. Social trends
5. Energy supply
6. Legislation
7. Energy demand and efficiency
8. CO2 emissions
9. Investment
10. Energy integration and storage
11. Fossil fuel subsidies
12. Electrical vehicles

- Not on track for 2°C scenario
- Improving but more is needed
- On track if pace is maintained

Source: Datamaran, World Bank Group, IEA (International Energy Agency), BP, IMF, MSCI, Bloomberg NEF (New Energy Finance), ZIG (Zurich Insurance Group)

PART 4

Risk management responses

Climate change is similar to many other global risks: It is interconnected with other global risks e.g., the 'water-food-energy' risk nexus[2] and is therefore a multistakeholder challenge. How it differs is in its long-term nature, which makes it difficult for companies and governments to take immediate and urgent risk management actions.

Broadly, risk management responses to climate change risks fall into two categories; **adaptation** to the consequences of climate change (largely physical impacts) and **mitigation** of GHG emissions (largely linked to transition risks). The ethical challenge is one of timing, as the most significant financial impacts resulting from climate risks and falling living standards are likely to be felt by future generations, unless the current generation invests time and resources to address both climate change adaptation and mitigation today. Most politicians and business leaders operate on short timescales of a few years (with some notable industrial exceptions where capital-intensive assets may have operating lives that last for multiple decades and are amenable to long-term scenario planning). So, making these business and policy decisions needs to be rooted in short-term gains as well as long-term benefits.

The challenge for business leaders and politicians is to create strategies that optimize the risks associated with climate change adaptation and mitigation. In some cases, this can be done by individual initiatives carried out by the private sector and public sector, but in most cases, it will require multistakeholder action. In a few cases, it will require new technologies, new industries and new business models to be developed with new approaches to managing risk, including changes to legislation and regulation.

The FSB's TCFD has created a useful framework for companies to start to address corporate governance, risk management as well as strategic and measurement of actions to either adapt to or mitigate the impact of climate change. The hope is that this will form the basis of information that investors and other stakeholders can act upon to target 'green' investment and policies to enable the transition to the low-carbon economy. This task is of course challenged by the definition of what is 'green' and what needs to be prioritized to deliver sustainable finance.

However this is just a start, as further work needs to be done to understand not only the climate models, but how they link with natural catastrophe models and then ultimately modelling of the impacts on financial assets (bonds, equities, real estate, etc.).This will require a similar effort to that which allowed IPCC's scientists to successfully agree on the anthropogenic influence on climate change i.e., a multiyear, open-source data approach to generate new insights. However, the challenge is much greater as commercial interests make open-source data sharing much more difficult. The solution may be for supranational bodies like the G20 to mandate public-private data platforms for many experts to analyze and inform policy making and strategy.

4.1 Adaptation to climate change

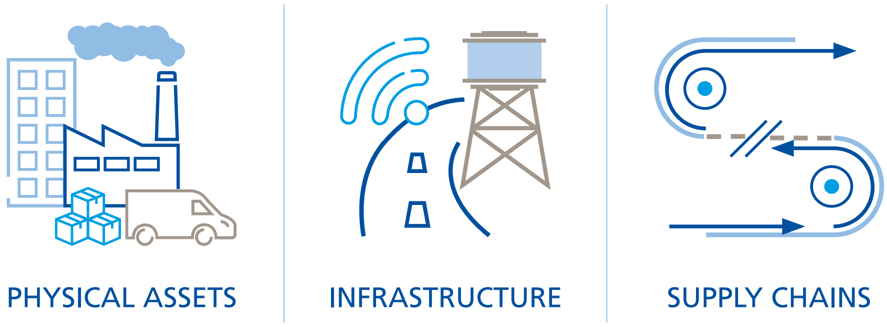
As the physical impacts of climate change progress in the next years and decades, changes in the frequency and intensity of severe weather (tropical cyclones, extreme precipitation, droughts) and other physical impacts of climate change (sea level changes, ocean acidification) will become more pronounced.

The challenge facing every industry sector and government is how to consider the impacts of the physical changes brought by climate change on their physical assets, infrastructure and supply chain, and how to adapt to those changes. In short, create climate-resilient infrastructure (see Section 4.1.1). Companies should use tools like bold scenario planning to link climate-change related risks to business impact.

The long-term nature of climate change is difficult to build in to project investment analysis and planning using existing tools. The easiest and most straightforward strategy when using currently available tools is to plan for the higher magnitude, lower probability (frequency) events, rather than 'prescribed' events. As an example, the '100-year event' is usually considered as the design flood' when planning flood defenses for a specific building or production facility or for new construction. In order to account for the uncertainties in climate change effects, lower probability and higher magnitude requirements (e.g., '200-year event') should also be considered in the planning and design processes. In addition, and whenever possible, we should aim to continuously validate and calibrate models to reflect changes.

Depending on industry sectors, risks and opportunities would also emerge in the area of public health, that overall would see a deterioration leading to an increased demand for medical services, increased insurance costs (either directly or indirectly) and increased regulation to address the risks to outdoor workers. Furthermore, infrastructure that companies rely on would become less reliable, with anticipated disruptions in property, electricity, water, roads and rail tracks. Properties need to be weather-event and wildfire resilient. Electricity needs to be sufficient and withstand heat waves.

Every industry sector and government must consider the physical impacts of climate change on:



[2] World Economic Forum "Global Risks Report 2011, Sixth Edition," 2011

Urgent and **effective** climate change adaptation is required...

...to avoid some low-lying areas and islands becoming **uninhabitable** in the next century

Example Benefit-cost ratio in flood risk reduction: $5 per $ invested

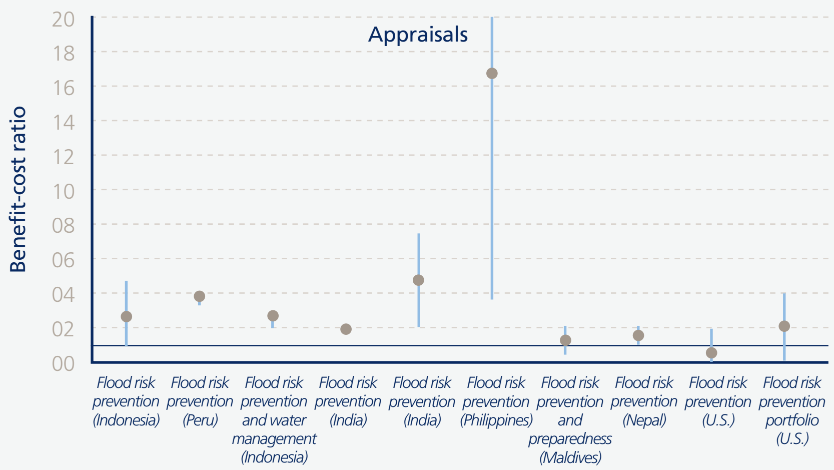


Figure 5 The good news: Prevention pays off. (The bad news: Inaction will be very expensive.)

Source: Zurich Flood Resilience Alliance White Paper: "Making communities more flood resilient: The Role of cost-benefit analysis and other decision support tools in Disaster Risk," 2015.

Roads need to be resilient to cracking, while rail tracks need to prevent buckling in higher temperatures. Fresh water needs to be available. This will create more stress on infrastructure that are critical for companies to operate and flourish.

A large fraction of terrestrial, freshwater and marine species faces increased extinction risk due to climate change during and beyond the 21st century, especially as climate change interacts with other stressors. Fisheries might experience some increase in catch potential in high and medium altitudes, while global productivity is expected to decrease by the end of this century.

The anticipated food and water shortages in specific areas resulting from climate change will also bring profound business implications: Opportunities to develop better quality food to protect humanity from health issues, increase productivity while reducing environmental impact will bring opportunities and stress to the current system, calling for changes along the business model of the entire food producing chain. As for the availability of water, companies may face limited supply and/or increased costs for that supply, operational disruptions for companies that use water in their production processes, and tensions in local communities. Industries such as technology, beverage, food, electric power/energy, apparel, biotechnology/pharmaceuticals, forest products and mining can be expected to be harder hit due to their water needs during production.

Companies may also particularly suffer from sales/production/supply chain interruptions. Examples include reduced sales due to trade barriers being (re)-introduced, migration issues, interdependencies and efficiencies of global production processes and supply chains (which could also see disruption as a result of key suppliers moving), or a sudden change in demand or supply simply due to a climate event.

Large-scale changes in weather patterns may influence customer behaviors. For example, we could see increased online sales (on hotter and colder) days when people want to stay inside. But, increased sales of some products such as bricks, mortar and soft drinks on warm, sunny days and less sales of other products such as soup and heaters as well as changes in preferred holiday timings and destinations.

Adaptation costs for climate change are much lower than damage costs, even without adaptation. This is true for most developed coastlines even when only considering property losses and human deaths.

As post-event impacts on coastal businesses (people, housing, public and private institutions, natural resources and the environment) generally go unrecognized in disaster cost accounting, the full benefits of adaptation are even greater.

Without adaptation, the high-end sea level rise scenarios combined with other climate change physical impacts such as increased storm intensity, are likely to make some low-lying areas and islands uninhabitable in the next century, so effective adaptation is urgently required. The question for many coastal communities and major urban areas located on shorelines will be about 'fight, or flight,' and the economic and social costs of adapting to, or retreating from slow, but inexorable sea-level rise, perhaps to levels not seen since the last inter-glacial period i.e., more than 10 m above the current mean sea level.

