# Getting started on Physical climate risk analysis in finance - Available approaches and the way forward

ClimINVEST Research Project
Work Package 1

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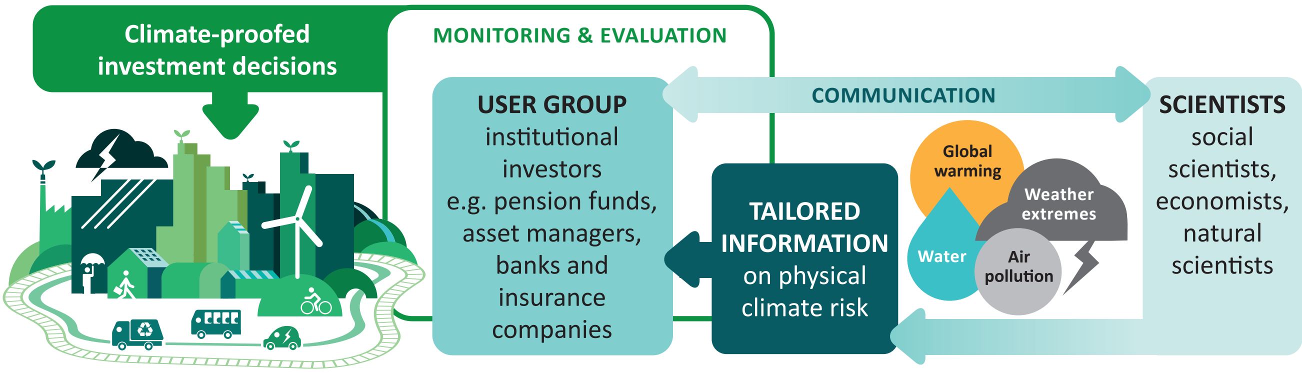
## DISCLAIMER

I4CE – Institute for Climate Economics is an initiative of Caisse des Dépôts (CDC) and Agence Française de Développement (AFD). This think tank provides independent expertise and analysis when assessing economic and financial issues relating to climate & energy policies in France and throughout the world. I4CE aims at helping public and private decision-makers to improve the way in which they understand, anticipate, and encourage the use of economic and financial resources aimed at promoting the transition to a low-carbon, climate resilient economy.

The research program under which this report was elaborated received financial support from ERA4CS. The research presented in this publication was carried out by I4CE on an independent basis. ERA4CS and the members of the ClimINVEST consortium are not liable under any circumstances for the content of this publication and recommendations are not necessarily endorsed by these institutions.

## FOREWORD ON THE CLIMINVEST RESEARCH PROJECT

Financial actors currently lack tools to assess how physical changes could affect their assets in specific sectors or locations. The ClimINVEST project aims to facilitate financial decision-making by offering tailored indicators, tools and maps for financial institutions. We intend to improve the communication between climate researchers and the financial community and contribute to capacity building on adapting to climate change. The tools developed by ClimINVEST should also help financial actors to disclose climate risk in their portfolios, in accordance with the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD).




### Key objectives

- Linking science and leading financial actors through regular science-practice labs, to:
  - Understand user needs and identify information gaps;
  - Co-design relevant indicators on physical climate risk for financial actors;
  - Map and visualize physical climate risk for investors;
  - Raise awareness of climate risk among financial decision-makers.
- Improving knowledge and tools to analyze climate risk.
- Building an expert network on physical climate risk.

### A first report from the ClimINVEST research project

The objective of this first report is to identify existing approaches of physical climate risk analysis that target financial actors. Next step of the project is to understand better the information needs of financial practitioners related to the analysis of physical climate risks in their portfolios. The comparison of their expressed needs with existing approaches will allow identifying information gaps. Starting from this information gap, climate scientists and financial practitioners will work on the co-design of indicators and tool to help assess physical climate risks.

### Consortium members

CICERO, carbone 4, I4CE Institute for Climate Economics, Wageningen University & Research, Climate Adaptation Services, Meteo France

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# Executive Summary



## What are physical climate risks to a financial institution?

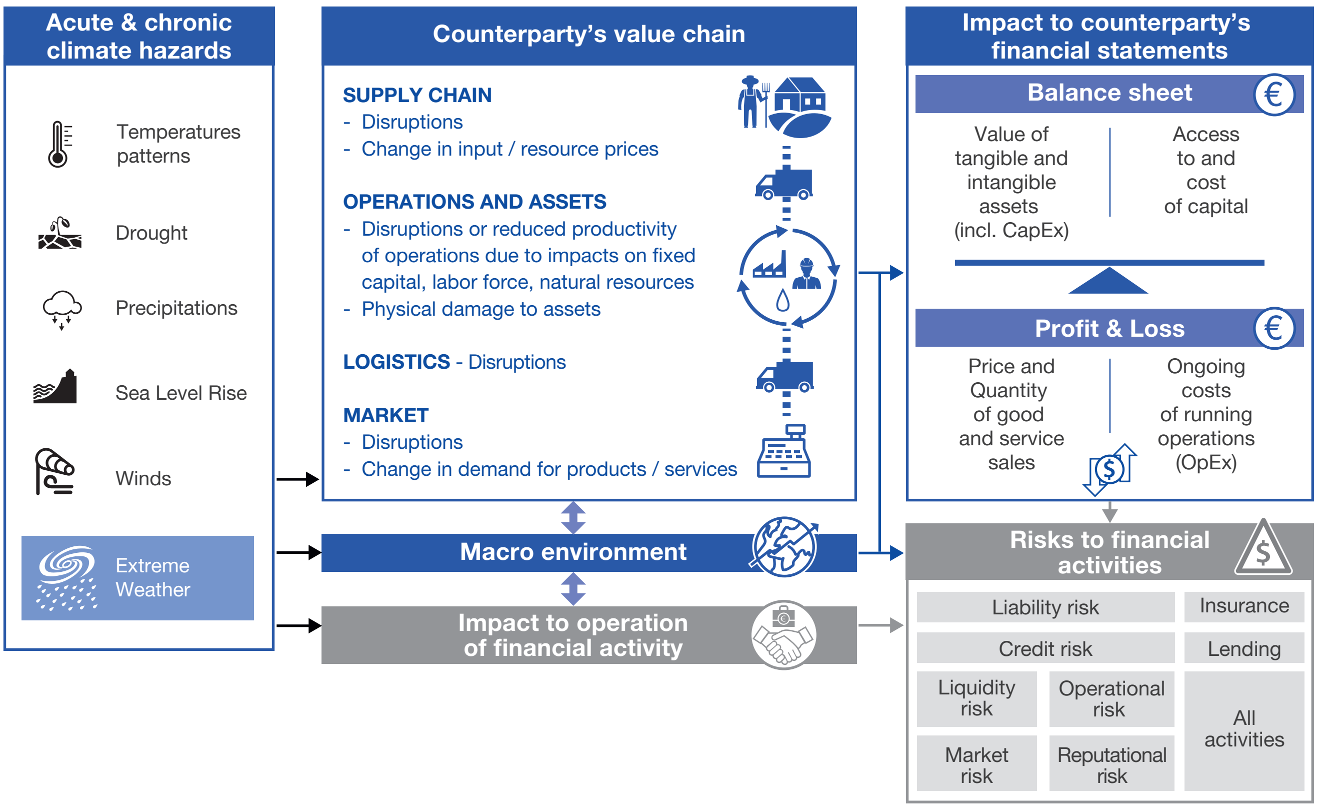
Climate change causes both acute hazards (i.e. event-driven hazards, including more frequent and intense extreme events such as cyclones or heatwaves), and chronic hazards (i.e. long-term change in the mean and variability of climate patterns such as mean temperatures). As shown on **Figure 1**, these hazards can affect financial institutions mainly through impacts on their counterparties in the real economy. These impacts can affect not only physical facilities that are directly exposed, but also the counterparty's results and value chain and the macro conditions[1]. Depending on the sensitivity and adaptive capacity of the counterparty to each specific impact, this affects its financial performance. In turn, it exposes the financial institution to financial risks that we call physical climate risks.

Physical climate risks have three main characteristics. First, they are linked to specific hazards – or a combination of different hazards[2] – that can lead to different impacts on the counterparty. Second, potential physical impacts depend on the specific situation of each counterparty and on its broader environment. Third, many physical impacts that scientists had originally anticipated over a much longer time horizon are being observed today across the globe, and will continue to increase in the next 10-20 years regardless of the greenhouse gas (GHG) emission trajectory. Such a trajectory will however influence physical impacts in the longer term (CICERO (2017)). This justifies the need for forward-looking analysis on short to longer time horizons.

1 'Macro' conditions define the broader business environment of the counterparty. They comprise socio-economic aspects including for instance macroeconomic, political, financial, sociological or technical conditions. These conditions may affect the resilience of the broader business environment to climate change impacts, with potential consequences on the counterparty.

2 For instance, hurricanes in combination with sea level rise result in exacerbate flooding in coastal regions.

**FIGURE 1. PROPAGATION CHANNELS OF CLIMATE RISKS TO THE REAL ECONOMY AND THE FINANCIAL SECTOR**




*Source: Authors, adapted from CICERO (2017) "Shades of Climate Risk"*

# Financial institutions are beginning to explore physical climate risks with service providers

### Financial institutions are gaining awareness on physical climate risks, but they are not yet necessarily taking action

I4CE carried out a review of information made public by a sample of 80 financial institutions on physical climate risks in 2017. This review indicates that financial institutions are gaining awareness on physical climate risks, with 51% of institutions mentioning this issue in their public documents. However, only less than a quarter of sampled financial institutions reported conducting a physical climate risk analysis. Moreover, among these the exercise was mostly qualitative, with a fragmentary scope, and built on available approaches from external sources for a majority of analyses.

### A limited number of service providers have developed approaches on physical climate risk analysis for financial institutions

As part of ClimINVEST, I4CE carried out a review of existing approaches to analyze physical climate risk dedicated to financial institutions. The pool of operational available approaches tailored for financial institutions is limited in number. Specialized service providers have developed most of the approaches that were included in this report, as shown on **Table 1**.[3] [4] Half of these approaches are available for payment, while WRI's Water Risk Atlas and Trucost's Water Risk Monetizer are available for free.

### Existing approaches address potential impacts of climate change on the counterparties of financial institutions

Service providers target different end-uses and end-users relevant for financial institutions. Nevertheless, they all try to answer the same type of question: how climate change can potentially affect counterparties such as projects, companies or governments. Not all of the selected approaches cover every type of counterparties and every aspect of potential impacts. In terms of counterparties, projects are in the scope of Acclimatise, Carbone 4 and Mercer's approaches; sovereigns are in the scope of Moody's Investors Service, 427, Carbone 4 and Mercer's approaches; companies are in the scope of 427, Carbone 4, Carbon Delta, Mercer and Trucost approaches. In terms of analysis of potential impacts, the WRI focuses on a sub-category of climate hazards, while the other approaches seek to incorporate the different aspects.

To investigate potential impacts, the approaches can combine information on the four broad categories explained in **Equation 1** below: on climate hazards; on the counterparty's exposure to these hazards; on the sensitivity of the counterparty to this exposure; and on its capacity to address these potential impacts.

3 This report has reviewed the approaches that were available when starting this review in late 2017. The report has selected approaches in order to establish an overview of methodologies.

4 For brevity, this report provides examples on the selected approaches by mentioning the name of the service provider. When the Water Risk Monetizer is concerned, "Ecolab, Trucost and Microsoft" are mentioned shortly as "Trucost".

**TABLE 1. SELECTED SERVICE PROVIDERS AND APPROACHES TARGETING DIFFERENT NEEDS**

| Target use | Target user | Service provider *(Approach)* |
|---|---|---|
| Pre-screening before financing | Project officers and risk managers – More suitable for development banks | Acclimatise *(Aware for Projects)* |
| Exploratory approach* | Risk managers – All financial institutions | Moody's Investors Service *(Physical Effects of Climate Change on Sovereign Issuers)* |
| Analysis of a portfolio exposure to climate hazards | Not defined – All financial institutions | WRI *(Aqueduct Water Risk Atlas)* |
| Analysis of physical climate risk | Not defined – All financial institutions | Carbon Delta *(Climate VaR)*<br>Carbone 4 *(CRIS)*<br>Ecolab, Trucost and Microsoft *(Water Risk Monetizer)*<br>Four Twenty Seven *(427 Climate Risk Scores)*<br>Mercer *(TRIP framework)* |

** Moody's approach is explorotory in the sense thot it does not constitute a new product to investors and it is based on illustrative data.*
Source: Authors

**EQUATION 1. PHYSICAL CLIMATE RISK COMPONENTS**

**Physical Climate risk** =

**Climate Hazard**: Potential occurrence of a trend or event that has adverse consequences to the system of interest. It may comprise the likelihood and magnitude of the event or trend.

X **Exposure**: Presence of the system of interest in a place and setting that could be adversely affected by a climate hazard.

X **Vulnerability**: Propensity or predisposition of the system of interest to suffer adverse consequences from its exposure to the considered hazard.

( **Sensitivity**: Degree to which a system of interest is affected, either adversely or beneficially, by a change.

– **Adaptive Capacity**: Total potential of the system of interest to adjust to the potential hazards or to respond to their consequences. )

*Source: Authors*

The approaches reviewed build on public data sources for climate hazards, with further steps of post-processing internally. The lists of climate databases used are easily accessible from service providers. The situation differs regarding the sources of information on counterparties (i.e. exposure, sensitivity and adaptive capacity data). The exposure can be provided by the end-user of the approach (in the case of Acclimatise, Trucost and Mercer's approaches), or combinations of counterparty's publicly reported information, commercial and proprietary databases (in the case of the other selected approaches). Sensitivity data can also be provided by the end user (in the case of Acclimatise and Trucost's approaches), or arise from combinations of public and commercial databases, public or proprietary cost functions, and expert judgment (in the case of the other selected approaches). The adaptive capacity is addressed for sovereigns with publicly available databases, while it is less covered for corporate counterparties. The tools and data sources on counterparties are less transparent than on climate hazards.

## Service providers' approaches use diverse information formats and methodologies

While service providers address the same type of question, they generate information with little cross-comparability. They make different methodological choices that can translate into different information formats.

### Existing approaches provide scores or quantitative estimates with different types of details

Five service providers choose to provide scores on the level of physical climate risk of the counterparty (see Figure 2 below). Four other approaches produce quantitative information such as estimates of potential costs or asset value impact resulting from climate risks to a single counterparty. Furthermore, this information is produced using a range of normalization methodologies and uses different scales and units.

The information provided to end users also differs regarding the type of detail (*e.g.* per: type of hazard; climate scenario; time horizon; category of impact; counterparty) and the level of detail (*e.g.* counterparty or sectorial level analysis) they provide as illustrated in **Figure 2**.

### Tradeoffs on specificity, exhaustiveness and detail result in different scopes of analysis

Service providers encounter difficulties in providing information that is exhaustive, detailed per type of impact and specific to the counterparty at the same time. They, in turn, tend to concentrate their efforts on specific aspects of physical climate risks that are more currently manageable.