4.1.1 Developing a climate resilience adaptation strategy

It is crucial that companies develop a climate resilience adaptation strategy and act on it. Such a strategy can be defined in three key steps:

Step 1: Identify the broad business and strategic risks
For this we recommend using the following scenario-based approach developed by TCFD:

1) **Governance:** Define the company's governance around climate-related risks and opportunities including:
   i) the board's oversight of climate-related risks and opportunities
   ii) management's role in assessing and managing risks and opportunities
2) **Strategy:** Identify actual and potential impacts of climate-related risks and opportunities on the company's businesses, strategy and financial planning
   i) Describe the climate-related risks and opportunities the company has identified over the short, medium, and long term
   ii) Assess the impact of climate-related risks and opportunities on the company's businesses, strategy, and financial planning
   iii) Assess the resilience of the company's strategy, taking into consideration different climate-related scenarios, including a 2 C or lower scenario
3) **Risk management:** Define how the company identifies, assesses and manages climate-related risks
   i) Develop processes for identifying and assessing climate-related risks
   ii) Develop the company's processes for managing climate-related risks
   iii) Integrate the processes for identifying, assessing and managing climate-related risks into the company's overall risk management
4) **Metrics and targets:** Implement metrics and targets used to assess and manage relevant climate-related risks and opportunities
   i) Disclose the metrics used by the company to assess climate-related risks and opportunities in line with its strategy and risk management process
   ii) Disclose GHG emissions and the related risks
   iii) Describe the targets used by the company to manage climate-related risks and opportunities and performance against targets

Step 2 – Develop a granular view of the risks involved including, for example, individual locations:
Determine the magnitude of risk and prioritize according to the company's particular circumstances (industry, maturity and risk appetite).

Over the last 30 years catastrophe models have evolved as innovative tools to identify, assess and manage natural catastrophe risks for a seismic and climate-related hazards. Today, sophisticated catastrophe models exist for tropical and extratropical storm, flood, storm surge, tornado, hail and bushfire for an increasing number of countries and lines of business.

Today's models are generally designed to reflect current climate conditions. Catastrophe models could also play an important role in capturing physical risks of climate change. However, it is important to recognize the limitations of today's catastrophe models and the complexity to condition them on a different climate. Current catastrophe models:

- Do not cover all geographic areas, perils and lines of business
- Are by definition a simplification of complex physical processes and include uncertainty
- May not fully capture and include all sources of uncertainty in the results reporting
- Have limitations to model (contingent) business interruption and supply chains
- Need a significant amount of accurate exposure data which can be a challenge

For physical risks, catastrophe modelling software – primarily built for the insured loss – can also give a solid understanding of the potential economic impact and relative likelihood of natural catastrophe risks.

This type of analysis is only as good as the data that underpins it, so the data must be meticulously checked and verified. Special attention needs to be given to location and age of the physical asset that is being modelled.

For those regions and perils not covered by existing catastrophe models, a hazard assessment applying a deterministic scenario-based approach using global hazard maps may be used.

Lastly, as catastrophe models do not cover all perils and countries, other tools, such as global or where available local peril-specific hazard maps, are necessary to assess these 'non-modelled' perils and regions. Such tools are not as sophisticated as catastrophe modelling software, as they do not include all the parameters necessary to accurately represent the location-specific variations of a specific peril. Such perils could dramatically change within a short distance, for example, effects of soil properties on earthquake shaking levels, or changes of topography within a short distance on flood depths. But they are an essential tool for performing a preliminary analysis of multiple locations with a global footprint to identify the natural hazard exposure levels.

Experience and judgment, in terms of local topographic conditions, construction practices or local protection mechanisms, play an important role in analyzing the output of the conventional tools used for multilocation hazard identification and assessment.

Besides information pertaining to accumulated annual loss, 'exceedance' occurrence probability and other parameters used in the design of the insurance policy, these tools may also help identify high-risk single locations, as well as concentrations of locations that could potentially be affected by a single event.

We recommend that the prioritization of locations for the second step of the resilience strategy is based on the definition of 'critical' in the company. For example, this may be a location or region that meets one or more of the following criteria:

- High concentration of value at one location
- Long replacement time for equipment or stock at a location
- The location is a significant contributor to the group value chain or revenue
- Large concentration of occupants or population in the immediate vicinity
- Large area around the site that could be impacted environmentally
- Multiple locations that could be affected by a single event

This review and analysis pertains to operations or locations within the stakeholder's own responsibility. Ideally, suppliers and critical infrastructure would also be included in the analysis.

Step 3 – Develop a mitigation strategy involving insurance and resilience

For those locations defined in the second step as at risk, a deterministic scenario-based loss estimate should be developed, based on detailed information regarding site vulnerabilities (physical and organizational). Local hazard maps, where available, are used and assumptions applied regarding climate change effects in the scenario process.

Such an analysis, which would include an on-site assessment of the reliability and effectiveness of emergency response and business continuity plans, any peril-specific protection measures (e.g., mobile flood protection elements, etc.), quality of structures, infrastructure and utilities, is an essential component of the resilience strategy. With this information in hand, a medium- to long-term resilience strategy can be developed in which budget for capital expenditure projects, as well as reallocation of existing budget toward resilience measures, can be defined.

This type of integrated approach involves not only insurance, which supports the site in restoring operations after the event, but also prevention measures (physical and organizational) that reduce the impact and severity of an event on the locations.

4.2 Mitigation of greenhouse gas emissions

Efforts to meet or even close in on the Paris Agreement goals to keep warming at or below 2 C warming require far-reaching changes to the global energy system, carbon-intensive industries and consumer behaviors. So far there is little evidence of a coordinated and comprehensive approach to decarbonization and less than 20 percent of greenhouse gases are covered by a carbon price.

Having said that the move toward development of EVs and the publication of the nationally determined reduction commitments, especially in decarbonizing the power generation sector, are underway. The dramatic reduction in manufacturing costs of photovoltaic (PV) cells in the last decade and the costs of onshore and offshore wind power have also contributed to significant growth in renewable energy penetration. However, it is just a beginning and much more needs to be done by the private sector in particular to drive the change and manage transition risks.

To meet the Paris Agreement's goals many industries other than power generation that also are carbon intensive and employ fossil-fuel burning processes (iron and steel, cement, glass, petrochemicals, agrochemicals, etc.) will need to decarbonize. Transition risk will as a consequence be a factor across a wide range of industrial sectors. This requires a serious multistakeholder approach to enabling reduction of carbon emissions on an industrial scale, whilst maintaining 'green' economic growth and revitalizing regions which were once the foundation of carbon-intensive economic growth.

Due to the complexity of the issues, policy measures are likely to be developed with a certain amount of 'trial and error' approaches that might lead to an uncertain investment climate. A recent example is the solar panel industry, where rapid changes in subsidy systems and tariffs in a number of countries have led to price fluctuations dubbed the 'solarcoaster.' Governments will also face the temptation to use climate legislation as a pretense to bolster national industries, instead of allowing for most the efficient approach to decarbonization to develop. All of these facts create uncertainty in the planning assumptions for companies to decarbonize.

Consumers are becoming more aware about the impact to the climate of various products. In some cases, this is leading to consumers mobilizing and demanding more social responsibility from the companies from whom they purchase their products. It can be reasonably expected that this pressure will only increase over time as consumers' knowledge and experience grows. One approach to managing this is labelling of products. In most consumer goods it is common to see energy efficiency labels, but it is not yet common to see a carbon-intensity measure.

One area where this has been seen is in EVs, where heavier EVs are banned in some countries as they are more carbon intensive on a lifecycle basis than even more efficient fossil-fuel cars. Although smaller EVs are designed to be lighter, with a lower range, they have lower lifecycle carbon emissions than their larger, heavier cousins, or fossil-fuel cars.

Additional scrutiny is also expected through either voluntary or mandatory disclosure standards that will require companies to understand and report what they do against climate change and how they might be impacted. While such disclosure standards are valuable frameworks to help companies understand their risks, they might also become a source of shareholder action and liability issues if findings are not appropriately addressed. Investors, regulators and the plaintiffs' bar all have the ability to review such disclosures. There is some concern that these third parties may treat this disclosure as an admission of misconduct. Omissions, misstatements or incomplete statements attributable to a company regarding climate issues could result in potential legal liability.

Responding to climate change-related risks need to be embedded across the company. At a strategic level, companies should determine the risks and opportunities linked to profound mid and long-term changes that climate change will bring to their business ecosystem. At an operational level, risk managers should build risk scenario impacts into strategic scenario planning to further determine which risk management response to have as an integral part of the company's enterprise risk management (ERM) framework.

Building an enterprise GHG emission mitigation strategy and framework, especially in carbon-intensive industries, will help to actively manage the downside and capitalize on the upside of climate change. That strategy must be in place before there is an adoption of any operational issues.

Scenarios are plausible and challenging visions of the future. They consider real and potential trends in politics, demographics and technology. They stretch our thinking and help companies make crucial choices and navigate critical uncertainties. Scenarios are not policy proposals – they do not argue for what should be done, nor forecasts – what will be done. They are not predictions, nor business plans and investors should not rely on them to make decisions. Scenarios can reveal useful insights and show us potential pathways the world might take. Some pathways are more plausible than others, but all challenge society to make tough decisions. Scenarios are used as part as the FSB's TCFD recommendations.