The scope of hazards covered by each approach is variable. Most of the current approaches address acute climate-related

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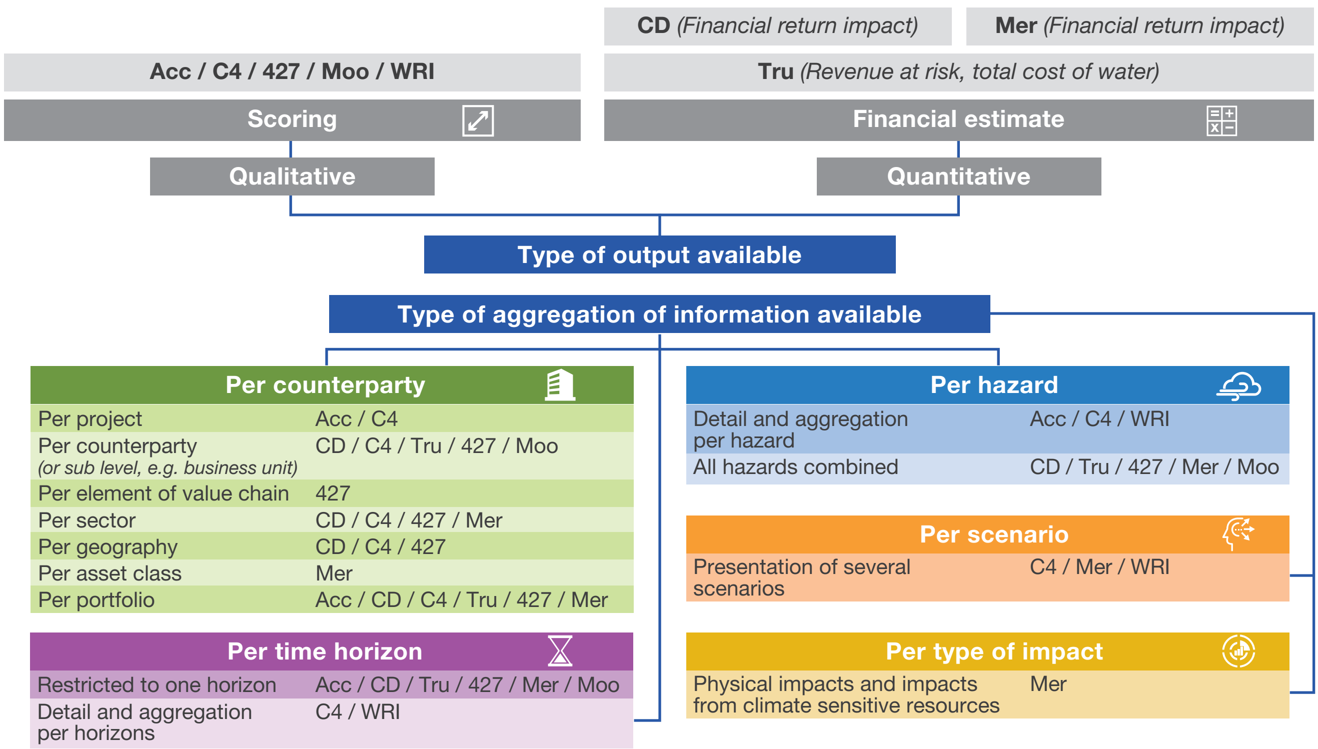
**FIGURE 2. EXISTING APPROACHES PROVIDE DIVERSE TYPES OF INFORMATION**




**Acc:** Acclimatise – Aware for Projects
**CD:** Carbon Delta – Climate VaR
**C4:** Carbone 4 – CRIS
**Tru:** Ecolab, Trucost and Microsoft – Water Risk Monetizer
**427:** Four Twenty Seven – 427 Climate Risk Scores
**Mer:** Mercer – TRIP framework
**Moo:** Moody's Investors Service – Physical Effects of Climate Change on Sovereign Issuers
**WRI:** WRI – Aqueduct Water Risk Atlas

*Source: Authors*

phenomena (*e.g.* hurricanes; heat waves; drought and floods) while coverage of chronic phenomena is emerging (*e.g.* some approaches focus specifically on water availability; no approach addresses wind patterns). There are potential further differences in the indicators that describe a given hazard (*e.g.* water stress can be studied through mean yearly water supply or intra-year variability of water supply) but in several approaches there is limited transparence about the chosen indicators.

In addition, the existing methodologies covered by this study address different climate-related impacts on corporate counterparties. They focus on different scopes of the counterparty's exposure; for instance, some methodologies cover the upstream and downstream value chain and the logistics whereas some others cover only operations. In the same vein, only a few cover capital, labor, natural resources and the macro context.

## The limited availability of counterparty-specific data is a major challenge

One major reason for the difficulty to provide exhaustive and specific information is the limited availability of counterparty-specific data, especially for companies. First, while exposure of operations and downstream value chain is always detailed at a counterparty-specific level (with data on fixed capital and sales, at latitude/longitude scale or country scale), supply chain exposure is always assessed using sectoral data - and the macro context is seldom explicitly addressed. Second, sensitivity is always assessed at a sectoral level; it could benefit from micro information specific to each counterparty, as well as macro information on the business environment. Third, adaptive capacity is not addressed in the methodologies studied in this report due to the lack of available information. Finally, in front of limited availability of counterparty-specific data, the service providers have chosen between providing quantified financial estimates of impacts and providing qualitative analysis presented through scoring.

## Forward-looking analysis is starting to be integrated in physical climate risk analysis

Assessing physical climate risks requires a forward-looking analysis on climate hazards and socio-economic aspects, in the short to long-term horizons. Many physical impacts of climate change are being observed today and will continue to increase in the next 10-20 years. In the longer-term, physical impacts will also depend on the greenhouse gas emission scenarios (CICERO (2017)). In any time horizon, climate change may generate unprecedented conditions with potential combinations of gradual change in current average climate patterns and more frequent and intense extreme events. The exposed counterparties and broader systems may also evolve and modify their capacity to adapt to these changes.

Service providers often include forward-looking scenario-based analysis for climate hazards with variable time horizons (from 15-years going along to 2100) and typically using a single scenario. These scenarios are either 'trend scenarios' in the sense that they extrapolate trends from the past, or 'exploratory scenarios' in the sense that they also consider a set of bio-physical and socio-economic hypotheses to extrapolate the future. In order to complement this forward-looking analysis, the exploration of unprecedented combinations of weather events could be useful, regardless of the time horizon of analysis. This would justify integrating the risk of occurrence and the impact of a combination of weather events in the analysis, including gradual change in average weather conditions.

However, few existing methodologies integrate socio-economic scenarios, *e.g.* evolution of the macro-economic context, evolution of sensitivity and adaptive capacity. Indeed, the uncertainty on socio-economic evolutions is more "usual" for financial institutions but it is also larger and less documented compared with climate uncertainties. Some methodologies nevertheless do integrate some socio-economic projections through user input or expert judgment.

# The way forward on physical climate risk analysis in finance

### Financial institutions need data and methodologies to develop their physical climate risk analysis

Physical climate impacts are occurring now and they will continue to grow in the near term even if significant GHG mitigation occurs. While financial institutions are increasingly aware of this topic, there is still little evidence of concrete integration of physical climate risk information into their decision-making processes.

Financial institutions have conducted a first round of physical risk assessments with the assistance of external service providers, without necessarily taking action based on this information. They need approaches on physical climate risk analysis that are tailored to their institutional needs.

### Service providers face barriers to improving methodologies and further development

While service providers have demonstrated their abilities to provide information on diverse aspects of physical climate risks, several barriers may hamper their potential for further developments. First, data availability is a challenge to produce relevant information at the appropriate granularity. This concerns in particular access to counterparty specific data on exposure, sensitivity and adaptive capacity. Second, the commercial environment of most service providers may also limit their direct capacity to explore financial institutions' needs thoroughly and to implement solutions in gradual steps or that require long-term, resource-intensive development.

### A public interest-minded 'co-design' approach could catalyze physical climate risk analysis in finance

The first challenge relates to data availability. The lack of public information in some domains (such as at the counterparty level) stresses the importance of improving public disclosure (*e.g.* through the implementation of the TCFD recommendations). This is clearly a necessary step toward a solution.

In addition, the other barriers could be lifted through a co-design approach between scientists and financial institutions in a public interest, non-profit approach. This could help scientists understand concrete decision-making processes within financial institutions to help overcome barriers to integrate information on physical climate risks. This could help raise the awareness of financial institutions that may currently consider climate risks not to be material for themselves. Reciprocally, financial institutions may benefit from climate scientists' exploration of available and reliable datasets on hazards, as well as relevant indicators and analytical techniques to overcome barriers. The co-design process in itself could yield relevant conclusions for further service providers' developments. Moreover, a public interest-minded approach to climate service development may be necessary to highlight the longer-term research avenues on physical climate risks.

In its next phase, the ClimINVEST project – which builds on a unique collaboration between academics, service providers, government data providers and financial institutions – will test a public interest co-design research approach to create actionable information on physical climate risk for financial institutions. The European team of climate and finance specialists will collaborate with financial institutions to co-design transparent and publicly available information and methodologies based on public data.

# Introduction

The 2018 edition of the World Economic Forum's Risk report places extreme weather events, natural disasters and failure of climate change mitigation and adaptation in the top 10 risks (both in terms of likelihood and impact). Impacts from the current climate conditions are already causing significant losses in the economy. In Europe, climate-related extreme events have caused EUR 436 billion of economic losses between 1980 and 2016 (in 2016 EUR) and doubling from the 1980 decade to the 2010-2016 period (European Environment Agency, 2018). Such losses may become normal in a changing climate (World Bank Group, 2014), where cyclones, heatwaves, droughts and other extreme events will become more frequent and/or intense, along with gradual change in temperatures, wind and rain patterns.

Climate change has already started (IPCC, 2013) and scientific evidence has identified regional impacts from climate change such as food production decline; change in repartition of species; alteration of water resource quality and quantity (IPCC, 2014). More generally, climate change will affect people's health, food production, economic activities, ecosystems and the physical environment. Financial institutions are exposed to these impacts, mainly through their counterparties in the real economy. The French Insurance Federation (2016) estimates for example that natural hazards arising from climate change in the metropolitan area will cost an additional EUR 13 billions to the French insurance sector by 2040.

Climate change and its impact will continue for a long time. Current efforts to limit emissions of greenhouse gases in the atmosphere can mitigate the aggravation of climate change impacts in the long-term if combined with adaptation measures. Since the signature of the Paris Agreement in 2015, the current objective is to decrease emissions fast enough to limit global warming below +1.5°C by 2100. This should help reduce the risk of extreme impacts such as the submersion of small island nations, but this will not resorb the climate change from greenhouse gases already accumulated in the atmosphere (Collins *et al*., 2013, p.1104).

The financial community has started to recognize how climate change impacts the so-called "physical climate risks" to financial institutions. This has accelerated since 2015, when financial authorities, governments and financial institutions started a momentum to integrate a broader set of "climate-related risks" in financial practices. Consequently, financial institutions are now expected to analyze their exposure to physical climate risks and to report on this issue following specific guidance (see **Box 1**).

Meeting these expectations requires the development of specific approaches to analyze the physical climate risks in financial portfolios. Raising the question; what type of approaches can financial actors mobilize for analyzing their exposure to physical climate risks? The objective of this report is to provide a comprehensive picture of the state of the art of approaches available to financial actors, including avenues for further developments. First, it provides a brief presentation of the scope of this analysis and main concepts used in assessments of risks related to the physical impacts of climate change. Then if offers a mapping of available approaches that financial actors can use to analyze their exposure to physical climate risks. Finally, it discusses limits of existing approaches and steps forward to overcome these limits.

This report is targeting financial practitioners who are looking for detailed explanation both on physical climate risk in finance and on the state of the art of approaches to analyze it. The next report of the ClimINVEST research project will present information and analyses needs expressed by financial actors related to the assessment of physical climate risks of their portfolios, and will conclude on information gaps that could be filled by the ClimINVEST research project and climate service providers more broadly.

**BOX 1. THE MOMENTUM FOR "CLIMATE-RELATED RISKS" ANALYSIS IN THE FINANCIAL SECTOR**

Global climate change and measures undertaken to mitigate it expose financial institutions to climate-related risks that comprise:

- Physical climate risks: the uncertain financial impacts that result from the effects of climate change on economic actors and portfolios;
- Transition risks: the uncertain financial impacts that result from the effects of setting up a low-carbon economic model on economic actors;
- Liability risks: the uncertain financial impacts that arise when those suffering climate change losses seek compensation from those they hold responsible* (Hubert, Nicol and Cochran, 2017).

Mark Carney's first speech on "Breaking the tragedy of the horizon – climate change and financial stability" in September 2015 was the catalyst for an unprecedented momentum to manage climate-related risks in the financial sector. As the Governor of the Bank of England, President of the Financial Stability Board and First Vice-Chair of the European Systemic Risk Board, Mark Carney has been the first leading financial Figure to raise explicitly attention of every financial institutions on their exposure to physical climate, transition and liability risks (Carney, 2015). He has also pointed out the necessity to address these risks with specific forward-looking analysis. While his arguments on the long-term nature of these risks and their systemic component suit a supervisor's point of view, the following momentum is of interest to every financial decision-makers.

Recognizing the importance of climate-related information gap, the FSB subsequently launched the TCFD (Task Force on Climate-related Financial Disclosure) in December 2015. One year and a half later, the working group released their final recommendations on the disclosure of climate-related information for the use of financial institutions. This provides an internationally recognized discussion framework for both physical climate and transition financial impacts.

Other public decision-makers have pushed for the development of climate-related risk analysis at financial institutions at various scales, and this pushes the reporting on climate risks for financial institutions. At the international level, the Paris Agreement signed at COP21 in December 2015 sets explicitly the objective of finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development. Recommendations of the FSB's TCFD have received support from States, companies and coalition of institutional investors at the One Planet Summit in December 2017. At the European level, in March 2018, the European Commission also issued an Action Plan on Financing Sustainable Growth building on the recommendations of the High Level Expert Group on Sustainable Finance launched in December 2016. That Action Plan supports corporate reporting in line with the TCFD. At country level, in France, the 2015's Energy Transition for Green Growth Act (Article 173) also requires larger investors to report on their exposure to physical climate risks. The government will assess the progress on reporting after the second reporting exercise in 2018.

Within the financial system, Central Banks and financial Supervisors are joining efforts in a network to share methods and best practices to address climate risk.** During a meeting of this network in April, François Villeroy de Galhau the Governor of the Banque de France stated that physical climate risk is a visible and immediate source of risk for the financial sector, and called for its careful monitoring. A number of financial institutions, such as multilateral development finance institutions, contribute to initiatives that also contribute to build capacity on climate-related risks (see for example the EUFIWACC Working Group at the European level (EUFIWACC, 2016) or the GARI Working Group at the international level (GARI, 2017)).

This momentum increases the need for financial institutions to develop thorough analysis of physical climate risks in their portfolios.

* Liability risk refers more specifically to the insurance industry. The ClimINVEST consortium treats this risk as part of both physical climate and transition risks.

** Constituted at the One Planet Summit in last December, the "Central Banks and Supervisors Network for Greening the Financial System" may deliver a first report in 2019.

# Methodology

I4CE has carried out a general mapping of existing climate services targeting financial actors, based on bilateral discussions with financial actors and a review of public information on financial actors' analyses of their exposure to physical climate risks.