Categorization of transition risks proposed by the FSB's TCFD	
Policy and legal	Increased pricing of GHG emissions Enhanced emissions-reporting obligations Mandates on and regulation of existing products and services Exposure to litigation
Technology	Substitution of existing products and services with lower emissions options Unsuccessful investment in new technologies Costs to transition to lower emissions technology
Market	Changing customer behavior Uncertainty in market signals Increased cost of raw materials
Reputation	Shifts in consumer preferences Stigmatization of sector Increased stakeholder concern or negative stakeholder feedback

Role of boards

Boards play a pivotal role in defining the company's risk appetite and in identifying major global risks. Boards also own the risk agenda because they own the strategy. Therefore, risk and strategy are inherently intertwined.

To achieve a company's strategic objectives, the board must decide what risks it is willing to take to drive the company's agenda forward. But it does not stop there. In order to best respond to the impact of GHG emissions mitigation on their business, boards should consider a strategic risk analysis on the type and scale of impact climate change will have in the mid to long term:

We recommend for such strategic risk analyses to answer the following 10 key questions as a baseline:

1. What is the likely impact of climate change on our business, now and in the future?
2. Have we followed the FSB's TCFD framework and what are the conclusions of that analysis? What are the impacts on the key drivers of performance now and in the future?
3. Is our business model still viable? If yes, for how long?
4. Should we focus on core areas of the business, even if they are carbon intensive, but add value in other ways to society, the economy and to investors?
5. Are there opportunities for us to create new products, to join new business ecosystems?
6. Which aspects of our climate change response do we need to advocate for to best protect shareholder value and best capitalize on climate-related opportunities or threats?
7. Do we need to make big technological shifts in order to cope and successfully compete with the new environment?
8. Which growth strategy we should aim for in light of the changes that climate change brings (e.g., organic, new products/services, strategic partnerships, or mergers and acquisitions)?
9. Should we change our product mix? Should we create entirely new supply chains?
10. What and how should we disclose?

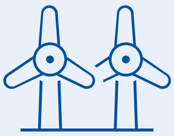
Role of government affairs function

It is increasingly important for a company to adopt a well-researched public policy position on critical issues including climate change that is driven by business values and needs. Some of the risks outlined in this report evolve from public and political pressures that question the role of companies when it comes to tackling climate change. To safeguard against risks emerging from these questions, companies should understand how climate change-related risk feeds into developing a robust public affairs strategy to articulate and communicate their contribution and monitor their risks.
A supported government affairs function can provide engagement with local stakeholders to advocate for priorities in regulatory and policy changes, in line with the strategic risk analysis on climate change and the priorities defined by the board of directors. Proactive stakeholder engagement programs at local and national levels can support positive relationships with key stakeholders and policymakers, making sure the company has a seat at the table prior to decision-making.

Potential upsides of the transition to a low-carbon society

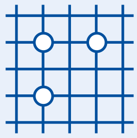
Transitioning to a low-carbon society not only presents an enormous challenge, but also a significant opportunity. The opportunity lies in the scalability of low-carbon solutions, including clean energy and mitigation technologies that can accelerate this growing market and support the transition of the global energy sector. Simultaneously, this transition will require significant capital to change a society that has been dependent on a fossil fuel-based energy system. According to a 2017 report by the International Finance Corporation (IFC), addressing climate change could create investment opportunities amounting to USD 23 trillion by 2030, in emerging markets alone. In more developed countries, renewable energy is creating jobs twice as fast as any other industry.

Renewable energy



One of the more obvious segments presenting immediate opportunity is the renewable energy sector. While the West has the longest history of setting goals to transition to a lower-carbon economy by increasing the share of renewable energy in their power sector and by increasing energy efficiency, the clear leader in the field is China which alone is responsible for over 40 percent of global renewable capacity growth. In their 13th Five-Year Energy Development Plan unveiled in 2017, China – which globally ranks first in total new renewable energy installation capacity – aims to achieve 15 percent of its energy generation from non-fossil sources (hydro, nuclear and renewables) by 2020 and 20 percent by 2030. China's investment, while largely driven by air pollution concerns, has positioned them as the world leader in one of the most rapidly growing technology segments today. The country represents half of global solar photovoltaic (PV) demand, while Chinese companies account for around 60 percent of total annual solar cell manufacturing capacity globally. As such, market and policy developments in China will have global implications for solar PV demand, supply and prices. China is also the world market leader in hydropower, bioenergy for electricity and heat, and EVs.

Smart Grid Technologies



Smart grid infrastructure will need to be a key enabler for the transition to low-carbon energy systems. A smarter electric grid can engage renewables at scale as it can address issues of intermittency of energy sources such as solar and wind, facilitate the electric transportation market and usher in a standard of sustainability. Smart grid technologies and policies can address both developed and developing world challenges in reducing GHG emissions while eliminating energy poverty with green energy sources. Compared to other industries, the electrical grid has been largely bypassed by technological innovation until relatively recently, owing to the fact that it historically has been heavily regulated and modeled, and its modernization priority low. This has created substantial opportunities for grid-connected distributed generation. With the progression of smart grid adoption, it is envisioned to increase rapidly all along the value chain, from suppliers and marketers to customers with the goal of a grid that is less expensive, more reliable and environmentally friendly.

Smart grid principles and technologies also support the creation of integrated electricity markets compared to the dedicated or compartmentalized markets of today. The benefits and needs of such a market are expected to attract new market participants and technologies which will encourage new ideas, products and services. Several of these markets are already well established with expected double-digit growth in the near term, including storage, sensor and distribution technologies. Longer-term smart grid adoption benefits will include growth in traditional technology industries such as information technologies, power electronics and data services.

Financial sector

Both physical and economic risks of climate change are becoming more apparent and measurable, but still present uncertainty to investors making decisions. On the other hand, opportunities presented by responses to climate change actions are readily recognizable. The immediate opportunities arise from clean energy investments including energy efficiency improvements (smart grid), renewable energy technologies (solar, wind, biomass, etc.) and carbon capture and sequestration (CCUS). According to Bloomberg New Energy Finance, an industry research firm, renewable energy sources that are zero-energy will by 2040 contribute more than 60 percent of total installed capacity, and wind and solar will account for more than 64 percent of the new power generation capacity added. Bloomberg estimates that more than USD 11 trillion will be invested in these areas over the next 25 years.

Insurance and reinsurance companies are among the most vulnerable industries in responding to climate change, which poses multiple threats to the industry as a whole. The industry has been realizing increasing costs from physical impacts of climate change and secondary impacts, such as the disruption of global supply chains and defense of carbon emitters. However, where there is risk there are also opportunities ahead. Climate change offers some interesting new opportunities for insurance including the expansion of traditional products such as EVs in the automotive sector, health coverages and an increase in demand for alternative risk transfer mechanisms. In addition to traditional offerings, the insurance industry has developed innovative products in their climate change response to cover risks ranging from emission trading to CCUS.

4.3 Harnessing risk management tools and practices

There are a number of risk management tools and practices at companies' disposal, in addition to the scenario planning described in Section 4.2, which can help to build their response to climate change. In this section, you will find some of the most important and effective ones currently available.

4.3.1 Standard risk management framework

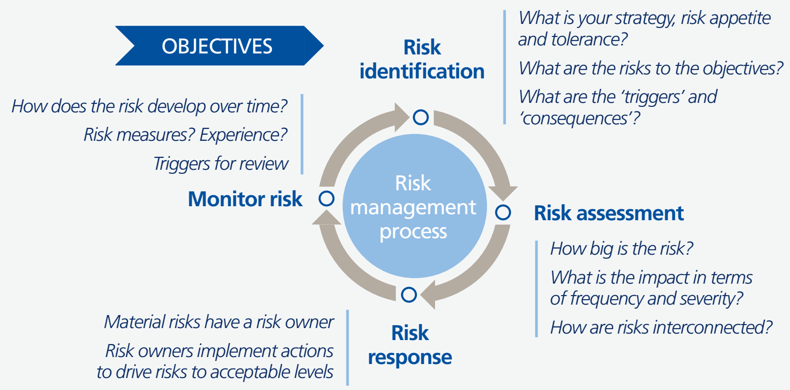


Figure 6 Standard risk management framework approach

4.3.2 Looking at the indirect effects of climate change

It is necessary to look beyond direct risks of weather-related events to the impact of interconnected risks, as part of an effective scenario analysis and risk mitigation plan. Many of these risks have been considered in Section 4.1 focusing on adaptation to climate changes. This includes interconnected risks connected to food and water shortages, deteriorating public health and the unreliability of infrastructure. Of course, one of the most important direct and interconnected risks facing businesses is reduced profitability from mitigation failure.

In addition, social instability could result, for example, from an increased gap between the 'haves' and 'have nots' occurring during the transition to new ways of living. This can also trigger social media campaigns against companies that are seen as contributing to this instability, with disruptions to transport, suppliers and operations being likely. On the migration side, business implications could well include a wage depression in poorer regions receiving large numbers of migrants, additional strain on public services and infrastructure possibly disrupting businesses, while on the positive side, as research suggests, the arrival of young people willing to work could drive economic expansion in advanced economies.

A further, more extreme example, would be greater risk of conflicts deriving from issues such as water scarcity. This would obviously have large implications to businesses operating or depending on the countries these conflicts would take place in. In such cases, business implications would include legal, security (people and assets) and supply chain risks, and potentially lead to reputational and financial risks.

The increased interconnectivity, complexity and potential impact of global risks are here to stay. In such a context, caring for business means considering everything that could affect it. Effective risk management requires taking interdependencies between risks into account, and more than ever demands a truly holistic risk management approach. Against this backdrop, it is necessary to look beyond the risks directly related to climate change and also look at how these will also impact other interconnected risks.

4.3.3 Carbon pricing

Carbon pricing should be considered as part of a company's overall climate change strategy. In doing so, companies should also anticipate potential increases in the price over the coming years.

1. **Engage your board:** It is essential that you discuss how carbon pricing could affect your strategy, market position, brand and reputation. Understand what your customers expect and how your competitors are performing. What are your investors' expectations?
2. **Consider implementing an internal carbon price.** Doing so where you are not already subject to a carbon tax at government level means you will be well prepared for its introduction. An internal carbon price effectively translates carbon emissions into business relevant terms and incentivizes support for innovative energy efficiency projects. It can this way be a key enabler for the delivery of ambitious GHG reduction targets, thus reducing your exposure to rising carbon prices. Ensure any internal price that you implement is high enough to influence business decisions.
3. **Understand your emissions:** the type of emissions and industry sectors covered by any pricing initiative will determine their impact on your company. Key to understanding this will be maintenance of a comprehensive GHG inventory covering all emissions. Any internal price implemented should cover all GHG emission hotspots in the value chain.[3]
4. **Understand the geographical footprint of your operations:** geographically distributed operations can be impacted in diverse ways owing to the nonstandard implementation of carbon regimes globally.
5. **Analyze your operations** to identify efficiencies that can be introduced to reduce emissions.
6. **Analyze your supply chain** to identify low carbon alternatives.

[3] https://www.ecofys.com/files/files/cpu-2017-how-to-guide-to-internal-carbon-pricing.pdf

4.3.4 Conduct a Total Risk Profiling on climate change

Apply a structured risk assessment process such as Zurich's **Total Risk Profiling (TRP) approach**. The table below shows how companies can apply Zurich's TRP approach from a climate change perspective to better assess hazard level, exposure and controls.

Risk factors	Issues	Comments
Exposures	How well do you know the value chain of your operations?	This includes not only suppliers, but also utilities and infrastructure as well as customer locations
	What is the definition of 'critical' for your company (including suppliers and customers)?	For example, are these locations with the highest value concentrations, containing equipment/stock with long replacement times, producing critical components for other locations or products/services that are profitable or have a high contribution to group revenue or where hazardous processes occur? Or is critical defined as locations with a high concentration of employees, or are situated in areas that can impact a large population if an accident occurs? From the perspective of a single location the above definitions of 'critical' apply to individual structure(s) or building(s).
	Have you identified your critical locations, your critical suppliers and the critical utilities and infrastructure at these critical locations?	Have you identified redundancies? How easily can these components of your operations be replaced? Is it possible to organize contractual arrangements to ensure priority of supply?
Hazards	Which natural hazards do you consider might have an impact on your global supply chain? Again, the scope is also in question: Does it involve suppliers and customers?	• Flood • Wind (hurricanes, typhoons, European winter storms, etc.) • Storm surge • Hail • Lightning • Heavy rainfall • Drought / water shortage • Tornado
Controls	For your critical locations: What is the level of urban development in the area of your critical operations?	High level of development, without corresponding upgrade of infrastructure to accommodate this development, means the capacity of the infrastructure is probability inadequate for climate change.
	What is the age of the buildings, especially the critical ones at those critical sites (owned ones, as well suppliers' ones)?	Not only buildings themselves but also contents and equipment should be designed to state-of-the-art structural design codes. These codes are regularly revised to reflect technological advances in construction methods, building materials as well as hazard maps, i.e., force levels to which the buildings and contents are designed, etc. When undertaking expansions or adding new equipment, a review of the existing buildings and equipment/contents should be performed by a qualified structural engineer to ensure compliance with the requirements of the latest code version.
	Has your business continuity plan (BCP) been developed based on risk scenarios?	BCP is an important organizational natural hazards control system. A BCP which only mentions the hazards is ineffective. An effective BCP should be based on a Business Impact Analysis (BIA) and should cover all hazards to which the region is exposed and the scenarios to ensure operations continue at the affected location. The scenario should consider the fact that a natural hazard event, in contrast to an on-site fire event, impacts an entire region. As such, not only loss of utilities and infrastructure, but also access and business will be severely impacted. In addition, issues such as duration until the restoration of services (which includes the duration of the event itself) should be considered. Try to achieve an understanding about the level of planning by your local authorities and especially their foreseen priorities for reconstruction. Consider a balance between community and business needs.
	How effective and reliable is your emergency response plan (ERP)?	As with BCP, the site ERP should be scenario based. The ERP should be realistic with respect to resources, especially (but not only) manpower. For each of the hazards identified to which the site is potentially exposed consider the time between receipt of the warning and the event impacting the site. Resources and actions should be planned accordingly.

4.3.5 Applying risk management lessons from Zurich's Post Event Review Capability (PERC) reports

As part of Zurich's flood resilience program, the Post Event Review Capability (PERC) provides research and independent reviews of large flood events. It seeks to answer questions related to aspects of flood resilience, flood risk management and catastrophe intervention. It looks at what has worked well (identifying best practice) and opportunities for further improvements.

Through this work, we have identified a set of risk management recommendations which we believe can apply to a wide range of climate and weather-related perils:

- Focus on prevention as a more effective risk management approach than recovery. Prepare for disasters by reducing exposure, while simultaneously developing a strong response and building continuity plans.
- Understand high-value supply chain vulnerabilities and interconnected risks. In managing these risks, companies lessen the chance that a disaster will cause unexpected ripple effects that could shut down operations.
- Stress employee preparedness at work and home. This ensures employees remain safe and are in a position to help keep the company running from a remote location if needed.
- Review insurance coverage. Proper multihazard coverage will speed recovery and allow companies to be up and running faster, which means retaining a customer base rather than re-attracting one.
- Review contracts and suppliers and ensure equipment/services are resilient enough to cope with the increased intensity expected from weather storms.
- Conduct a post-event review if disaster strikes. Lessons from what worked and what did not will better prepare the company for the next disaster, should it occur.
- Effective identification of catastrophe risk by using a state-of-the-art hazard maps and catastrophe modeling framework that reflects a validated view of risk.

4.3.6 Risk management response to physical risk

Additionally, we believe a five-step approach: assess and identify; explore and investigate; implement, appoint; collaborate can together frame the risk management response to a wide range of physical climate-related perils. The five-step response to water scarcity, rising temperatures, flooding and windstorm are listed in the table found in Section 5.3.

Whichever the tools and/or frameworks one uses, we believe it is essential for companies and risk professionals to assess/consider the following questions and issues:

- How climate resilient is the critical infrastructure your business relies upon in order to operate? (e.g., water supply/ treatment, waste, access to sites). In too many cases, people take critical infrastructure services/delivery for granted but:
  - They do not control it, in terms of operations, maintenance, etc.
  - Climate change impact include the possibility of temporary (and more frequent) infrastructure delivery failures.

  This is why there should be a twofold analysis when looking at climate change, from a portfolio analysis to a site analysis (including critical infrastructure in both cases, but at different levels of granularity).
- Do you fully understand your value chain, and can you identify the risks regardless of the peril? The value chain risk assessment is outlined below:
  - Immediate risk: price and volatility of raw materials, cost of energy, composition of current materials
  - Intermediate risk (within a decade):
    - Product risks: climate risk drive clients to change their buying behaviors, which can lead to loss of product share (reputational risk)
    - Regulatory risks: Regulation changes follows the electoral calendar and are not always aligned with the need for sustainable policies that climate change adaptation requires.
- Do you have a greenhouse gas inventory to measure the exposure of your company to carbon taxes? And do you understand the short-, medium- and long-term impact of reducing carbon emissions to your company strategy, including operations and the impact of changing technologies to reduce carbon emissions on your sales?
- Have you made a water usage assessment to help manage dependencies as consequences of climate change such as droughts and deterioration of water quality?
- Do you have the detailed information needed to assess supply chain risk from natural catastrophes and extreme weather? Remember that local regulations could complicate the replacement of suppliers. A change in suppliers is, in some regions, associated with a long approval process.
- When building resilience at a location level, have you incorporated the three key changes in thinking that are required? These are:
  - First, a longer-term, scenario-driven risk assessment, as opposed to the more frequently used short-term and medium-term views.
  - Second, a stronger outside perspective in risk assessment. Assessments are often a little internally or industry focused.
  - Third, an assessment that captures indirect risks that develop from interconnectivities. For example, those relating to holding redundant stocks and part, or the reputational impact of moving investment and jobs away from an area subject to weather-related events.
  - Finally, have you considered the benefits of investing in prevention rather than recovery? If we look at flood risk for example, for which climate change has an impact, we note that most of the investment are usually routed to recovery versus prevention. Zurich, through its Flood Resilience Initiative, has demonstrated that every dollar spent on flood prevention measures on average saves five dollars on recovery efforts should a flood event occurs. This should serve as food for thought for companies discussing resilience and risk management costs.

Case study: Understanding and managing climate-related reputational risks

Failure to act scenario

The potential impact on a company reputation in a failure to act scenario depends on how the company is perceived by various stakeholders. Two perspectives are considered: one in which the company is perceived as part of the solution ('be a leader') and one in which it is perceived as part of the problem (i.e., not playing its role – 'status quo').