The identified methodologies, tools and services were analyzed in depth, through desk review of available documents on these approaches (mostly grey literature) and interviews with each service providers that could be identified during the first stage of general mapping. Detailed information on each approach is available in the annex of this report and has been sent for review to involved service providers.

Finally, these different approaches have been compared in order to identify similarities and differences, and preliminary recommendations are provided on next steps for developing climate services aimed at financial actors, which will be further analyzed within ClimINVEST.

# 1. The need for specific approaches to analyze physical climate risks in finance

Characterizing physical climate risk to a financial institution represents a specific challenge. It involves a broad perimeter of climate and socio-economic aspects at various scales and horizons, as will be explained in section 1.1. Managing this complex exposure requires specific analytical approaches to provide actionable and relevant information for different decision-making processes, as explained in section 1.2.

**KEY MESSAGES OF SECTION 1**

- Physical climate risks are the potential impacts (positive or negative) of climate hazards on a financial institution or their counterparties.
- Physical climate impacts are occurring now and will continue to increase in the near term regardless of GHG emission scenarios.
- Physical climate risk arises from climate change hazards, in the form of gradual change (*e.g.* in wind, temperature and precipitation patterns, as sea level rise) or change in frequency and intensity of climate events (*e.g.* hurricanes).
- The direct exposure of a counterparty's or financial institution's operation (through physical assets, labor or dependence to natural resources) may represent only a fraction of their exposure to the risk. Consequences of climate change to a counterparty may also arise from exposure of its value chain (*i.e.* supply chain and market) or through consequences in the macro business environment (*e.g.* raise in insurance premiums).
- Net impacts to a counterparty depend on its sensitivities to a type of hazard and on its capacity to adapt to this hazard.

## 1.1. Financial actors are already exposed to complex physical climate risks

### 1.1.1. Climate change triggers hazards in the form of weather trends and amplified extremes

Intensified economic activities since the industrial era have led to unprecedented levels of greenhouse gas (GHG) emissions that increase the temperature of the global atmosphere. This triggers a **climate change** that surpasses the pace and extent of natural climate variability.[1]

Climate change causes **physical climate hazards**. They are conditions with potential adverse consequences on given systems of interest, such as the environment, the economy or humans. The IPCC definition of climate hazards includes both the change in climate events or trends and their "physical impacts" (Agard *et al.*, 2014).

"Physical impacts" according to the IPCC are impacts of climate change on geophysical systems, including floods, droughts, and sea level rise. These phenomena are complex since they are the combination of climatic variables with climatic or non-climatic variables. For example, long-term sea level rise may arise as the combination of two climatic variables: land ice melting and the thermal expansion of waters (Church *et al*, 2013). Landslides may also arise from combination of extreme precipitations (climatic variable) and other variables such as the morphological setting, *i.e.* the land is a mountain, hill, etc. (non-climatic variable) (Gariano and Guzzetti, 2016). In addition, the phenomena may combine and generate aggravated conditions (*e.g.* sea level rise can amplify the effects of storms).

**Figure 3** below summarizes simple and complex climate phenomena (including "physical impacts" of climate change as defined by the IPCC), adapted from Cicero (2017).

1 The climate and the weather are two different things, so do climate risks and weather risks. **The weather** is the conditions of the atmosphere or, even more simply, the conditions of the air in a particular time and location. The description and analysis of such weather events on a short period (*i.e.* on the order of days) is the domain of meteorological sciences. **Climate** describes the statistical distribution of weather phenomena over long periods. In other words, the weather is what you get in a specific date and geography whereas climate is what you expect over time and in large geographies. Characterizing the climate, which is the aim of the climatology sciences, requires to account for a broader "climate system" to explain how the energy flows around the globe in the longer-term, and how it influences the statistical distribution of the weather, that is, the climate.

Research by Cicero shows that extreme weather and physical changes are already happening and are going to increase in the next decade (Berg *et al*, 2018). For example, since the 1950's, the global scientific community has observed change such as lower cold temperature extremes, higher warm temperature extremes, increase in extreme high sea levels and increase in the number of heavy precipitation events in a number of regions. They link these changes to human influences (Pachauri *et al*, 2014). Other extreme weather and climate events such as heat waves or droughts are increasingly linked with human-induced global warming (Stott, 2016). The gradual change and the rise of frequency and intensity of many extreme events will continue. The surface temperature is projected to rise over the 21st century according to all of the IPCC projections. According to the IPCC, it is very likely that heat waves will be more frequent and last longer and that extreme precipitation events will become more intense and frequent in many regions. The global mean sea level will also continue to rise (Pachauri *et al*, 2014). Thus, there is clear evidence that climate change is leading to more frequent and extreme weather events, as well as gradual changes in average weather patterns.

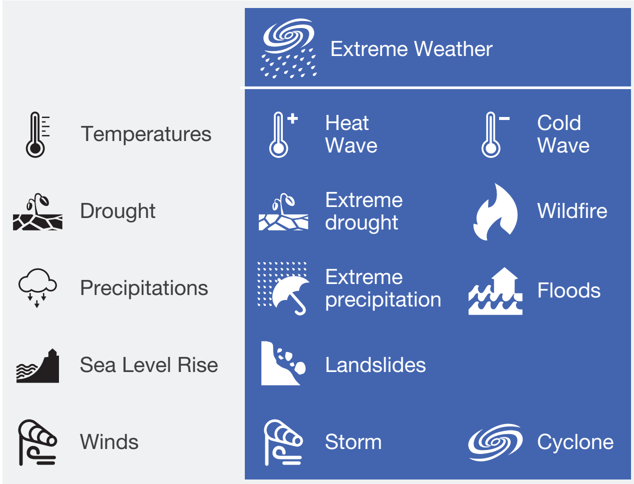
### 1.1.2. Physical climate hazards expose economic agents to physical climate risks

**Physical climate hazards may impact the financial performance of economic actors both directly and indirectly**

Physical climate hazards trigger a range of impacts. As shown on **Figure 4**, one specific economic agent (state, company, project, individual) may undergo **direct** impact from a climate hazard on its assets, such as the destruction of buildings or a production downtime due to flooding, or loss of labor productivity. It may also undergo **indirect** impact through its value chain or through its macro environment in many ways.[2] These direct and indirect impacts on the production environment of the counterparty may result in a range of financial impacts (TCFD, 2017; *Direction Générale du Trésor*, 2017).

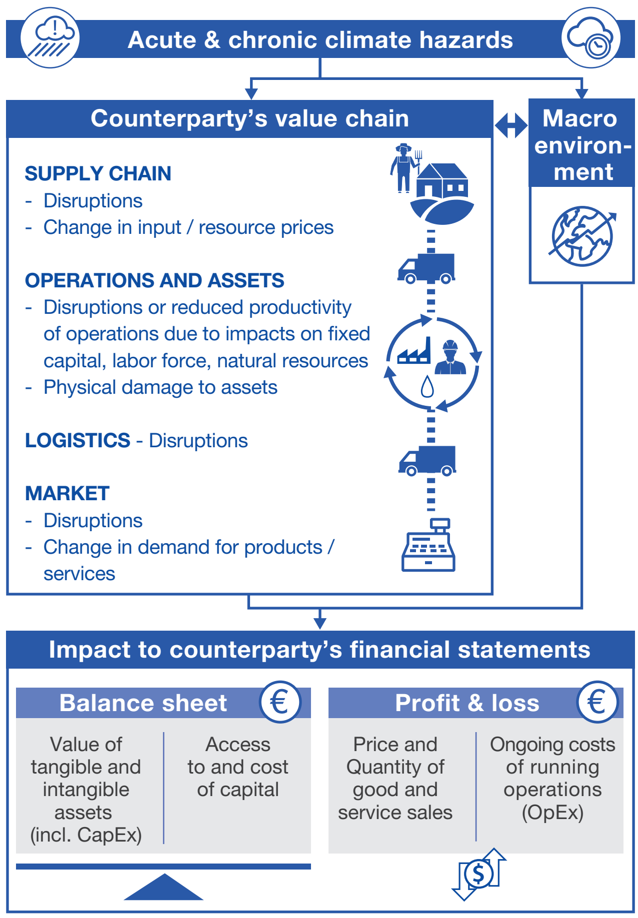
2 'Macro' conditions define the broader business environment of the counterparty. They comprise socio-economic aspects including for instance macroeconomic, political, financial, sociological or technical conditions. These conditions may affect the resilience of the broader business environment to climate change impacts, with potential consequences on the counterparty. A recent report by the Bank of England provides examples of macroeconomic risks from climate change in terms of demand (through investment; consumption and trade) and supply (in terms of labour supply; energy, food and other inputs; capital stock and technology) (Batten, 2018).

**FIGURE 3. ILLUSTRATIVE LIST OF CLIMATE-RELATED CONDITIONS**




*Source: Authors, adapted from Cicero (2017) "Shades of Climate Risk. Categorizing climate risk for investors"*

**FIGURE 4. PROPAGATION CHANNELS OF CLIMATE CHANGE IMPACTS TO THE REAL ECONOMY**




*Source: Authors (2018)*

## The potential consequences of physical climate hazards are called physical climate risks

The potential consequences of physical climate hazards on people, the economy and the environment detailed above are the so-called "**physical climate risks**" (see Box 2).

The TCFD separates physical climate risks in two categories. A physical climate risk is **acute** when it is event-driven. Concretely, it includes the change of frequency or magnitude of extreme events (*e.g.* cyclones, heatwaves, storms). A physical climate risk is **chronic** when it refers to persisting changes in mean and variability of climate patterns (*e.g.* sea level rise; change in mean temperature patterns, with chronic heatwaves at the end of the spectrum) (Source: adapted from TCFD (2017)).

For analytical purposes, physical climate risk is usually broken down in several components. Components used and their meaning is not stable across communities and over time (Gallopin, 2006). Equations 2 and 3 and the paragraphs below present the formulas and definitions on the analytical components used in this report.

**Hazard** is the potential occurrence of the trend or event that has adverse consequences to the system. It may comprise a description of the likelihood and magnitude of the event or trend.

**The exposure** is the presence of the system of interest in a place and setting that could be adversely affected by a hazard.

**The vulnerability** describes the propensity or predisposition of the system to suffer adverse consequences from its exposure to the considered hazard. The same hazard may trigger different ***sensitivities*** in the system, leading to adverse consequences. **Sensitivity** may depend on a range of factors. For example, when climate change affects production inputs from one major supplier, the company will be more sensitive if it has a weak bargaining power such that the supplier can pass his cost through to the company. The net hazard consequence however may be lower thanks to the adaptive capacity of the system.

**Adaptive capacity** represents the total potential of the system to adjust to the potential hazards or to respond to their consequences. This potential depends on the availability of resources for the counterparty to address considered hazards. When referring to short-term survival, one may talk more specifically about ***coping capacity***. When referring more broadly to the capacity to adapt to current but also evolving hazards overtime, with a focus on maintaining critical functionality of the system, one may talk about ***resilience***. Such capacities are not static overtime and across contexts.

**BOX 2. PRECISIONS ON THE DEFINITION OF RISK USED IN THIS REPORT**

The definition of the term "risk" by scientists, financial practitioners and "industrial" risk professionals slightly differs. Therefore, we need to clarify how we conceive "risk" in this report.

**Risk is the potential consequences (positive or negative) arising to a specific system – such as an ecosystem, a company, a country - exposed to a hazard, and depends on the specific vulnerability to this hazard of the system assessed.**

**EQUATION 2. BREAKDOWN OF RISK IN ANALYTICAL COMPONENTS (1)**

$$\text{Risk to the System} = \text{Hazard } \textit{(likelihood x magnitude)} \times \text{Exposure} \times \underbrace{\text{Vulnerability}}_{(\text{Sensitivity} \; - \; \text{Adaptive capacity } \textit{(coping capacity; resilience)})}$$

*Source: Authors (2018)*

**EQUATION 3. BREAKDOWN OF RISK IN ANALYTICAL COMPONENTS (2)**

$$\text{Risk to the System} = \text{Likelihood of hazard} \times \text{Impacts}$$

*Source: Authors (2018)*

1. THE NEED FOR SPECIFIC APPROACHES TO ANALYZE PHYSICAL CLIMATE RISKS IN FINANCE

The counterparty can also take actual **adaptation** measures that reduce the hazard, the exposure or the sensitivity of the counterparty. Adaptation can occur in many ways, in anticipation of or reaction to the occurrence of hazards. One example of adaptation to physical climate risk is the transfer of the risk of loss to another agent. This is the case of insurance policies.[3]

**Impact** refers to the negative consequences of a hazard exposure that triggers a specific aspect of the system's vulnerability (*i.e.* one hazard may trigger several aspects of vulnerability and thus several impacts to the system).

### 1.1.3. Financial actors are exposed to physical climate risks through several propagation channels

The potential consequences of physical climate hazards (*i.e.* climate change impacts) may propagate to the financial sector in diverse ways. In the same way as the propagation of impacts to the real economy, physical climate hazards may propagate directly to financial actors in the form of operational risk, for example due to damages to facilities. More importantly, they may also propagate through exposure of the financial sector to the real economy (*e.g.* households, companies, countries).

The hazard to the financial actor arises when counterparties suffer climate change impacts that jeopardize their capacity to pay back loans, provide dividends or impact their valuation.

Physical climate risks then increase usual risks to which financial actors are exposed.

Physical climate risk may translate into increased credit risk[4] for banks, when potential climate change impacts to the counterparty reduces the creditworthiness of counterparties (Direction Générale du Trésor, 2017). Physical climate risk may also translate into increased market risk – *i.e.* risk arising from financial markets, such as a change in equity price – for example if markets have not already priced adequately some potential adverse impacts of climate change on equity prices, which may trigger high volatility or a downward shock on market values when some events create awareness of these risks. Finally, liquidity risk[5] may also arise due to an abrupt repricing of physical climate risk on financial markets.