	Company position 1 'status quo'		Company position 2 'be a leader'	
Stakeholder	Risk*	Opportunity*	Risk*	Opportunity*
Distribution	Medium	Low	Low	Medium
B2B customers	Medium to high	Medium	Medium	Medium to high
Retail customers	High	Low	Low	High
Employees	High	Low	Low	High
Government	Medium to high	Low	Low	High
Investors	Medium to high	Low	Medium	Medium
Media	High	Zero	Low to medium	High
NGOs	Very high	Zero	Medium	Medium

*Illustrative

Position 1: Status quo

In this scenario, company X chooses to leave the activity level regarding climate risk around the status quo and lets the market mechanisms steer the direction. In light of rising temperatures and materializing physical risk, companies will, generally speaking, be perceived as part of the problem. The company accepts to be under scrutiny from activist investors and NGOs for not doing much to fill the gap that has been created by the lack of actions by governments and other businesses to fundamentally tackle climate change. In relation to other stakeholders, the reputational risk remains low to medium, because most business relationships are defined by market price conditions. Suppliers are actually given a competitive disadvantage if they voluntarily tackle climate change to the point of having to raise prices in markets that are solely defined by price. The reputational upsides from this position is relatively low vis-à-vis all stakeholder groups.

Position 2: Be a leader

Company X aims to lead the way in implementing proactive practices that can compensate for the lack of government and industry actions to manage climate risks. The company's reputation may be enhanced relative to its peers, but there is a risk of being seen as doing too much by the investor community while still not satisfying the high demands of NGOs. There is, though, a considerable reputational opportunity in relation to stakeholders if company X is perceived as a leader in a scenario where a lack of action will have significant negative consequences for many among company X's stakeholder communities.

Meet the Paris Agreement's scenario

The potential impact on a company reputation in a Paris Agreement scenario depends on how the company is perceived by various stakeholders. Two perspectives are considered: one in which the company is perceived as part of the solution ('be a leader') and one in which it is perceived as part of the problem (i.e., not playing its role – 'status quo').

	Company position 1 'status quo'		Company position 2 'be a leader'	
Stakeholder	Risk*	Opportunity*	Risk*	Opportunity*
Distribution	Low	Low	Low	Medium to high
B2B customers	Low to medium	Low	Medium	Medium
Retail customers	Low to medium	Low	Low	Medium to high
Employees	Low	Low	Low	High
Government	Medium	Low	Low	High
Investors	Medium	Low	Medium	Medium
Media	Low	Medium	Low	High
NGOs	High	Low	Medium	Medium

*Illustrative

Position 1: Status quo

The transition scenario is characterized by significant policy action, technological developments and changes in business and consumer behavior. Meeting regulatory requirements and addressing the most immediate market forces would already require an increased level of activity and thus the reputational downside from not 'going the extra mile' is actually lower than in the failure to act scenario. A failure to take decisive action could, however, be perceived as not living up to the economic imperative by certain stakeholders such as investors. Such a company could be perceived as a laggard, making it harder to attract and retain talent looking for a sustainable employer. This position would have minimal reputational opportunities.

Position 2: Be a leader

As a leader, the company would be perceived as a key supporter of the low-carbon economy transition and set the best practice example within the industry for its proactive approach. Given the potential market opportunities, being perceived as a market leader could result in significant benefits, although more effort would be required to attain such a position under this scenario as compared to the failure to act scenario, given a much higher 'baseline' of activity across sectors.

PART 5
Appendices

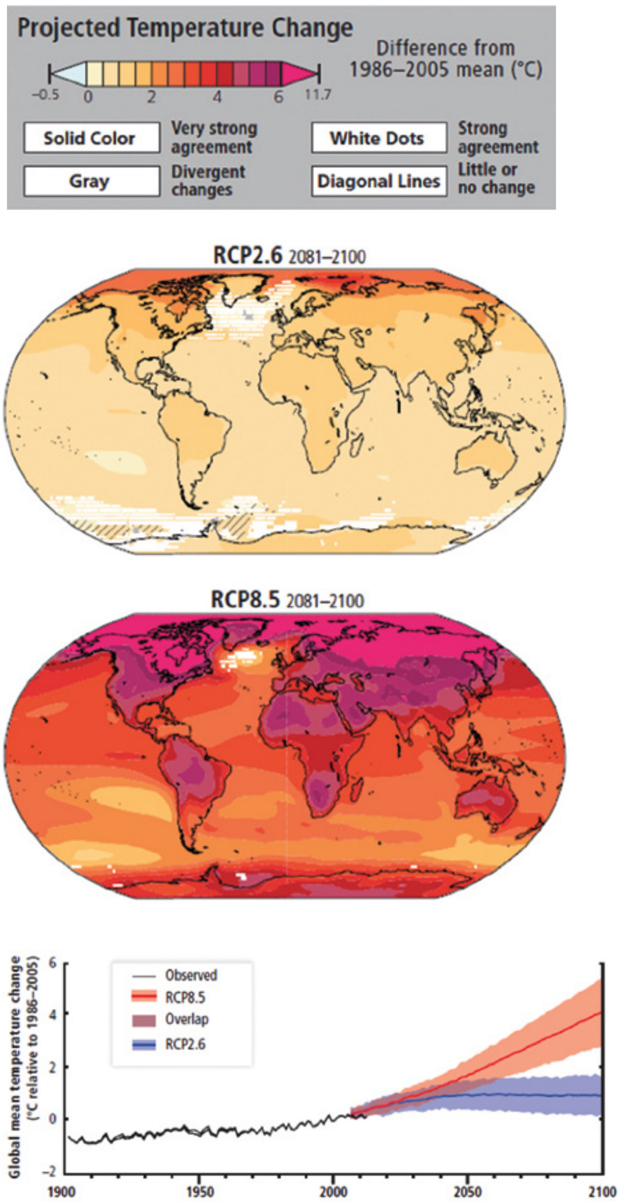
5.1 Physical risk impacts

This section explores the impact of both scenarios – failure to act and a two-degree compliant world – in greater detail, and is based on desk research combined with experts' opinions.

5.1.1 Heat waves, heat stress and drought

Historical temperature records show that the global average land temperature has already increased by about 1 C compared to 1900. Seventeen of the 18 warmest years in the 136-year record NASA maintains for global surface temperature have all occurred since 2001, with the exception of 1998.

Projected global changes in annual average surface temperature.



Source: IPCC "Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects," 2014.

Extreme heat

There is evidence that heat waves already are changing and are expected to continue to increase in frequency and duration – these increases will continue to produce a growing impact on societies beyond 2 C warming. Even with a 2 C change in global average temperature, parts of the world will experience considerably higher average temperatures. Regional differences in temperature increases will only be exacerbated as the global average rises.

Heat stress will impose significant limits on outdoor activities at 2 C warming and the capacity to work outdoors will decrease rapidly beyond this value.

Heat stress on humans is caused by a combination of high temperature and high humidity. Humidity is important because it prevents the body from cooling through evaporation of sweat. In very high humidity air temperature exceeding 31 C can lead to increasing fatality rates for many outdoor activities.

Climate change increases both the air temperature and the amount of moisture in the air, with the result that heat stress rises at between two and a half and three times the temperature increase alone. Even a 2 C increase in mean global temperatures will result in cities such as Kolkata and Karachi in India experiencing their deadly 2015 heat waves on an annual basis. This rapidly extends to many other cities if temperatures continue to rise. If warming continues to increase, the capacity for external work will continue to sharply decrease.

Extreme heat is also expected to impact transport infrastructure, with roads and runways softening under the heat, potentially leading to disruptions in air and road traffic.

Drought

Drought impact increases with climate change through two major processes: increased frequency of successive hot and dry periods, and more rapid drying of vegetation due to the overall warmer conditions. There is an additional cumulative effect where successive years of moderate drought depletes river discharge and ground water levels leading to increased impacts for irrigation fed agriculture, and residential and commercial water use. Extraction of ground water above the rate is able to be replenished is already a concern in a number of areas, which is likely to increase with growing populations and living standards. Estimations are that by the 2080s about half of the global population will be exposed to water stress compared with about 30 percent today.

Below a 2 C increase in global temperature, the changes in water use caused by population growth and expected changes in living standards are expected to outweigh changes in water stress caused by climate change. Once warming moves beyond 2 C, climate change would dominate changes in water stress in many regions, while local population changes and water demand will remain important aspects in determining specific water stress developments. If the world is moving beyond 2 C, warming droughts that have never been experienced are expected to become the norm in most regions.

Issues will likely arise not only from changes in average water availability, but also in changes in seasonality of precipitation and runoff. While the average amount of water flow might increase for rivers such as the Nile or Ganges, the uneven annual distribution might lead to increased flood risk for part of the year, while water stress will remain constant or increase during the rest of the year.

The potential societal impacts from the predicted changes in runoff and water stress are linked to high amounts of uncertainty, as resolving a detailed geographical distribution of runoff and ground water changes as well as corresponding affected population is beyond the means of today's climate models. It is particularly difficult to predict the response of monsoon rainfall that a significant share of the world population depends on.

Water availability in any location will also heavily depend on water management practices, water-use efficiency as well as industrial and agricultural uses. Other effects are expected to reduce the availability of usable water even further, such as increasing salinity of groundwater and estuaries resulting from the combined effects of groundwater overextraction, rising sea levels as well as increasing pollution of surface and groundwater through inadequate sewage treatment systems, particularly in developing countries.