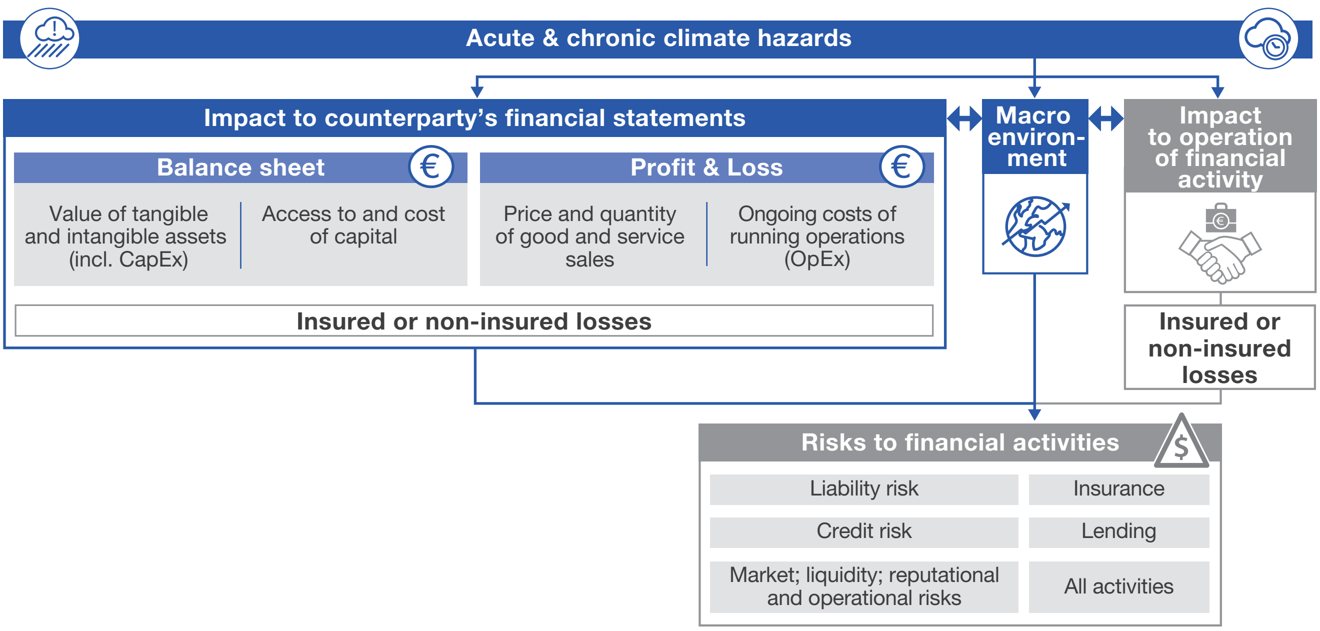
**Figure 5** is limited to the primary propagation channels of climate-related impacts to the financial sector and it hides further complexity. There is a porosity between the financial

3 For more information about the components of risk and the types of adaptation, see the thematic glossary in **Annex 1** of this report.

4 Credit risk is "the risk of an economic loss from the failure of a counterparty to fulfill its contractual obligations, or from the increased risk of default during the term of the transaction" (Crouhy *et al*, 2014).

5 Liquidity risk refers to the ability to make cash in a satisfying manner and applies to all financial actors. It often refers to "trading liquidity risk". This is "the risk that an institution will not be able to execute a transaction at the prevailing market price because there is, temporarily, no appetite for the deal on the other side of the market" (Crouhy *et al*, 2014). Liquidity risk may also refer to "funding liquidity risk" that "relates to a firm's ability to raise the necessary cash to roll over its debt; to meet the cash, margin and collateral requirements of counterparties; and to satisfy capital withdrawals" (Crouhy *et al*, 2014).

**FIGURE 5. SIMPLIFIED PROPAGATION CHANNELS OF CLIMATE CHANGE IMPACTS TO THE FINANCIAL SECTOR**




*Source: Authors (2018)*

sector and the real economy, for example with companies owning security portfolios. Impacts are not necessarily unidirectional from the real economy to financial actors. Finance may impact the real economy (through cost of and access to capital or financial tools for risk management such as insurance policies). There are also second round effects between and within finance and the real economy that may expand or mitigate final impacts to financial actors. Physical climate risks to financial actors is an "emergent risk", meaning that it propagates through complex channels revealing interdependencies in the system (Agard *et al*, 2014).[6]

Since present and future physical climate hazards cannot be totally avoided, financial actors may incorporate this issue in risk management, as the current momentum on climate risks in finance seems to lead to. To do so, the first step is to measure the physical climate risks of their portfolios.

## 1.2. Financial actors need specific assessment methodologies for their physical climate risk analysis

### 1.2.1. A vast pool of studies and tools provide some information for physical climate risk analysis

A vast array of studies and tools help analyzing physical climate risks to financial actors, without providing complete and targeted analysis. We provide below an overview of this vast universe.

Several approaches may be useful to proceed the analysis of physical climate risks for financial actors. Their contribution to the analysis may be straightforward or require further processing depending on the need at the financial institutions. They may provide information on one or several aspects of risk (*i.e.* hazards; exposure; sensitivity; adaptive capacity), and focus on environmental, socio-economic or financial impacts. This array of interesting approaches can be categorized as follows:

- **Efforts to understand the propagation channels of physical climate risks:** As explained in section 1.1.2 of this report, the momentum on climate-related risks in finance in 2015 has triggered significant efforts to identify how climate-related events may propagate to the financial sector.
- **Methodological guides to analyze the physical climate risk to a specific entity:** For instance, the French Environment and Energy Management Agency has released some guidance to analyze the impacts of climate change on a territory to the use of territorial agents.
- **Data, indicators and models to feed physical climate risk analysis to financial actors:** Several approaches exist to produce data on physical climate impacts to an entity. This can be done with studies on observed impacts of physical climate hazards on a given entity, or by combining separate data on climate hazards and on the entity's specific points of vulnerability. A range of models may also serve to identify physical climate risks in a forward-looking manner (concerning the future climate or the future of socio-economic systems and their interaction). The scientific literature has developed significant material on all of these aspects in three overlapping fields: Climate models, Integrated Assessment Models (IAM) and the field of Impacts, Adaptation and Vulnerability (IAV) as depicted in Moss *et al* (2010). The IPCC's second Working Group has made periodic Assessment Reports on the evolution of this knowledge worldwide, with sectoral and regional considerations.
- **Further processing of data and analytical frameworks:** Composite indexes are one way to proceed information. For instance, the Notre-Dame Global Adaptation Initiative developed the ND-GAIN Country Index to summarize a country's vulnerability to climate change and other global challenges in combination with its readiness to improve resilience (Chen *et al*, 2015). Financial actors may use it as a final information or as an intermediary indicator. Data can also be processed in diverse analytical frameworks that focus on one or several aspects of physical climate risks with different media.

The academic literature also provides broader directions that are of interest to frame physical climate risk analysis. Indeed, it calls for considering an array of risk analytical frameworks that is larger than prevailing frameworks in finance. Some of the prevailing metrics in finance do not capture all of the aspects of risk (Artzner *et al*, 1999). This might be a problem since the risk metric is sometimes taken as a definition of risk itself, instead of an instrument to measure risk. More broadly, the prevailing rationale for risk decision-making in the form of optimal decision is not the only rationale available. Approaches such as robust decision-making propose alternative ways to account for uncertainties that are a key aspect of physical climate risks (Kunreuther *et al*, 2014).

### 1.2.2. Financial actors need climate risk information that fits into their existing risk management frameworks

Physical climate risk information to financial actors needs to be relevant in the context of a broader risk management process, with specific constraints.

Financial institutions – and the financial system more broadly – have therefore comprehensive risk decision-making process and risk analysis frameworks in place that inform

6 For example, Batten *et al*. (2016) shows key interactions between the insurance and banking systems in the propagation of physical climate risks to these systems.

risk management strategies, in which physical climate risk analysis should aim to be integrated.

Financial actors have a diverse understanding of what risk is, depending on their activities. To reflect these different understanding of risks, financial actors use a wide range of risk analytical frameworks.

Risk analysis in finance is presented frequently as a quantitative process with a range of metrics, such as the beta of an asset (correlation between the asset's variability of return and the market's variability of return), Value at Risk (VaR) (maximum potential loss to the analyzed entity within a given time horizon and with a given level of confidence). Such quantitative metrics are typically based on historical data.

Risk analysis in finance can also be forward-looking to a certain extent, notably in stress-testing exercises. Stress testing analyzes the resistance of an entity to an extreme but plausible scenario.

Qualitative risk analysis approaches also exist in financial practices. The example of Environmental, Social and Governance (ESG) risk analysis is salient in the context of this report. This framework has applied primarily in the context of corporate social responsibility and responsible investment. The analysis often yields qualitative indicators that may combine diverse aspects of environmental, social and governance factors.

Finally, financial actors require climate risk analysis that fits their existing frameworks and that is detailed over a large number of counterparties. This motivates the need for tailored physical climate risk analysis to financial actors. How do existing approaches address this specific need? Next sections of this report provide a mapping of existing approaches that target physical climate risk analysis for financial actors. It analyzes the perimeter and choices to address the need for tailored information.

# 2. A mapping of existing approaches to analyze physical climate risks in finance

**KEY MESSAGES OF SECTION 2**

Financial actors are getting aware of physical climate risks but they may not be necessarily integrating it in decision-making processes. The first actions on risk analysis are exploratory, and often rely on external service providers.

Service providers have developed heterogeneous and generally privatized 'fee-for-service' approaches that financial institutions are starting to use as they explore physical climate risk analysis:

- The available approaches of physical climate risk analysis dedicated to financial actors provide either qualitative scores on the counterparty's level of risk or estimates of potential cost or value impacts. They provide diverse coverages and levels of detail in terms of: hazard; use of climate scenario; time horizon; type of impact; counterparty.
- They currently face difficulties to address the exhaustive range of climate risks, and to provide at the same time detailed and specific analysis for each counterparty. This results in concentration of efforts on diverse hazards (typically acute hazards) and types of impacts.
- Limited availability of counterparty-specific data results in partial or sectorial-level analysis of some impacts to the counterparty:
  - While exposure of operations and downstream value chain is always detailed at a counterparty-specific level (with data on fixed capital and sales, at latitude/longitude scale or country scale), supply chain exposure is always assessed using sectoral data – and the macro context is seldom explicitly addressed;
  - Sensitivity is always assessed at a sectoral level; it could benefit from micro information specific to each counterparty, as well as macro information on the business environment;
  - Adaptive capacity is not addressed in the methodologies studied in this report due to the lack of available information.

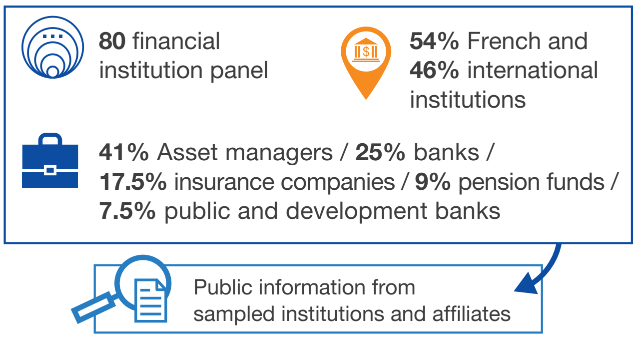
Forward-looking analysis starts to be integrated on long-term climate aspects but not yet on socio-economic aspects with larger uncertainties.

## 2.1. Review of financial practitioners' approaches to physical climate risks

As a first step to analyze what is the state-of-the-art of methodologies of physical climate risk assessment available for financial actors, the authors carried out a review of information provided on physical climate risks by financial institutions.

### 2.1.1. The sample and data collection

A sample of 80 financial actors were analyzed (43 based in France and 37 based in 15 other countries in Asia, Northern America and Europe) through a review of public information available online. Our sample is composed of 41% asset managers, 25% banks, 17.5% insurance companies, 9% pension funds and 7.5% public and development banks.



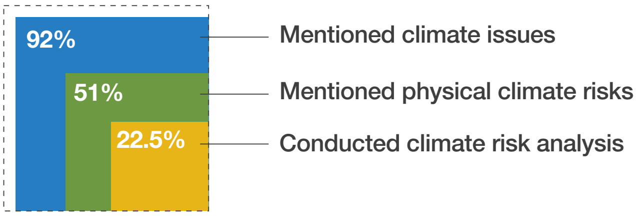

The documents reviewed were publicly available annual reports, extra-financial reports, environmental and climate stewardship online documents, article 173 compliance reports, risks policy reports, as well as institutional communication and publications from dedicated research centers affiliated with a financial actor.

Annex 2 of this report provides the names of sampled financial institutions and links to relevant documentation reviewed.

### 2.1.2. Climate reporting dynamic goes mainstream while climate risk analysis is emerging

**If the climate disclosure dynamic has become almost mainstream for financial players, the climate-risk approach is still emerging.**

Among the tested actors, 92% publish information about climate, 51% mention physical climate risks, and 22.5% had conducted a climate risk analysis.




Results from the whole panel study also show the dynamics of financial actors regarding physical climate risk analysis:

- **No information**: for 48% of the panel, no physical climate risk analysis is to be found, or the analysis is considered impossible to conduct;
- **Physical climate risk factors taken into account qualitatively in ESG analysis**: 20% of the panel did not conduct an ad-hoc study to measure their exposure to physical climate risk, however they recognize the importance of this risk and they take it into account in their ESG analysis. Physical climate risk is, for these actors, criteria that should be integrated in a risk policy, to complement the investment decision. Here, physical climate risk is either considered as "an operational risk"[7] or "not a new category of risks but an aggravating factor of the types of risks taken into account in the risk management system (and particularly credit, operational risk, and risk related to insurance activities)"[8];
- **Analysis to be developed in the years to come**: 10% of the panel recognizes the need for a physical climate risk analysis and indicate their will to develop this type of approach in the years to come;
- **Physical risk analysis**: 22% of the panel conducted a physical risk analysis with various approaches.

7 https://www.cmcic-am.fr/fr/particuliers/notre-presentation/qui-sommes-nous/pdf/ESG-article-173.pdf

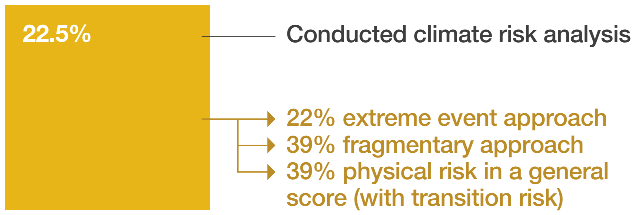
8 https://www.societegenerale.com/rapport-rse/files/SG-RSE2016-2017-FR.pdf

### 2.1.3. Exploration of physical climate risk analysis translates into diverse approaches

**On the limited panel of actors who conducted a physical climate risks analysis, we can note the experimental nature of the exercise. Information is mostly qualitative and produced following heterogeneous methodologies.**

Most of the physical risk analyses are qualitative and do not provide figures. The physical risks exposure is often qualified as less important or less relevant compared with the exposure to transition risks. Qualitative analysis can be presented in a map of investments at risks[9], or in a graph with sectors or companies at risks and weather sensibility[10]. When there are quantified data, the amplitude of results varies widely, ranging from zero assets[11] (destruction or decommissioning assets exposed to physical risk – drought, floods – or operational disruption), few buildings[12] to 15 million euro worth assets[13] (through the modeling of destruction rates of a centennial storm).

Considering only financial players who conducted such analysis of physical climate risks of their portfolios, we can classify the approaches used along the following typology:




- **Fragmentary approach**: 39% of actors who conducted a physical risk analysis chose to limit the exercise to a part of their portfolio. Some actors -mostly insurers and reinsurers- tested their real estate portfolios for a certain type of risks: floods and drought risk[14], floods and storms[15] and floods and extreme events[16][17]. An insurance

9 https://institute.eib.org/wp-content/uploads/2017/05/SciencePo-Presentation-v.1.pdf

10 http://www.fondsdereserve.fr/documents/Rapport-2016-article-173-Ite-2.pdf

11 https://www.cmcic-am.fr/fr/particuliers/notre-presentation/qui-sommes-nous/pdf/ESG-article-173.pdf

12 https://www.ca-assurances.com/espace-investisseurs/rapports-extra-financiers-0

13 https://www-axa-com.cdn.axa-contento-118412.eu/www-axa-com%2Ff570ad25-6178-47a0-afb9-59a5b7d3d70a_changementclimatique_rapport_risqueinvestissement_vf_30.08.17-b.pdf

14 http://institutionnel.generali.fr/sites/default/files/rapport_art_173_fr_vdef_12.05.17_com.pdf

15 https://www.aviva.fr/documents/corporate/nous-connaitre/rapports-annuels/RAPPORT_ESG_CLIMAT_VDEF-compresse.pdf

16 https://www.covea.eu/wp-content/uploads/2017/07/rapport_esg_covea_finance-1.pdf

17 http://www.novethic.fr/fileadmin/templates/novethic/img/static/colloque-2017/RIR-2016-CNP-Assurances-VF.pdf

company conducted an **experimental analysis**[18], focusing on the physical exposure of 8 assets, total worth of €1bn: 4 buildings and 4 infrastructures projects. This experiment should enable to test the assessment method, before further development.

- **Extreme events approach**: 22% of this limited panel have conducted a physical climate risk analysis, however limited to the scope of extreme events (*i.e.* excluding chronic risks).
- **Physical risk expressed as a dedicated or broader rating**: 39% of actors that have undertaken a physical climate risk analysis have chosen to use an index or a score to disclose their exposure to physical climate risk. This notation calculates either global climate risks (transition and physical risks) or physical risk only. The methodology employed is detailed for five institutional investors. The indexes are mostly produced by external providers, who combine indices of sectoral and geographical vulnerability.

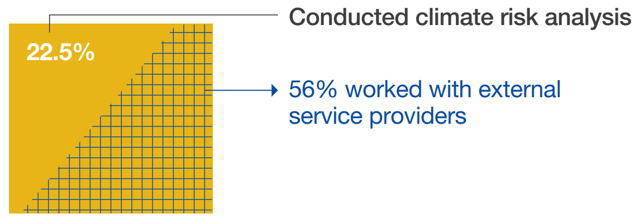
The different approaches are fragmented and do not aim for completeness, some are only focusing on operational risk, or real estate assets, choosing an extreme event scope, or analyzing only the exposure to floods and drought. Only two actors had already implemented the TCFD recommendations for their 2017 report and included the use of scenarios in their climate risk analysis.

Yet, almost all financial actors acknowledge that methodologies for physical climate risks are still under development and that their analysis will be (further) developed in the future.

These findings are compatible with analyses carried out on other samples of financial institutions by Novethic (2017)[19]; EY (2017)[20]; WWF (2017)[21], the Shift Project (2017)[22] and Four Twenty Seven.[23]

### 2.1.4. Most financial practitioners use external services to analyze physical climate risks

**On the limited panel of actors who conducted a physical climate risks analysis, more than half (56%) used external services, and for those who have chosen internal analysis, only two actors detailed their methodology.**




Twenty of them (56%) have used external services for their analysis. We have identified that their analysis builds on data from:

- climate service providers: Trucost, Four Twenty Seven, Carbone 4, Indefi, Clim'Pact were cited;
- research projects: including ND-Gain index, Sciences Po group project;
- or conclusions of reports from supervision authorities (ACPR).

Only six financial institutions that have conducted a physical climate risks analysis used an internal model (mostly insurance companies). Internal methodologies are not detailed, except for two insurance companies:

- One has developed a methodology to analyze the impacts of physical risks on its real-estate portfolio. It only takes into account storms and floods as physical climate hazards, which represent the most frequent extreme weather events on the concerned territory. The analysis covers EUR3.6 billion of real estate assets, for the vast majority located in France. The model uses information such as the location of the property, its type of occupancy and the nature of the building, to determine a potential weather-related event loss corresponding to an extreme event occurring once every 200 years.[24] Results of this analysis are expressed in euros and in a percentage of total portfolios value.
- The second insurance company is doing its physical risk analysis internally for its real estate and infrastructures assets. The analysis of the real estate portfolio is based on a qualitative analysis of the typology of real estate assets, their date of construction or renovation, their geographical location and finally the existence of an energy label. With this methodology, results are expressed in levels of risks: low, medium or high. For their infrastructure

18 https://www.ca-assurances.com/espace-investisseurs/rapports-extra-financiers-0
19 https://www.novethic.fr/fileadmin/user_upload/tx_ausynovethicetudes/pdf_complets/173-nuance-de-reporting_web.pdf
20 http://www.ey.com/Publication/vwLUAssets/ey-how-have-investors-met-their-esg-and-climate-reporting-requirements-under-article-173-vi/$FILE/ey-how-have-investors-met-their-esg-and-climate-reporting-requirements-under-article-173-vi.pdf
21 https://www.wwf.fr/sites/default/files/doc-2017-11/281117_Etude_Des_e%CC%81pargnants_lost_in_translation.pdf
22 https://theshiftproject.org/article/rapports-article-173-annee-zero-lassurance-vie-collectivement-en-marche-vers-une-meilleure-prise-en-compte-du-risque-climat-selon-lobservatoire-climat-assurance-vie-du-shift/
23 http://427mt.com/2018/03/21/art-173-lessons-learned-climate-risk-disclosures-france/
24 https://www.aviva.fr/documents/corporate/nous-connaitre/rapports-annuels/RAPPORT_ESG_CLIMAT_VDEF-compresse.pdf

portfolios, their methodology is an analysis of each of the 48 projects held. The assessment considers the typology of the infrastructure and its geographical location. The risk assessment model is based on impact databases from international sources (such as US Climate Resilience Toolkit, Notre Dame Global Adaptation ND-GAIN Index, UNU-EHS World Risk Report, German Watch - Global Climate Risk Index). Results are presented in a table crossing the probability and the severity of the risk, each divided into three levels (low, medium, high) and each project is mapped between these two scales.[25]

This review shows that financial actors are mainstreaming climate issues in their reporting, however they only start exploring physical climate risk analysis. Most of them currently rely on external service providers to carry out the analysis. Thus, it is relevant to map especially the type of information that service providers produce on physical climate risk analysis for financial institutions.

## 2.2. Scope and methodology of the detailed analysis of specific approaches

### 2.2.1. Specific approaches targeting physical climate risk analysis for financial institutions

The scope of this state of the art report is a specific universe. It consists of the **existing approaches** that target **directly financial institutions' needs** for the **analysis of physical climate risks** to their **portfolios**. We detail below what this means for the selection of approaches.

Concretely, the term "**approach**" covers every type of methodologies and tools aimed at helping financial institutions assess physical climate risks of their portfolios. **Existing** approaches means that selected approaches were available for use at the time of collecting data.

The scope of approaches does not target the use at specific **financial institutions**; however, it targets usefulness to investment and lending activities (excluding insurance coverage business). This mapping focuses on approaches that are useful for **risk analysis**. Therefore, it excludes those approaches that focus on the broader risk decision-making process (*i.e.* it excludes approaches that specifically question risk decision-making frameworks or tools that support risk management decisions).

This mapping focuses on approaches that are of **direct use** for the analysis at **portfolio level**. Therefore, the approaches of this mapping provide aggregate indicators at the scale of a counterparty, which is necessary for financial actors to carry out the analysis in large portfolios involving multiple counterparties, or directly at the scale of a portfolio. The approaches also analyze the link between physical climate hazards and the vulnerability of the counterparty. Ideally, they cover an array of physical climate hazards. In practice, some approaches focusing on different aspects of water risk are also included in the mapping (*e.g.* WRI and Trucost). The rationale is that the underlying methodologies involve climate scenarios and they can be combined to provide a link between water-related hazards and vulnerabilities of the counterparty.

### 2.2.2. Service providers develop most of the identified approaches

The selected perimeter of approaches leads to review the initiatives of a number of actors: academics, financial actors, service providers, etc.

In practice, due to the perimeter of this report, we consider a limited number of approaches developed in the academic literature. Dietz *et al* (2016) is the academic paper that fits best the target of this report, that is, actual physical climate risk analysis to financial institutions. It provides a macro approach to the value at risk from climate change on global financial assets. The academic literature has also provided more general frameworks that will be mentioned in the course of this report when talking about tales of future weathers. More generally, this review mentions reports and articles from the academic and grey literature, as long as they help frame concretely risk analysis for financial actors. This can be analytical frameworks or guidelines.

Service providers currently appear to be the main developers of physical climate risk analysis for financial actors. According to our review of financial institutions' practices (section 2.1), financial institutions are only starting to explore physical climate risk analysis. A limited pool of institutions implemented first exercises of physical climate risk analysis and more than half of them relied on external service providers (in terms of data or tools). Among the institutions who did not call for external services, only two of them developed their own internal models, including an insurance company. While insurance companies may have large analytical capacities, this report does not review how their models develop such approaches, as explained in **Box 3**. These aspects motivated the authors of the report to focus in priority on Service providers. Such approaches often come in the form of analytical frameworks or tools with concrete outputs for risk analysis and using various types of media.

25 http://www.malakoffmederic.com/groupe/blobs/medias/s/326248d416e00eb7/Rapport-RSE-Malakoff-Mederic-2016-VFext.pdf

**BOX 3. THE CASE OF THE INSURANCE INDUSTRY**

The insurance industry provides insurance policies where compensation might arise in case of catastrophes. As such, insurance companies are likely to have large analytical capacities on natural processes, starting with data collection.

In terms of methodologies, insurance companies carry out highly sophisticated risk analyses based on actuarial science. This report does not address the technicity of insurance analytical tools, which may require specific in-depth research. As a comment, one major focus of insurance is to price pure risk. This means that the analysis relies on the identification of objective distribution of losses, typically through past data. The insurance industry has made also progress in analyzing catastrophes that are rare and extreme events (and thus it is difficult to draw a probabilistic distribution on them). However, it is still difficult to integrate projections of future climate impacts in insurers' analysis because of uncertainty. For instance, the Lloyd's (2014) reports that catastrophe modelling is only able to account implicitly for past effects of climate change, due to the use of past observations. Catastrophe modelers typically do not integrate climate scenarios to catch impacts from future climate change. (Lloyd's, 2014).

As a result, this report provides analysis of existing approaches that service providers built and made available on the market, as detailed in **Table 2.**[26 27] Please note that this analysis only covers approaches from service providers that responded to our call for interview. Also note that authors of this report aimed at providing the most comprehensive analysis as possible, but that some approaches may have been – not purposely – missed. This mapping exercise provides an instant picture of the approaches that were available as of early 2018.[28] With the current momentum on climate risk analysis arising from the TCFD recommendations, we acknowledge that a number of approaches are currently under development or under improvement.[29]

### 2.2.3. Data collection methodology

The initial strategy for data collection builds on online information to identify the streams of literature, relevant reports and available approaches. An important amount of additional information was collected from service providers who kindly accepted to answer the questions of the authors during a bilateral interview process. **Annex 3** of this report comprises recapitulative tables for each of the approaches we explored in-depth. These recapitulative tables can be useful for any person who is willing to learn more about a specific approach. The tables are the final result of the interview process and of the written material that the service providers shared with the authors. The service providers gave consent to release these tables.

Interviews with other stakeholders have provided valuable information on the state of approaches to analyze physical climate risks.

**TABLE 2. LISTING SERVICE PROVIDERS WHOSE APPROACH WAS ANALYZED IN DEPTH FOR THIS REPORT**

| Service Provider | Approach |
|---|---|
| Acclimatise | Aware for Projects |
| Carbon Delta | Climate VaR |
| Carbone 4 | CRIS |
| Ecolab, Trucost and Microsoft | Water Risk Monetizer |
| Four Twenty Seven | 427 Climate Risk Scores (Company, Sovereign and Muni Risk Scores, Real Assets On-demand Scoring) |
| Mercer | TRIP framework |
| Moody's Investors Service | Physical Effects of Climate Change on Sovereign Issuers |
| WRI | Aqueduct Water Risk Atlas |

*Source: Authors (2018)*

26 Some service providers also carry out physical risk analysis in the frame of specific studies that are not covered in the frame of this report. For instance, Ecofys worked with the DNB on physical climate risks in the Netherlands, and part of the results are publicly available in the DNB's 2017 "Waterproof?" report.

27 For brevity, this report provides examples on the selected approaches by mentioning the name of the service provider. When the Water Risk Monetizer is concerned, "Ecolab, Trucost and Microsoft" are mentioned shortly as "Trucost".

28 Therefore, this report does not cover in detail the results of the Acclimatise and UNEP-Fi's report "Navigating a new climate" that was published in July, 2018.

29 For instance, Beyond Ratings is developing a Sovereign Risk Monitor. It aims to enhance financial analysis with the integration of emerging risks factors, such as climate, transition and physical risks, to complete the traditional economic and financial indicators used in standard sovereign rating assessment.



2. A MAPPING OF EXISTING APPROACHES TO ANALYZE PHYSICAL CLIMATE RISKS IN FINANCE

## 2.3. Service providers have segmented and partly overlapping targets

The background of service providers and their targets are useful to understand the diversity of information they generate.

### 2.3.1. Service providers mobilize different climate and financial expertise

**The service providers we target encompass different business models: data providers, consultancy, financial rating agency, think tank. They are able to mobilize diverse expertise in terms of climate and financial needs.**

Several institutions have developed climate expertise as their core business or as part of a broader focus on environmental issues. This expertise can cover climate-related science, data and development of indicators and tools. Most of them have developed a capacity to identify and treat a large amount of complex data and to convert them in climate-related indicators. Their expertise can be internal and, in some instances, they collaborate directly with academic scholars. These climate experts develop their approach in an interdisciplinary manner, with backgrounds in economics (industrial, macro, environmental), engineering, finance, etc.

The service providers also integrate financial needs in various manners along the development cycle of their approaches. In some instances, they have internal expertise. In many cases, they work in connection with financial actors through advisory groups, project steering committees, working groups and bilateral feedbacks at different stages of development. In other instances, the service providers are financial service providers such as Moody's Investors Service. Thus, their approach to climate risk is primarily undertaken through the lens of their financial rating standards and they acknowledge that they are not essentially climate specialists.

### 2.3.2. Service providers have specific and partly overlapping targets

**The population of service providers is heterogeneous also in terms of targets. This includes targeted user, decision-making process and type of portfolio (*i.e.* financial instrument and counterparty). While the whole spectrum of potential targets is still to be explored, the available approaches already have initiated a consequent work on partly overlapping targets.**

A first identified target use is the "pre-screening" of projects, that is, the early stage of project selection for further due diligence (in the case of Acclimatise's approach). This information is useful for stakeholders in the project finance chain (*e.g.* project officers and risk managers), mostly in development banks.

A second target use is actually to explore the need to complement existing approaches. For instance, Moody's Investors Service studies the correlation of sovereign credit ratings with an illustrative analysis of physical climate risks. This information can be useful for the risk managers at all types of financial institutions.

A third target use is the analysis of exposure to climate hazards (in the case of WRI's approach). This analysis is not centered around a type of counterparty but around the severity of a type of climate hazard (the WRI focuses on the water resource). It provides indicators that can be potentially useful for a range of financial users in all types of financial institutions.

A fourth target use is the analysis of physical climate risk applicable to large portfolios. These methodologies focus on the different components of risk to a specific type of counterparty (*i.e.* exposure to climate hazards and impacts to the counterparty). This type of analysis targets financial institutions managing their portfolios.