The increased water stress can be expected to lead to increasing conflicts between water users, such as residential, commercial and agricultural users, with prices for water use to increase while water security is set to decrease for affected regions.

5.1.2 Oceans

Eustatic and relative sea level change

Global (eustatic) mean sea level has risen by 19.5 cm between 1901 to 2015, at an average rate of 1.7 mm/year. There is strong consensus that sea levels are further rising in response to climate change due to a combination of thermal expansion and the melting of land ice. Further warming will result in an accelerating rise in mean sea level, with the main uncertainty arising from the projections of greenhouse gas emissions. By the year 2100 current projections vary from a rise of approximately 30 cm from now for low emissions (equivalent to 1.5 C) to more than 1 m for high emissions (exceeding 2 C).

As global temperatures warm beyond 2 C, so does the potential for a rapid increase in sea level due to melting of land-locked ice. When, or even if this will occur is not currently predictable with confidence, but it is understood that such changes may proceed very rapidly once started. For example, partial or complete melting of a major ice sheet such as Greenland would result in many meters of increased sea level.

Regional changes in relative sea level (i.e., sea level relative to local land surface elevation) will vary considerably around any given mean sea level change due to a range of processes such as local land subsidence and rise, local effects due to geographic characteristics and wind forcing, variable local oceanic warming, ice melt and a range of other effects. Recent changes in sea level alone due to climate change indicate that the largest increases have been in the western Pacific and the largest decreases in the eastern Pacific.

While some land subsidence can occur naturally, human effects including increasing coastal populations pumping subsurface water with consequential compression of the land can be a dominant driver for local effects. This is the predominant driver for the subsidence in Jakarta, which has recently been highlighted as the world's fastest subsiding city, due to overextraction of ground water.

Increases of coastal erosion will further exacerbate the effects of sea level rise, especially where natural defenses such as mangroves and coral reefs are being damaged through climate change, pollution and land use. Detailed effects are however highly localized and will depend on local adaptation plans.

There is high confidence that for coastal cities the combined effect of rising sea levels, higher proportions of intense tropical cyclones (see Section 5.1.3) and greater levels of coastal fluvial flood from enhanced rainfall will lead to more frequent and intense damages from tropical cyclone storm surges. Given the already high, and further growing, concentration of population and assets in coastal port cities, the exposure to flood risk is expected to increase significantly both in terms of people and assets affected.

If and to what extend this exposure can be mitigated by increased flood protection will be highly dependent on local geographical and political factors. Deltaic cities, many of the largest are found in Asia, will be particularly exposed as they tend to be at lower elevations, are more prone to experience natural and man-made subsidence and might face the additional threat of river flooding.

Ocean acidification

Oceans will also become more acidic as a consequence of rising water temperatures and able to dissolve less oxygen. Higher acidity will impact any organism with calcium carbonate shells, such as corals, mollusks and some forms of plankton. With coral reefs already heavily affected in a 2 C scenario, most coral ecosystems are likely to disappear in a 4 C warming scenario.

Toxic algae blooms are expected to become more frequent, with potential negative impacts on aquaculture and fishing. Changes in temperature and oxygen levels will also lead to shifts in geographic ranges, seasonal activities, migration patterns, abundances and species interactions. The net effect is expected to lead to an overall decrease in fish stock, although fisheries could see increased yields in high latitudes. Quantitative predictions on such changes however do not yet provide a robust consensus.

These effects will impact ecosystems already weakened by pollution and overfishing. Overall effects will heavily depend on whether such other stresses can be adequately managed.

5.1.3 Tropical cyclones

Over the last years a growing consensus on the effects of climate change on tropical cyclones seems to emerge. The frequency of tropical cyclones globally is expected to either remain the same or even experience a slight decrease, though frequency changes in individual regions remain somewhat uncertain. Observed changes to date vary between an increase in the north Atlantic to a decrease in the southwest Pacific.

There is also increasing confidence that climate change has already increased the proportion of high intensity (Category 4 and 5) hurricanes. It is unclear how this trend will continue with further warming but the maximum achievable intensity that a tropical cyclone can reach is expected to increase at a rate of 5 to 10 percent for every degree of warming. Recent research points to a trend in slower movement of cyclones which will further increase their potential for localized destruction.

A relevant trend that is not yet well understood is a poleward movement of the location where tropical cyclones reach maximum intensity that is associated with the expansion of the tropics resulting from climate change. This might lead to cyclones reaching locations where they have not been previously experienced.

The combined effects of those changes should increase the potential for devastating storms and do pose the question if current building standards, and coastal and flood defenses will be adequate under future scenarios.

5.1.4 Extreme precipitation and flooding

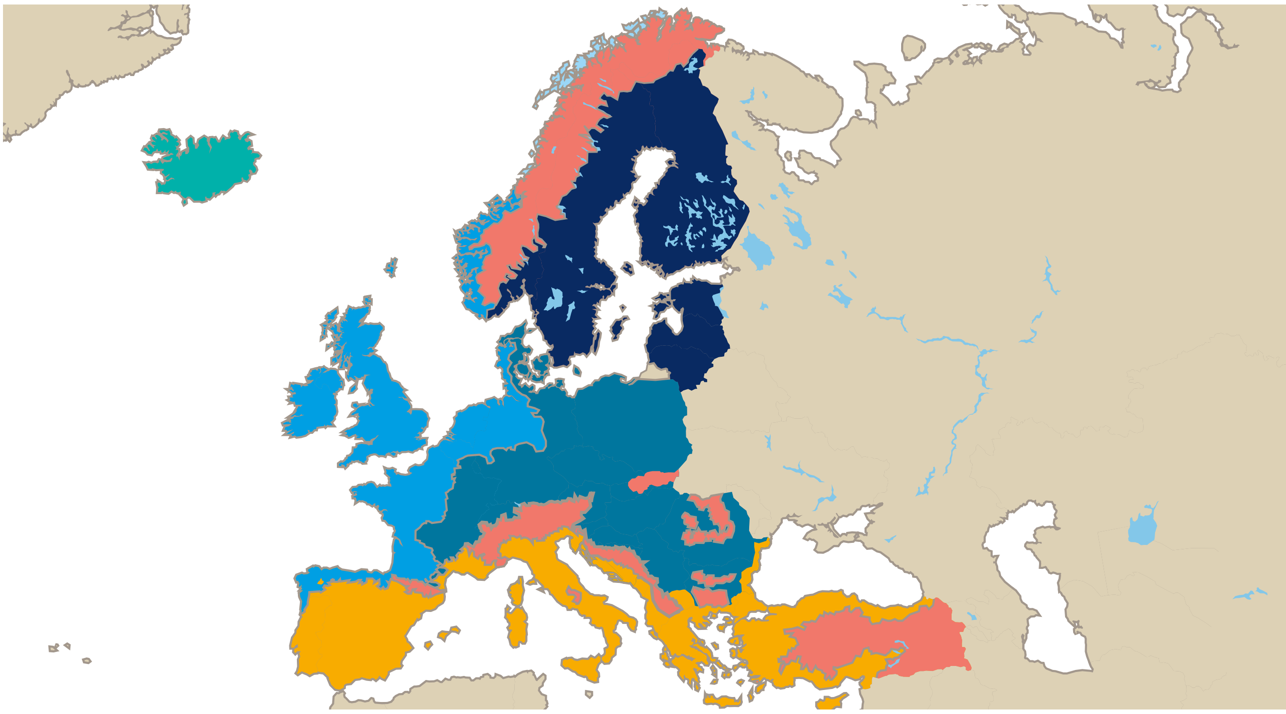
Extreme rainfall is expected to increase with progressing climate change, primarily due to the increased ability of the atmosphere to hold more water vapor as the temperature increases. However, while universal increases in extreme rainfall can be expected, there will be considerable variability in the actual rainfall changes in different regions, with the largest changes expected in high latitudes and the monsoon regions.

Existing community-level flood defenses might need to be reassessed against these changes, as they will be based on too optimistic assumption in terms of return periods.

Much damaging flooding occurs from local severe storms that are not resolved by the relatively course climate models and will require the application of local flood models and maps for any impact assessment. The development of such local models is resource intensive, costly and requires dedicated expertise, therefore unlikely to be feasible for companies to develop themselves. Impact assessments are further complicated by the uncertainty around the application of additional public flood defenses, which have the potential to reduce economic damage substantially.

5.2 Regional implications

5.2.1 Europe



Arctic
Temperature rise much larger than global average.
Decrease in Arctic sea ice coverage.
Decrease in Greenland ice sheet.
Decrease in permafrost areas.
Increasing risk of biodiversity loss.
Intensified shipping and exploitation of oil and gas resources.

North-western Europe
Increase in winter precipitation.
Increase in river flow.
Northward movement of species.
Decrease in energy demand for heating.
Increasing risk of river and coastal flooding.

Coastal zones and regional seas
Sea-level rise.
Increase in sea surface temperatures.
Increase in ocean acidity.
Northward expansion of fish and plankton species.
Changes in phytoplankton communities.
Increasing risk for fish stocks.

Northern Europe
Temperature rise much larger than global average.
Decrease in snow, lake and river ice cover.
Increase in river flows.
Northward movement of species.
Increase in crop yields.
Decrease in energy demand for heating.
Increase in hydropower potential.
Increasing damage risk from winter storms.
Increase in summer tourism.

Mountain areas
Temperature rise larger than European average.
Decrease in glacier extent and volume.
Decrease in mountain and permafrost areas.
Upward shift of plant and animal species.
High risk of species extinction in Alpine regions.
Increasing risk of soil erosion.
Decrease in ski tourism.