**TABLE 3. SELECTED SERVICE PROVIDERS AND APPROACHES HAVE DIFFERENT TARGETS**

| Target use | Target user | Service provider *(Approach)* |
|---|---|---|
| Pre-screening before financing | Project officers and risk managers – More suitable for development banks | Acclimatise *(Aware for Projects)* |
| Exploratory approach* | Risk managers – All financial institutions | Moody's Investors Service *(Physical Effects of Climate Change on Sovereign Issuers)* |
| Analysis of a portfolio exposure to climate hazards | Not defined – All financial institutions | WRI *(Aqueduct Water Risk Atlas)* |
| Analysis of physical climate risk | Not defined – All financial institutions | Carbon Delta *(Climate VaR)*<br>Carbone 4 *(CRIS)*<br>Ecolab, Trucost and Microsoft *(Water Risk Monetizer)*<br>Four Twenty Seven *(427 Climate Risk Scores)*<br>Mercer *(TRIP framework)* |

* Moody's approach is explorotory in the sense thot it does not constitute a new product to investors and it is based on illustrative data.
*Source: Authors (2018)*

The scope of applicability to a type of portfolio is another major element defining the target of the approach. The type of portfolio can be described here as the type of title held by a financial institution and the type of underlying counterparty. Most approaches target a specific type of counterparty, that is mainly corporates, sovereigns and physical assets such as infrastructure.[30] The focus on a given type of counterparty conditions highly the methodological issues to be tackled. Portfolios of financial titles on corporate counterparties raise a strong constraint in terms of asset-level data availability along the whole value chain of the counterparty. In some instances, the risk analysis to the counterparty is further processed into a financial valuation model (Carbon Delta; Mercer). This yields quantification of impacts to the counterparty in the frame of a specific financial title (*e.g.* equity, bonds).

The whole spectrum of potential needs is still to be explored but service providers have already initiated work on an array of specific targets. Methodologies are partly overlapping in the coverage of needs (in terms of targeted use, users and scope of applicability to different portfolios). The combinations of elements that define the targeted needs raise specific challenges to the development of different approaches.

***

Service providers are heterogeneous in their strategy to mobilize expertise, their business models and their targets (in terms of users, decision-making process and type of portfolio). These heterogeneous actors address their targets with different choices. Section 2.4 explains some key choices on the display of information to the end-user. Section 2.5 explains some key choices on the underlying methodology.

## 2.4. Final information formats are diverse

The Service providers present diverse types of final information to the end-users. This shows different approaches to provide actionable information.

### 2.4.1. Risk analysis expressed as quantitative or qualitative information

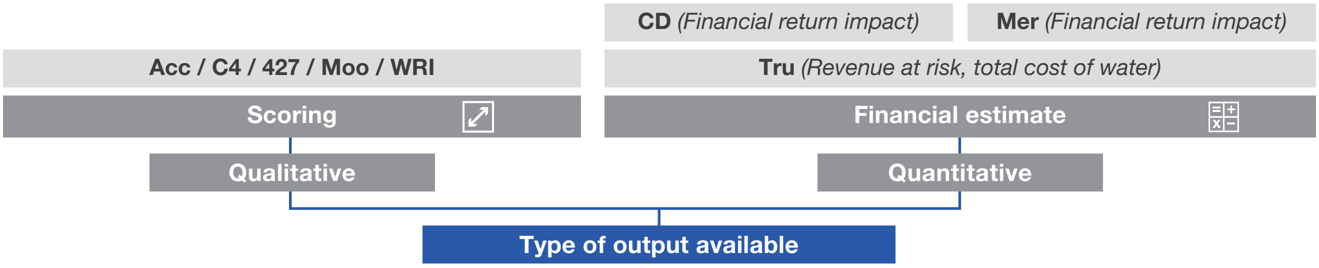
**Physical climate risk analysis comes in either a qualitative or a quantitative form, respectively as scorings and financial estimates. Both types of information arise from a methodology with qualitative judgments and sophisticated analysis.**

As shown in **Figure 6**, the matjority of the methodologies provide scorings on the physical climate risk to a counterparty (Carbone 4, Acclimatise, Four Twenty Seven, Moody's Investors Service). A scoring is an information expressed on a scale. The scale can come in the form of a grade, a rating, a scale of colors or any other visual support. It provides comparability of the physical climate risk level across counterparties. Scorings can result from radically different methodological frameworks. The methodology can include a varying degree of expert judgment. It can involve some sophisticated quantification at diverse stages. The scoring is only the final presentation of information after a normalization process that allows comparing results on the same scale. Service providers may have diverse motivations when providing scoring as a final information (*e.g.* consequences of methodological choices; opinion on feasibility and robustness).

In some instances, Service providers produce financial estimates on the physical climate risk to the counterparty (Carbon Delta, Trucost, Mercer). A metric is a quantified information expressed in a given unit. It provides comparability of the physical climate risk measure with other types of risk to the same counterparty. Depending on the type of unit, it can also provide comparable information across several counterparties. In this report, this typically comes in the form of costs to a counterparty or to potential losses on the financial asset value. The ability to provide quantified metrics refers to different methodological assumptions and choices. These can also include a level of expert judgment where necessary.

30 Some specific studies also investigate potential impacts of physical climate change on financial services. For instance, the DNB's "Waterproof?" report investigates potential impacts of physical climate change on insurance claims.

**FIGURE 6. SELECTED APPROACHES PROVIDE DIFFERENT INFORMATION FORMATS**




**Acc:** Acclimatise – Aware for Projects
**CD:** Carbon Delta – Climate VaR
**C4:** Carbone 4 – CRIS
**Tru:** Ecolab, Trucost and Microsoft – Water Risk Monetizer
**427:** Four Twenty Seven – 427 Climate Risk Scores
**Mer:** Mercer – TRIP framework
**Moo:** Moody's Investors Service – Physical Effects of Climate Change on Sovereign Issuers
**WRI:** WRI – Aqueduct Water Risk Atlas

*Source: Authors (2018)*

### 2.4.2. Aggregating information on different criteria to favor meaningful analysis

**Existing approaches target the possibility to aggregate and disaggregate information across different criteria. The main focus is on providing detail on counterparties and aggregation at portfolio level. A few approaches also propose detail and aggregation of information on a counterparty across the types of climate hazards, of impacts and different scenarios and time horizons.**

All of the selected approaches produce information – in the form of scoring or financial estimates of impacts – that can be compared across a given type of counterparty. Service providers have also targeted possibilities to aggregate information at different scales, for both the scorings and financial estimates. They allow for aggregation on different sorting criteria, including characteristics of counterparties and financial instruments; hazards; impacts and time horizons.

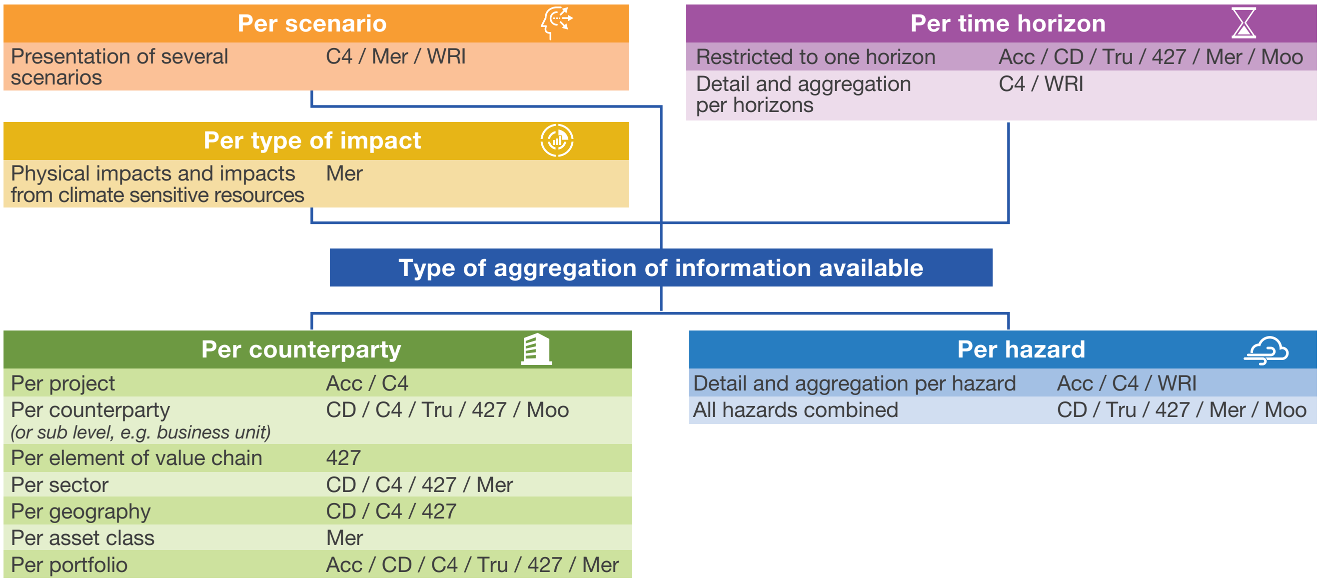
**Figure 7** below indicates the criteria of aggregation as well as the scales of aggregation available. The finer scale of disaggregation of the final information (*e.g.* per counterparty) does not necessarily correlate with the scale of input data used to generate this information (*e.g.* it could be asset-level or sectoral-level data). The granularity of data will be discussed in **section 2.8**. In addition, the criteria of aggregation are not applicable to all of the approaches, depending on the type of counterparties they target. For instance, aggregation across the upstream or downstream value chain makes sense to corporate counterparties but not to sovereigns.

In some instance, it is possible to aggregate or disaggregate information at the counterparty – *i.e.* company, state, etc… – level, based on the **types of impacts.** Trucost provides information on revenue at risk, total cost of water to the facility. Mercer's approach also informs on impacts at a counterparty in the form of two scores about exposure to climate sensitive resource and exposure to physical impacts in the value chain.

Some other approaches provide detailed information per **type of hazards**, such as Carbone 4's CRIS methodology, Four Twenty Seven's Climate Risk Scores, Acclimatise or WRI. Some methodologies also provide detailed information **per type of scenario**, such as Carbone 4, Mercer and WRI. We found that only Mercer provides **sensitivity factors**. These factors are given on a sectoral basis and for an aggregate pool of impacts (*i.e.* physical impacts or impacts from climate sensitive resources), with a unique figure calculated from several scenarios. Some methodologies also provide details per **time horizon**, such as WRI and Carbone 4's CRIS methodology.

Some service providers also target aggregation on several characteristics of the counterparties and at different scales. Some approaches generate information at a disaggregate level, per project (Acclimatise), per corporate or sovereign counterparty (Four Twenty Seven, Carbon Delta, Carbone 4, Trucost, Moody's Investors Service), sometimes based on an analysis at the scale of facilities or business units. The analysis may also provide detail and aggregation per element of the counterparties' value chain, such as supply chain, operations and market (Four Twenty Seven). In some instances, it is possible to aggregate information across counterparties based on activity sectors (Mercer, Carbon Delta, Four Twenty Seven, Carbone 4) or geography (Carbon Delta, Carbone 4). Some approaches also allow for aggregation at the asset class level, such as bond or equity portfolios (Mercer). Mercer comments that investors use mostly such asset class breakdown of impacts consistently with their portfolio management strategy. However, Mercer also provides portfolio analysis under a sectoral breakdown of impacts since they find it is more appropriate for diversifying physical climate risk. Carbon Delta, Carbone 4 and Four Twenty Seven also provide sectoral analysis. The ability to aggregate information on different criteria depends on the targeted financial user need and the underlying methodology.

**FIGURE 7. SELECTED APPROACHES ALLOW FOR DIFFERENT TYPES OF AGGREGATION**




**Acc:** Acclimatise – Aware for Projects
**CD:** Carbon Delta – Climate VaR
**C4:** Carbone 4 – CRIS
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**427:** Four Twenty Seven – 427 Climate Risk Scores
**Mer:** Mercer – TRIP framework
**Moo:** Moody's Investors Service – Physical Effects of Climate Change on Sovereign Issuers
**WRI:** WRI – Aqueduct Water Risk Atlas

*Source: Authors (2018)*

### 2.4.3. Conveying messages with different media

**Service providers use a spectrum of media to convey actionable information to financial institutions. This ranges from disaggregate output spreadsheets to interactive mappings. Efforts of transparency can still benefit from additional synthesis of the underlying methodologies deployed.**

The spectrum of media includes output spreadsheets, sometimes with additional level of disaggregation to meet more user needs. It also includes media that help visualize the outputs in context, sometimes featuring interactivity to change scope, scales, etc. This includes for example interactive mappings or plots. Contextualization efforts sometimes also come as detailed narratives on the potential future impacts.

Some service providers also formulate guidance for further action on risk analysis and risk management (*e.g.* Acclimatise lists questions to launch dialogue with stakeholders). More broadly, a number of service providers have released reports where they provide general guidance for organizing physical climate risk analysis and favoring its use in the broader risk decision-making process (cf. Mercer).

The service providers are generally transparent on the scope of hazards, counterparties and impacts that they analyze. However, methodological choices are not always made fully explicit in the interface, while more transparent in side documents. Depending on their business model, some service providers cannot make their whole methodology totally explicit for competitive reasons. Few service providers give some precisions on the availability and quality of data for analyzing impacts, as well as comments on sources of uncertainty (with indications on the agreement across climate models) (Carbone 4; Acclimatise).

In a nutshell, service providers have developed information addressing a growing scope of targets with some overlaps. To do so, they have developed a richness of information formats – in terms of quantification, aggregation or media – to guide risk analysis. At the scale of the market, this diversity also generates some challenges for the comparability of information addressing the same needs.

In order to generate this synthetic information on physical climate risk to different counterparties, the service providers have to address complex networks of impacts in a data constrained universe. This implies to make several methodological choices. These are essential for they determine the very definition of the "physical climate risk" that is analyzed. The following sections synthesize the main aspects of methodological strategies to generate this information on physical climate risk, that is, the strategy to analyze impacts; the underlying scope of impacts; the input data and scenarios to characterize them; and the strategies to deal with the specificities of physical climate risks.

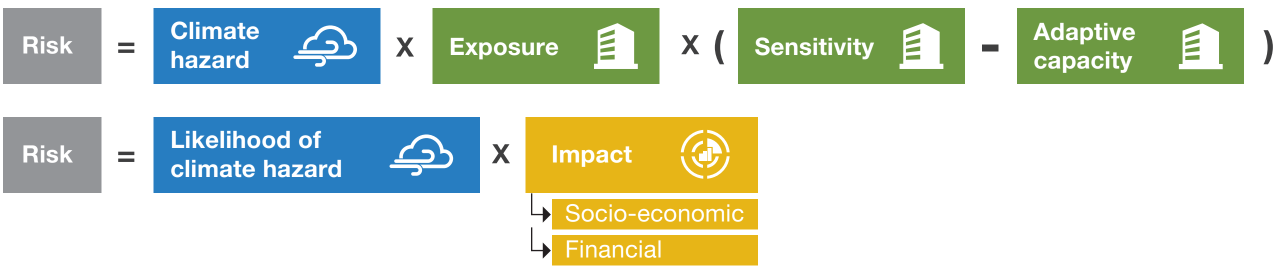
2. A MAPPING OF EXISTING APPROACHES TO ANALYZE PHYSICAL CLIMATE RISKS IN FINANCE

**REMINDER: THE GENERAL SCHEME OF RISK ANALYSIS**

- Physical climate risk analysis for portfolios needs to include two types of analyses:
  - ➤ analyzing climate hazards expected per geographic area and
  - ➤ analyzing potential impacts of these hazards on the objects under study.
- In the context of physical climate risk analysis for a portfolio of financial titles, two steps are necessary:
  - ➤ Investigating potential impacts on "concrete economic objects" (*e.g.* a company, a country or a project) that underlie financial titles
  - ➤ And then investigating how these impacts on "concrete economic objects" translate into impacts on financial titles. (see **section 1.1.** on the propagation channels of physical climate risks to financial risks).

The following sections detail how existing approaches analyze the building blocks of physical climate risk, as detailed in the formulas below:

**FIGURE 8. SYNTHETIC VIEW OF PHYSICAL CLIMATE RISK ANALYSIS IN EXISTING APPROACHES**




*Source: Authors (2018)*

## 2.5. The scope of hazards covered is heterogeneous

Risk information on a given counterparty may differ depending on the scope of impacts that is analyzed. Climate impacts are the consequences of a given climate hazard on a specific aspect of the counterparty.

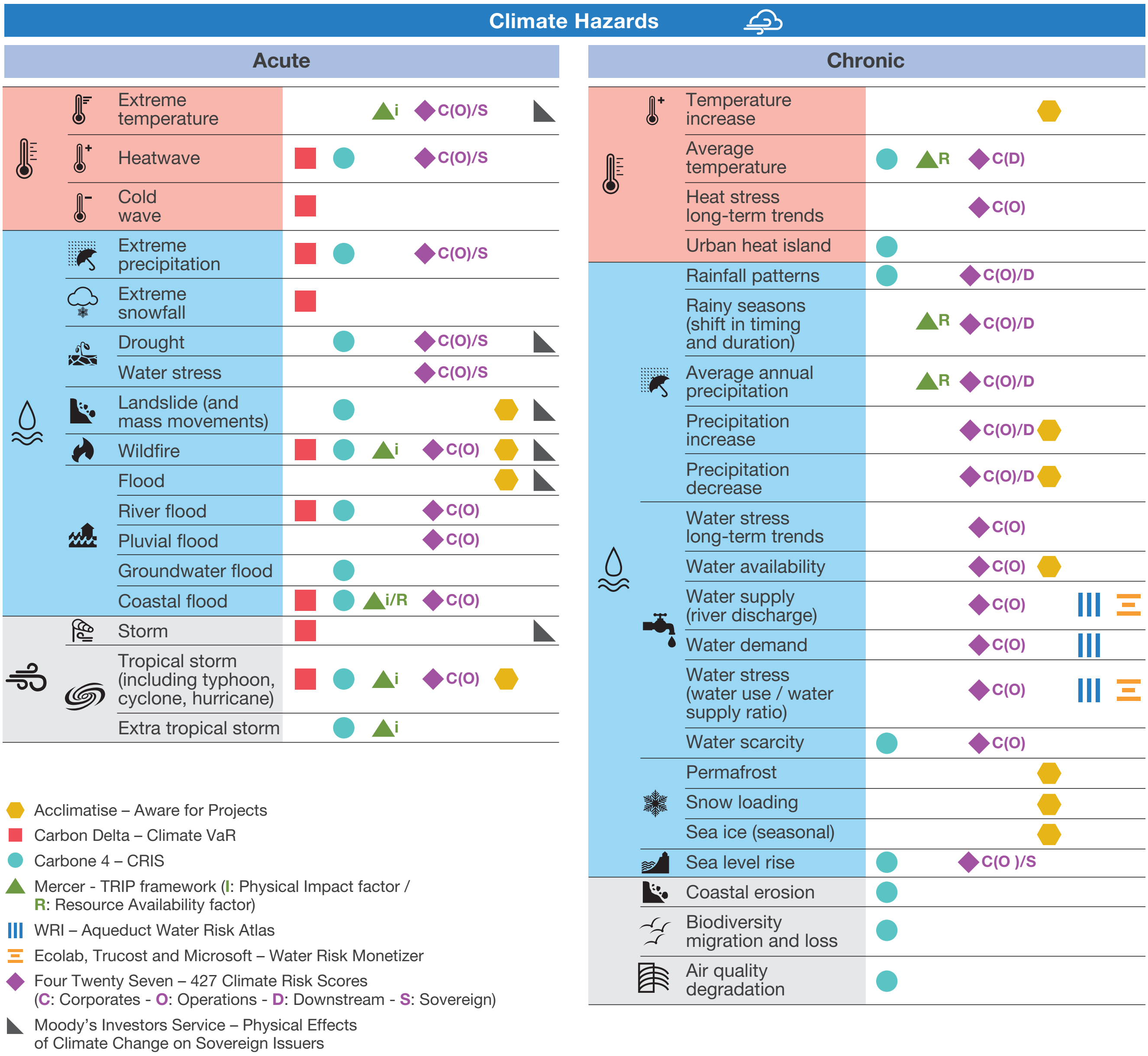
### 2.5.1. Various scopes of climate-related phenomena

The coverage of physical climate hazards differs in the methodologies at different levels.

**Most of the current approaches address acute climate-related phenomena while coverage of chronic phenomena is emerging.** As shown in **Figure 9**, the existing approaches focus on a wide range of abrupt phenomena, with emphasis on events that trigger disruptions in business activities. This covers phenomena of diverse natures related to temperatures, water cycles and winds (*e.g.* heat and cold waves, wildfires, drought and floods, typhoons). Fewer approaches cover gradual change in climate patterns. Two of them have focused specifically on the aspects of water availability, including socio-economic drivers for water demand. None of them addresses the evolution of wind patterns. This is consistent with current uncertainty about the evolution of wind patterns, as highlighted in Cicero (2017). Some service providers also define some "indirect climate hazards" that can be acute or chronic. These arise from a hazard that is purely defined by climate variables and that is aggravated by non climatic variables (*e.g.* Carbone 4 refers to coastal floods and erosion as indirect climate hazards arising from sea level rise due to the presence of aggravating factors such as a low-lying coastal areas; they also refer to wildfires as indirect hazards arising from extreme drought due to the presence of aggravating factors such as dry forest, pressures on water resources, etc.).

**For a given type of phenomena, service providers can also focus on a range of statistics, which changes considerably the nature of information.** These hazards can be defined over different time scales (*e.g.* daily or yearly temperature). In terms of acute hazards, service providers usually cover intensity, frequency and duration of abrupt events. In terms of chronic hazards, it usually refers to trends and variability. With the example of chronic hazard from water supply, the WRI examines the evolution of mean yearly water

**FIGURE 9. COVERAGE OF CLIMATE-RELATED CONDITIONS AND EVENTS AT THE BASIS OF ACUTE AND CHRONIC CLIMATE HAZARDS**




*Source: Authors (2018)*

supply arising from surface runoff but also the intra-year variability (*i.e.* seasonal variability) of this water supply as a separate indicator.

### 2.5.2. Various strategies to analyze hazards from climate-related phenomena

**Climate change**, properly speaking, *i.e.* the change in weather patterns and extremes, is not always involved in the set of climate-related hazards. Some approaches analyze impacts from past individual weather events (Acclimatise and Four Twenty Seven for a selection of chronic and acute climate-related hazards; Moody's Investors Service). Others define impacts arising from current climate conditions (*e.g.* WRI; Trucost). Finally, some approaches target more specifically the impacts from future climate conditions, using scenario-based analysis (*e.g.* WRI, Carbone 4, Carbon Delta, Four Twenty Seven, Acclimatise for a selection of chronic climate hazards).

**When studying the evolution of climate, different angles were found across existing approaches.** The focus can be on the absolute level of the climate variable at the end horizon, it can also be the exceedance of a threshold, or the relative evolution of the variable at the end horizon compared with a past level in a reference period.

## 2.6. Different scopes of impacts analyzed

### 2.6.1. Methodologies analyze impacts on different elements of the value chain of a counterparty

**Existing approaches recognize that counterparties have exposure to climate hazards in various aspects. Analyses of corporate counterparties include value chain or macro considerations, while sovereign analyses are more essentially macro by principles, and project analysis focuses on the operations.**

Some approaches have delimited their analysis to the direct consequences of climate change impacts to specific **"physical" assets**, for which they provide more in-depth analysis of hazards, impacts and risks. This is consistent in the case of **project analysis**. For example, Acclimatise provides information on the risk to infrastructure projects. The scope of impacts is connected directly to consequences on the physical assets of infrastructure and the conditions on the sites of operations. The level of metric is defined in an expert committee with sanity check by the client.

Several approaches analyze impacts along the value chain of the counterparty. This **applies most of all to corporate counterparties**. This encompasses not only **direct impacts to the counterparty's assets and operations** when producing a good or service. This also incorporates impacts to the **upstream value chain** (*e.g.* suppliers' operations; transport to the counterparty's sites of operations) and to the **downstream value chain** (*e.g.* transport to the point of sale; consumption of the produced goods and services) and how this affects the business of the counterparty (*e.g.* change in the price and quantity of inputs; quantity produced; price and quantity of sales). This concept of value chain involves a focus on impacts to the agents that contribute to the supply of inputs, distribution and consumption of the goods and sales produced at the counterparty (Four Twenty Seven, Carbone 4, Carbon Delta focuses on business interruption based on facility level and points of sales).

Some approaches also expand the scope of corporate analysis to **the larger socio-economic environment**. This aims at reflecting how the larger socio-economic environment is exposed and sensitive to climate hazards, and how it is able to cope with such hazards. Indeed, the adaptive capacity of the broader socio-economic environment may influence the adaptive capacity of the counterparty and the agents along the value chain (Four Twenty Seven).

Additionally, several service providers carry out the analysis of **sovereign counterparties**, which includes necessarily some **macro** considerations about the economic, social and financial strength of the country (Four Twenty Seven; Carbone 4; Moody's Investors Service) or at the city-level (Four Twenty Seven).

### 2.6.2. The methodologies analyze different types of impacts

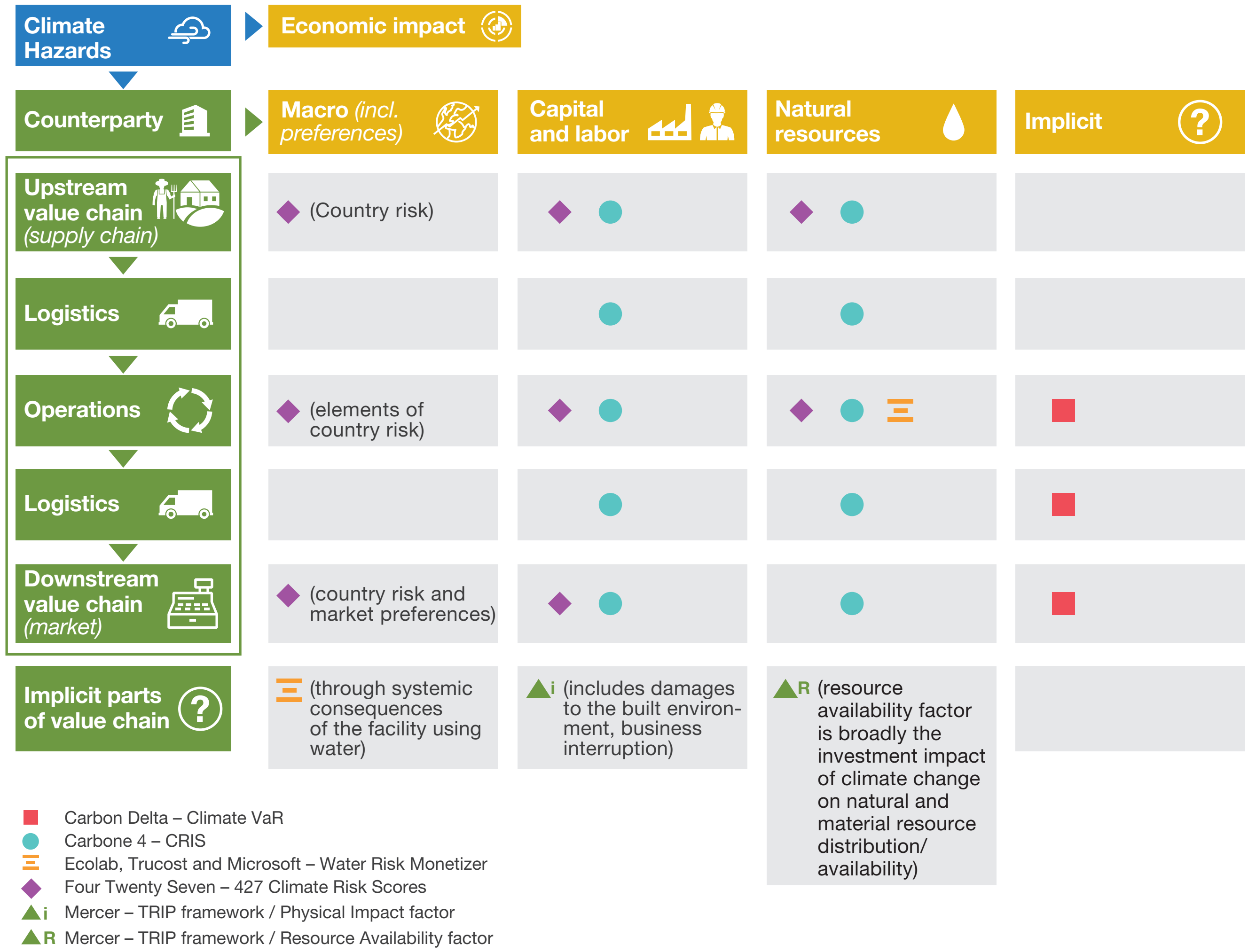
**While service providers recognize the importance of the different aspects in counterparties' exposures, methodologies currently offer partial or implicit coverage of resulting impacts on each aspect. These impacts concern the economic activity through the value chain or the resulting financial impact on the counterparty.**

#### Economic impacts to the counterparty's activities

**Figure 10** on the case of corporates shows that climate change may have impacts on multiple aspects of the counterparty's activities throughout its value chain (*i.e.* direct operations of the counterparty, but also its supply chain, its market and demand and its logistic chains). For each part of the value chain, the exposure concerns the means of production such as assets, labor force, natural resources that the production depends on, but also the broader environment that may have impacts on the capacity to produce. The economic consequences may materialize at the scale of the counterparty in the form of a rise in costs, loss of productivity, disruption in the value chain, permanent damage, etc.

Operations is the aspect of exposure that receives the most of explicit treatments in existing approaches on corporates

**FIGURE 10. ANALYZING ECONOMIC IMPACTS ON CORPORATE COUNTERPARTIES**




*Source: Authors (2018)*

(Four Twenty Seven, Carbone 4, Trucost, Carbon Delta), with additional implicit treatment when focusing on specific categories of impacts (Mercer and Trucost). Several service providers also emphasize explicitly the dependence of the counterparty to **climate-sensitive resources** for operations (*e.g.* natural resources such as water, human-processed resources such as agricultural products or energy) (Four Twenty Seven; Carbone 4; Mercer computes an indicator that is visible in final information on impacts from resource availability including natural resource and human-processed resource). Impacts to the **capital** are also likely to receive attention from existing approaches, given that the built environment receives attention in exposure datasets. However, we found limited information on the explicit treatment of impacts to the assets (Carbone 4, Carbon Delta, Mercer computes an indicator that is visible in final information on physical impacts to the counterparty, with no specific focus on the operation phase).