Central and eastern Europe
Increase in warm temperature extremes.
Decrease in summer precipitation.
Increase in water temperature.
Increasing risk of forest fire.
Decrease in economic value of forests.

Mediterranean region
Temperature rise larger than European average.
Decrease in annual precipitation.
Decrease in annual river flow.
Increasing risk of biodiversity loss.
Increasing risk of desertification.
Increasing water demand for agriculture.
Decrease in crop yields.
Increasing risk of forest fire.
Increase in mortality from heat waves.
Expansion of habitats for southern disease vectors.
Decrease in hydropower potential.
Decrease in summer tourism and potential increase in other seasons.

Compared to pre-industrial times European land areas have increased by around 1.5 C for the period 2006-2015, i.e., faster than global average. This trend is expected to continue, with the strongest warming projected for northeastern Europe and Scandinavia in winter and for southern Europe during the summer month. Overall the climate impacts for Europe need to be seen against a relatively high adaptive capacity to cope with emerging effects. The greatest vulnerabilities are expected in the southeastern and southern parts of Europe.

In terms of **heat waves**, both frequency and duration are expected to increase, with particularly strong impacts for southern Europe.

Annual precipitation is expected to increase in large parts of northern and central Europe, while the southern parts are expected to see a decrease. Projections predict an increase in heavy daily precipitation in most parts of Europe during the winter and in large parts during the summer, except for regions in south and southwestern Europe that might see decreases. However, how this will translate to changes in flood frequency and severity is still highly uncertain.

Projected **decreases in glacier volumes and annual snow cover** are expected to impact river flows, as melt water is a major contributor to runoff. Reduced retention of water as snow and earlier snowmelt are expected to lead to peak flows occurring earlier in the year than currently. And generally, river flows in summer are projected to decrease during summer.

The frequency of **droughts** in southern and central Europe seems to be increasing. Further warming is expected to lead to increases in frequency, duration and severity of droughts within Europe, particularly in southern Europe where water use conflicts already are occurring. Some north European areas might see a decrease in drought conditions.

The increase in dryer and hotter climate will also increase the length and severity of wild fire seasons, particularly in southern Europe. The combined effects of climate change are expected to **increase the suitability of northern Europe for agricultural use** and reduce crop yields in southern Europe. Increasing demand on irrigation to maintain crop growth is expected to lead to further **conflicts over water availability and use**.

Continuous warming will lead to **more intense and potentially more frequent storms**, particularly during the winter and for the North Atlantic and northern, northwestern and central Europe.

Changes in storm surge are also expected to affect **extreme coastal water levels**, particularly for the northern European shoreline. Even a rise of 30 cm, at the low end of expected changes is estimated to more than triple annual damages from coastal floods for the EU from EUR 5 to 17 billion without further adaptation.

Increasing cooling demand in southern Europe might exacerbate **energy demand peaks** during summer, at a time when water availability for hydroelectric power generation and cooling for thermal power generation will be the lowest.

5.2.2 Sub-Saharan Africa

Under higher-emission scenarios almost all African regions, especially the tropics, would experience summer heat significantly above historical norm, with especially strong increases in tropical West Africa.

Impact on **precipitation** are expected to vary across the continent, with high uncertainty in some regions. Southern Africa is generally expected to receive less precipitation while parts of East Africa might become slightly wetter. The accompanying change in rainfall pattern however could lead to more pronounced dry periods combined with more extreme rain events and increased flooding damage in high-emission scenarios.

Increased evaporation in higher temperatures will contribute to aridity. Many rural areas of Sub-Saharan Africa heavily rely on groundwater. **Recharge rates of the groundwater aquifers is expected to decrease**.

There is more certainty that extraction rates will increase due to **increased incidence in droughts** and more irrigation.

Impacts to agricultural production due to changes in water availability and rising temperatures are expected in the near-term. For maize, available cropping areas could shrink by 40 percent by the 2030s at a warming between 1 and 5 C. Even production of sorghum, a crop well adapted to arid climates and an important food staple in Africa, is expected to see significant negative yield impacts for the western Sahel and southern Africa. **Changes in crop yield have significant impacts both on food security and economic growth**, with 20 to 40 percent of GDP depending on it. With three quarters of agriculture rain fed, stronger fluctuation and changes in precipitation potentially having devastating effects. At a 4 C warming a third of cropland might become unsuitable for cultivation. Costs and availability of ground water also limit the viability of changing to irrigated agriculture.

Heat and water stress as well as changes in feed quantity and quality can have significant **impacts on livestock health and mortality, animal growth and milk production**. This comes as global demand for livestock is expected to double by 2050 as living standards change.

5.2.3 Latin America and the Caribbean

The region is expected to experience a strong increase in **heat extremes**, with increasing risk for **droughts**. The combination of **more intense storms and increasing sea levels** will be particular impacting large low-lying coastal cities.

Decrease in tropical glacier volume is likely to have long term impacts in water availability, with an interim period of increased run off and the large glaciers located in the southern Andes being less sensitive to warming.

5.2.4 Asia Pacific

Warming in East Asia is expected to increase strongest in Mongolia and the northern China. In addition, most of this region is expected to become wetter. Central and West Asia on the other hand could see increased droughts. The shrinking of the Aral Sea is a prime example of the combined impacts of overuse, environmental degradation and climatic changes.

As general trend, an increase in flood risk is expected due to seasonal changes in water flow. Also contributing will be a combination of sea-level rise, cyclonic activities and deterioration of mangrove habitats as natural defenses. Especially vulnerable are the big river deltas such as on the Mekong, Red and Irrawaddy rivers. Large coastal cities of the region are also susceptible to combination of river and coastal flooding. Local water stress could be exacerbated by salt-water ingress due to sea-level rise. Much of South Asia's coast is also expected to see increased coastal flooding. Due to the nature of low-lying islands the Pacific region will see major impacts from sea-level rise, and if tropical storms and cyclones increase in intensity, they will see more devastating damage if they are hit.

China
Climate simulations point to serious potential vulnerabilities in China's future **agricultural security**. In China, warming is believed to be harmful to rainfed crops but beneficial to irrigated agriculture.

According to regional climate models, the frequency of **heat waves** and rainfall extremes in the future may increase over most of the country.

Several studies converge on the conclusion that **glacier melt runoff** may peak between 2030–2050 and could gradually decline afterward. Even though the exact timing and magnitude of the 'tipping point' of each glacier is still uncertain, the projected long-term exhaustion of glacial water supply should have a considerable impact on the availability of water for both agricultural and human consumption.

5.2.5 North America

Extreme temperatures are expected to increase, with cold waves projected to become less intense, while heat waves become more intense. In the southwestern U.S. average precipitation will decrease, if only slightly, while many other regions will not experience significant change in average precipitation.

Frequency and severity of heavy precipitation events are expected to increase. The largest increase is expected to occur in the northeastern U.S. Thunderstorm clusters are also expected to increase in intensity and number in the central U.S.

In the western U.S. snowpack will substantially decline and there will be a shift from snow to rainfall in many parts of the central and eastern U.S. Earlier spring melt and lower snow cover are likely to lead to more hydrological droughts toward the end of the century.

Large forest fires are however projected to increase in the western U.S. and Alaska.

Relative sea level rise is expected to be greater than average in the northeastern U.S. and the western Gulf of Mexico, while for low-emission scenarios a lower level rise is expected for the northwestern Pacific and Alaska. Recent studies have shown that southern Louisiana including New Orleans is subsiding at around 9 mm a year, a level that effectively doubles the local sea level rise due to climate change. For higher emission-scenarios all U.S. coastlines outside of Alaska are expected to see above average sea level rise due to the influence of Antarctic ice loss.

Tidal flooding will also increase in depth, frequency and extent.

5.3 Risk management responses to physical risks

Risk management responses to physical risks should include the following five-step approach: assess and identify; explore and investigate; implement, appoint; collaborate.

Peril	Assess and identify	Explore / investigate	Implement	Appoint	Collaborate
Water scarcity	Total water usage. Minimum water quality required in operations. Operations for which water is a critical component. Regional water sources. Quality of available water infrastructure (transmission/distribution networks, water treatment, wastewater treatment, etc.). Water-intensive processes critical to maintaining productivity and outdated inefficient equipment. Alternative locations where water-critical operation can be relocated.	Alternative water sources. Cost of solutions for water infrastructure upgrade (retrofit, new build, etc.). Improvements in existing processes and equipment to reduce water usage.	A water management and conservation plan. A business impact analysis and continuity plan to identify critical trigger levels (water levels, quality) and corresponding actions. Minimum specifications for processes and equipment with regard to water consumption.	Water stewardship champions on management teams. Company contact/representative with local authorities to plan and discuss water management issues at community level. Water management expert.	With other regional stakeholders to arrive at collective solutions. With regional authorities and communities.
Rising temperature (heat waves, heat stress, reduced water quality and availability)	Historical trends in temperature variation (number of days temperatures exceeded a certain value). Quality of existing buildings (age). Seasonality of power consumption at the individual locations within the group. Processes, equipment or building occupants that are susceptible/vulnerable to high temperatures. Quality of energy infrastructure, e.g., age and condition of power generation plants, transmission and distribution networks, etc. Locations (regions) that may be impacted by a heat wave. Locations that have processes, equipment, and/or equipment that are vulnerable to high temperature effects. Alternative sources of energy. Priority list of locations and buildings to be retrofit/ upgraded and measures to be implemented. Experienced structural engineers, designers, contractors for design, detailing, installation, and maintenance of new construction systems, energy sources, etc. as some of these technologies are new to the industry/market. Local suppliers of operations-critical equipment, e.g., emergency power generators, water suppliers (tankers).	Trends in new construction material (facade elements, windows that are reflective, provide good insulation, etc.). Implementation of alternative energy sources on buildings (solar). Installation of 'green roofs,' where local regulations allow. Identify local building codes and regulations that support retrofit/ upgrade of older buildings to more energy-efficient construction. Alternative locations to relocate building occupants vulnerable to high temperature (hospitals, daycare centers, retirement homes, etc.). Equipment and processes that may need to be operated at reduced capacity during the duration of high temperature.	Flexible working hours when high temperatures occur. Building maintenance program for building envelope to extend design life (roof drainage systems, roofing systems, etc.). Roofing replacement plan that considers replacement of roofing systems at shorter intervals and using modern, energy-efficient material. Emergency response plan that includes alternative locations to relocate operations or people during the heat wave event. Increased data backup during heat wave event (contingency against loss of power). Include heat wave in health, safety and environment (HSE) action plan. Exclusivity contractors with suppliers of operations-critical equipment.	Emergency response team to implement the response plan at pre-defined triggers (temperature levels). An operations team to source energy from most cost-effective sources (in countries where energy markets are open). A planning team to prioritize locations and buildings for upgrade/retrofit. A team to negotiate exclusive supply contracts for power, water, transport, and other operations-critical utilities. Include any measures implemented in the risk management process, e.g., installation of skylights (increase natural light to reduce power consumption) or installation of PV panels on the roof, may increase exposure to other risks (hailstorm, lightning, windstorm, etc.). Careful planning, design, detailing and execution, are imperative.	Suppliers of energy, water, and other operations-critical or essential utilities. Construction experts to develop energy efficient and environmentally-friendly buildings using state of-the art construction materials and methods.

Peril	Assess and identify	Explore / investigate	Implement	Appoint	Collaborate
Flood: Precipitation	Quality of existing buildings and infrastructure, e.g., maintenance quality, year of construction of buildings, quality of drainage systems, etc. Extent of urban development in the vicinity of locations identified as 'critical' for group operations. For 'critical' locations, identify the elevation of the ground floor (above terrain height), and buildings with basements. For 'critical' locations, identify the age of the buildings (which could be used as an indicator of quality of drainage systems). For 'critical' locations, assess surrounding terrain to identify features, which could increase flood hazard, e.g., nearby hills or mountains, alluvial plains, soft soils. Regions with a history of wildfires are susceptible to flooding triggered by intense rainfall (where certain topographic and soil conditions prevail, i.e., alluvial plains). Identify 'critical' locations. Rainfall 'design level' intensity-duration-frequency data. This information is location specific and describes the rainfall event to which various components of the drainage system (roof drainage components, road drainage system elements, etc.) should be designed. Identify local agency/authority which issues extreme weather warnings (if available). High value or operations-critical stock or equipment at basement or ground levels are highly exposed to flood. Since damage is triggered by ingress of water into the building through the building envelope (and not only at ground level) such content immediately under the roof or in the vicinity of walls or windows is also potentially exposed to damage. Suppliers of operation-critical equipment, e.g., emergency generators, construction material and equipment, qualified contractors, engineers, damage surveyors (for insurance purposes).	At critical locations, deploy qualified experts/contractors to assess retrofit/improvement measures required, e.g., of building envelope (roofing system, facade, windows or doors). Impact of increased urbanization on local infrastructure, e.g., public records indicate whether infrastructure has been retrofit/ upgraded, performance of infrastructure during recent extreme events, etc. Consider distribution of high value stock and content to upper levels, but not directly under the roof or adjacent to the building envelope. Upgrade/retrofit of site drainage systems. Increasing drainage system capacity, e.g., sump pits and pumps, water retention pits, etc.	Cost-benefit analysis for various solutions, e.g., retrofit/repair/ upgrade/replacement, increased maintenance, relocation of equipment, etc. Develop a database, which includes basic information to assess building vulnerability, e.g., elevation of ground floor (above sea level or surrounding terrain level, etc.), presence of basements, etc. Such information is readily available in the engineering documentation. This can be used for the purpose of building maintenance, prioritization of structural upgrades, etc. Exclusivity contracts with local builders, suppliers of construction materials, qualified professionals (structural engineers, site foremen, etc.).	Project and site managers to implement any structural retrofit/ upgrade solutions to buildings. Coordinators with local authorities (maintenance/upgrade works of local infrastructure). Technical advisers to support/ coordinate with local authorities to determine 'design' level event, design and detailing regulations for buildings, etc.	Local experts/qualified contractors/ project team for any construction activities. Local authorities to establish extreme weather early warning infrastructure (monitoring, notification, etc.). Local authority to identify critical infrastructure, urban development zones and building regulations (to prevent construction in areas that can increase flood hazard). Local authorities, research institutes, etc. to develop hazard maps, determine 'design' level event, detailing parameters, etc.

Peril	Assess and identify	Explore / investigate	Implement	Appoint	Collaborate
Flood: Riverine	Determine if any water bodies (rivers, lakes) or seasonal streams, rivers, etc. are in the vicinity of 'critical' locations. Dams or other manmade structures (e.g., bridges) within run-of-river, which could increase probability of flooding (reduction of river section). Extent of urban development in the vicinity of locations identified as 'critical' for group operations. For 'critical' locations, identify the elevation of the ground floor (above terrain height), and buildings with basements. For 'critical' locations, identify the age of the buildings (which could be used as an indicator of quality of drainage systems). For 'critical' locations, assess surrounding terrain to identify features, which could increase flood hazard, e.g., nearby hills or mountains, alluvial plains, soft soils. High value or operations-critical stock or equipment at basement or ground levels are highly exposed to flood. Identify local agency/authority which issues flood warnings (if available). Determine 'design' flood hazard levels. These are typically the flood depths at '100- year return period' flood events or based on local analyses. Determine not only the depth, but also duration of flood event as well as the duration between warning (for locations where warning system exists) and flood impacting the site. Local flood protection measures (dikes, levees, embankments, gates, etc.), responsible authority for maintenance and operation. Suppliers of operation-critical equipment, e.g., emergency generators, construction material and equipment, qualified contractors, engineers, damage surveyors (for insurance purposes).	Consider relocation of high value content (stock and, where possible, equipment) to upper levels. Implementation of fixed flood protection measures, e.g., water-resistant building construction at lower levels of buildings, as well as boundary wall, mobile flood protection for openings at ground level, etc. Construction of local (community) flood protection with local authorities (shared resources, know-how, etc.).	Cost-benefit analysis of implementation of physical protection measures (fixed and mobile, e.g., retrofit of building with water-resistant construction material, flood panels, sandbags, etc.). Develop a database, which includes basic information to assess building vulnerability, e.g., elevation of ground floor (above sea level or surrounding terrain level, etc.), presence of basements, etc. Such information is readily available in the engineering documentation. This can be used for the purpose of building maintenance, prioritization of structural upgrades, etc. Exclusivity contracts with local builders, suppliers of construction materials, qualified professionals (structural engineers, site foremen, etc.).	Project and site managers to implement any structural retrofit/ upgrade solutions to buildings. Coordinators with local authorities (maintenance/upgrade works of local infrastructure.	Local authorities to establish flood early warning infrastructure (monitoring, notification, etc.). Local authority to identify critical infrastructure, urban development zones and building regulations (to prevent construction in areas that can increase flood hazard). Local authorities, research institutes, etc., to develop hazard maps, determine 'design' level event, detailing parameters, etc.
Windstorm	Impact of increasing wind speeds and associated rainfall on roof-mounted equipment, building envelopes, etc. For 'critical' locations assess the structural stability of force-resisting (columns, walls, etc.) and secondary elements (windows, doors), not only for 'design' level wind event, but also for water-tightness and impact resistance (wind-borne debris). Identify local agency/authority which issues extreme weather warnings (if available). Suppliers of operation-critical equipment, e.g., emergency generators, construction material and equipment, qualified contractors, engineers, damage surveyors (for insurance purposes).	At 'critical' locations, deploy qualified experts/contractors to assess retrofit/improvement measures required, e.g., of building envelope (roofing system, facade, windows, doors).	Cost-benefit analysis of implementation of upgrade/ retrofit if older buildings. Develop a database, which includes basic information to assess building vulnerability, e.g., age of buildings. Such information is readily available in the engineering documentation. This can be used for the purpose of building maintenance, replacement of roofing systems, prioritization of structural upgrades, etc. Exclusivity contracts with local builders, suppliers of construction materials, qualified professionals (structural engineers, site foremen, etc.).	Project and site managers to implement any structural retrofit/ upgrade solutions to buildings. Coordinators with local authorities (maintenance/upgrade works of local infrastructure). Technical advisers to support/ coordinate with local authorities to determine 'design' level event, design and detailing regulations for buildings, etc.	Local experts/qualified contractors/project team for any construction activities. Local authorities to establish extreme weather early-warning infrastructure (monitoring, notification, etc.). Local authority to identify critical infrastructure, urban development zones and building regulations (to prevent construction in areas that can increase flood hazard). Local authorities, research institutes, etc. to develop hazard maps, determine 'design' level event, detailing parameters, etc.

Acknowledgements

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