Fewer approaches on corporates emphasize the impact on **labor force** for operations (Carbone 4 explicitly). Labor force is more addressed in sovereign analyses (it is done for sovereigns by Moody's Investors Service, Four Twenty Seven and Carbone 4, through impacts on population). The **broader environment** is also treated actively by Four Twenty Seven in the form of the country risk context that may affect the counterparty's capacity to produce. Other methodologies focus on the consequence to the counterparty's cycle of production (*e.g.* disruption of production) and thus they do not target specifically a type of consequence to each factor of production at the counterparty's (*e.g.* Carbon Delta).

Concerning the broader value chain, downstream exposure (*i.e.* market issues) receives the most of explicit treatments in existing approaches on corporates (Four Twenty Seven, Carbone 4, Carbon Delta) with additional implicit treatment

2. A MAPPING OF EXISTING APPROACHES TO ANALYZE PHYSICAL CLIMATE RISKS IN FINANCE

when focusing on specific categories of impacts (Mercer and Trucost). Market issues are addressed at **macro level** through sensitivity of the demand preferences to climate change (Four Twenty Seven uses a weather sensitivity indicator; Carbone 4 also considers the weather sensitivity of price volatility and of sales), or through the country risk (Four Twenty Seven uses a country of sales indicator that reflects how countries in the supply chain are sensitive to climate risks). Some methodologies also address broadly the market issue with a focus on disruptive events (*e.g.* Carbon Delta) or as part of a focus on specific categories of impacts (Mercer and Trucost).

Upstream exposure (*i.e.* supply chain) is addressed mainly through dependence to **natural resources** (Mercer's indicator on impacts from resource availability including natural resource and human-processed resource; Four Twenty Seven: sectoral resource intensity and efficiency for upstream value chain; Carbone 4: consideration of climate sensitive resources in the upstream value chain) or through **macro aspects** (Four Twenty Seven uses a country of origin indicator that reflects how countries in the supply chain are sensitive to climate risks) or as part of a focus on specific categories of impacts (Mercer and Trucost).

Considerations on logistics are included by Carbone 4 explicitly when providing qualitative sensitivity factors, and potentially as part of larger indicators by some other approaches.

**In a nutshell, existing approaches address economic impacts to the counterparties with multiple combinations.**

### Financial impacts to the counterparty

The TCFD recommends explicit analysis of financial impacts to the counterparty's balance sheet as well as profit and loss. As shown in **Figure 11**, these are covered in different manners in the methodology (and emphasized in different manners in the final information), given data constraints and methodological choices.

Some methodologies study the consequences of climate hazards on various specific financial items of the Profit & Loss and Balance Sheet for each element of the counterparty value chain (Carbone 4). This exhaustiveness is reached through qualitative correlations.

Some approaches have quantified methodologies that help target financial impacts with some varying degree of specificity. Some approaches focus specifically on those events that produce disruptions in the value chain, which results in a loss of revenues or additional expenses (Carbon Delta in the form of cost estimates; Moody's Investors Service sovereign analysis also factors in sovereign loss of income through 10-year average GDP loss from natural disasters). This produces consequences on the Balance Sheet or the Profit & Loss without specific identification of items. Other methodologies start with estimates of GDP loss from various climate-related hazards and they allocate it to different sectors. In this sense, it provides a rating on the counterparty's production, but it does not provide detail on the Profit & Loss and Balance Sheet impacts (Mercer). In other instances, the focus on a specific aspect of the counterparty value chain and type of economic impact helps target a specific financial item (Trucost focuses explicitly on profit and loss arising from water input and output of facilities).

Other approaches focus on a range of economic impacts and it is also difficult to extract explicitly some specific consequences on Balance Sheet and Profit & Loss items (Four Twenty Seven).

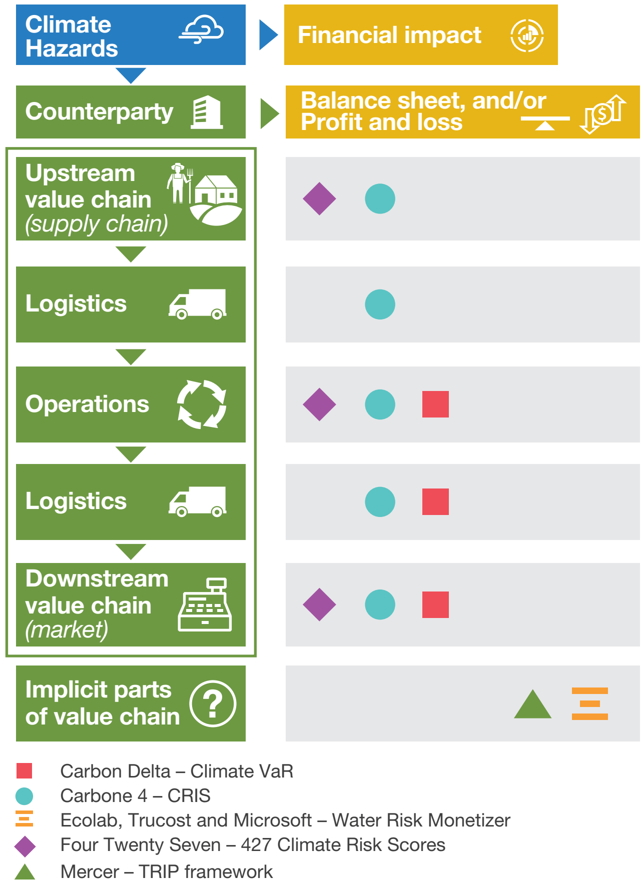
The state of the art reveals other approaches to cover impacts (see **Box 4**).

**In a nutshell, current treatment of financial impacts is limited and rarely specific.**

**BOX 4. LINKING IMPACTS TO THE COUNTERPARTY AND IMPACTS TO THE SOCIO-ECONOMIC SYSTEM**

This is the case of Trucost's Water Risk Monetizer, with specific focus on the water resource. Trucost shows how climate change may engender water stress on incoming water at a facility, causing reduced production and loss of revenue. The particularity is that it also monetarizes how the counterparty triggers losses in the broader socio-economic system by competing for water use and by polluting water (*e.g.* reduction of water availability to the ecosystems and monetarization of impacts in terms of ecosystem services loss). In this part of the Water Risk Monetizer, the focus is on the responsibility of the counterparty to the rest of the system in terms of water resource. This full cost is then allocated to the counterparty as an impact to the counterparty. However, this is different from climate-related impacts to the counterparty's value chain (*i.e.* how climate change impacts the availability and quality of water to the counterparty and to the agents of the counterparty's value chain).

**FIGURE 11. ANALYZING FINANCIAL IMPACTS ON CORPORATE COUNTERPARTIES**




*Source: Authors (2018)*

# 2.7. Input data and the case of scenario-based analysis

## 2.7.1. Basic principles of scenario-based analysis on physical climate risk

The TCFD points out the importance of forward-looking analysis to understand the potential impacts of future climate conditions. They also recommend proceeding with a scenario-based analysis.

According to the TCFD, a scenario in itself describes a path of development leading to a particular outcome. They are hypothetical constructs and they are not meant to be exhaustive (*i.e.* they focus on central elements of a possible future and their goal is to raise attention on key drivers of future change). Scenarios are not deterministic forecasts or sensitivity analysis on separate variables.

As shown in **Figure 12**, scenario-based analysis can inform several aspects of physical climate risks, with climate scenario on physical climate hazards, socio-economic scenario, climate impact scenario, etc.

Scenarios can arise from different methodologies that change the information content. Some of them are "trend scenarios" in the sense that they extrapolate a trend identified from past events. Other scenarios are "exploratory scenarios" in the sense that they also consider a diversity of potential evolutions that are not necessarily in line with the historical trend. Scenarios on a future trajectory can be used to generate a projection of the situation around a given time horizon.

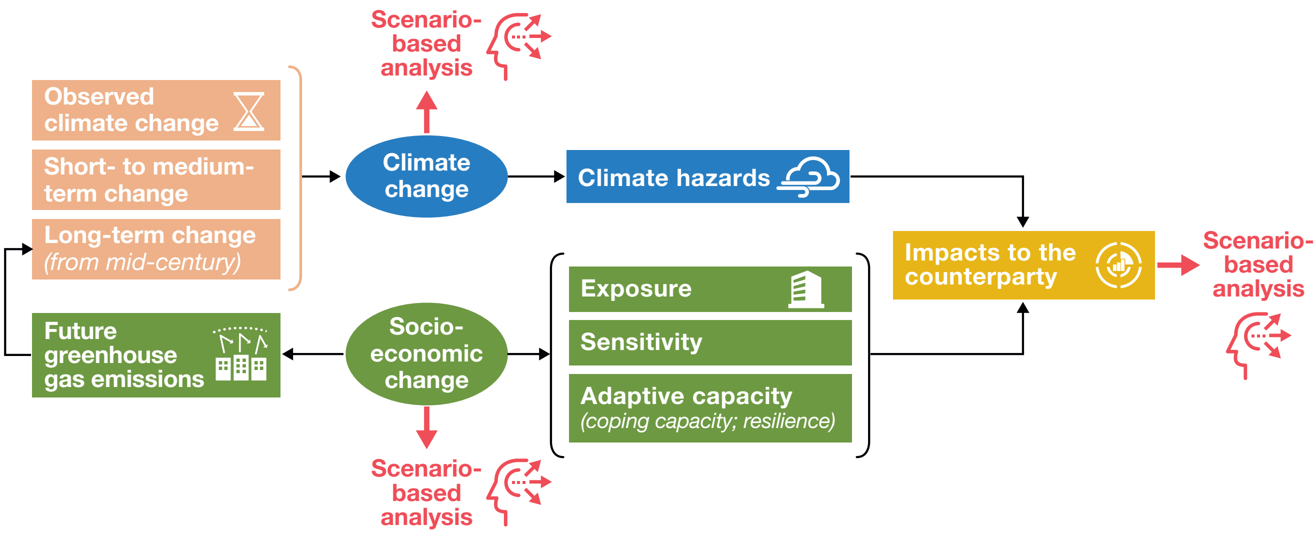
## 2.7.2. Implementing climate scenario-based analysis

### Diverse types and sources of climate scenarios

**The current approaches use different types of climate scenarios, which involves a focus on different processes: past and current conditions, trends or exploration of other major sources of variability. The sources of information are also variable, with a number of approaches relying at least partly on IPCC data. Exploration of unprecedented combinations of weather conditions could be useful for analyzing impacts to a specific counterparty.**

In order to characterize physical climate hazards, several service providers use **exploratory scenarios**, as shown in **Figure 13**. They are generated consistently with a socio-economic scenario on GHG emissions. In most instances they use up to date IPCC scenarios and projections. These are generated in complex climate models detained at specialized institutions coordinating efforts in international exercises such as the CMIP (Coupled Model Intercomparison

**FIGURE 12. SCENARIO-BASED ANALYSIS ON DIFFERENT ASPECTS OF PHYSICAL CLIMATE RISKS**




*Source: Authors (2018)*

Project). These scenarios are constructed consistently with specific scenarios describing the future trajectory of GHG atmospheric concentration (the RCP or Representative Concentration Pathways in the IPCC's Fifth assessment report) or GHG emissions (called SRES in the IPCC's Fourth assessment report) (Four Twenty Seven for climate risk on operations uses a worst-case scenario with RCP8.5; Carbone 4 provides 3 alternative IPCC climate scenarios depending on GHG emission levels: below 3°C for low emissions level, above 3°C for medium level, above 4°C for high level; Acclimatise uses also worst-case scenarios consistent with RCP8.5 and SRES A1B data. WRI and subsequently Trucost also characterize water stress hazards with climate and socio-economic drivers, using respectively RCP scenarios and SSP scenarios). These scenarios could be complemented with further exploration of potential weather conditions at a particular place. While the future of climate may lead to unprecedented chronic or acute weather conditions in terms of intensity, frequency, duration, it may also lead to unprecedented combinations of weather conditions at the same time or in a concentrated timeline, in one or multiple locations.

Other service providers decide to generate **trend scenarios** of physical climate hazards based on the extrapolation of past weather events, as a mean to reflect business-as-usual conditions in a short-term 15-year horizon (Carbon Delta).

As pointed out in this report, some approaches do not always focus on hazards arising from a future climate. Some of them refer to **current and past** conditions (Moody's Investors Service; Four Twenty Seven, Acclimatise and Carbone 4 for a selection of hazards; WRI for current climate conditions).

Finally, a limited number of approaches account for several alternative futures. This is the case of Carbone 4's CRIS methodology or the WRI.

### Some service providers use directly IAM scenarios already combining climate and socio-economic variables

Some approaches (Mercer) produce indirectly some climate scenarios as part of a broader simulation in Integrated Assessment Models (IAMs). In this case, climate data is generated in a simple climate module within the IAM that translates a GHG trajectory into a climate variable. The input GHG trajectory arises from hypotheses of the authors on socio-economic trajectories and they recognize that such models may lag behind the state of scientific literature.

The climate scenario generated by the IAM is then integrated directly in a further module that uses a damage function. This generates a socio-economic scenario on GDP impacts in different domains. The specification of the damage functions arises from diverse studies in the academic literature. They do not necessarily include specific behavior of impacts in extreme future climate conditions and the data used to calibrate the damage functions is not necessarily forward-looking.

### The horizon of analysis conditions the relevance of climate scenarios

**Horizons of analysis are diverse (from decade to end of the century) and condition the relevance of the different types of scenarios. This reveals some potential avenues for enriching scenario analysis.**

At any time horizon, climate impacts may arise depending either on natural variability in the climate system or on the long-lasting climate change. However, the first source of variability prevails in the short-term while the second one prevails in the long-term. This is true especially for the evolution of global temperatures. This creates different needs of scenario analysis depending on time horizon.

At shorter horizons, the possible variations in climate hazards depend most of all on natural variability. Some low-frequency phenomena are still difficult to anticipate and they can trigger additional variability in future weather trends (*e.g.* El Niño and impacts around the world). In addition, natural variability and climate change are both sources of impacts and it is still difficult to attribute specific events to one or the other. Some methodologies provide scenario analysis on short time horizons. It can use trend scenarios built on the last 35 years of observed weather events (Carbon Delta). However, this might not reflect the potential range of short-term variability. Other methodologies use exploratory scenarios from the IPCC, which are more powerful to differentiate long-term trajectories especially when talking about global temperatures. Therefore, it might be useful to provide alternative scenarios on the potential combined effects of trends and additional hypotheses on natural variability or climate change.

At longer time horizons (*i.e.* from mid-century), the possible variations in climate hazards depend much heavily on long-lasting climate change (with GHG emissions as a major driver) and, to a lesser extent, on natural variability. This is true especially for global temperatures. This is where exploratory climate scenarios based on GHG trajectories are more useful (Cicero, 2017).

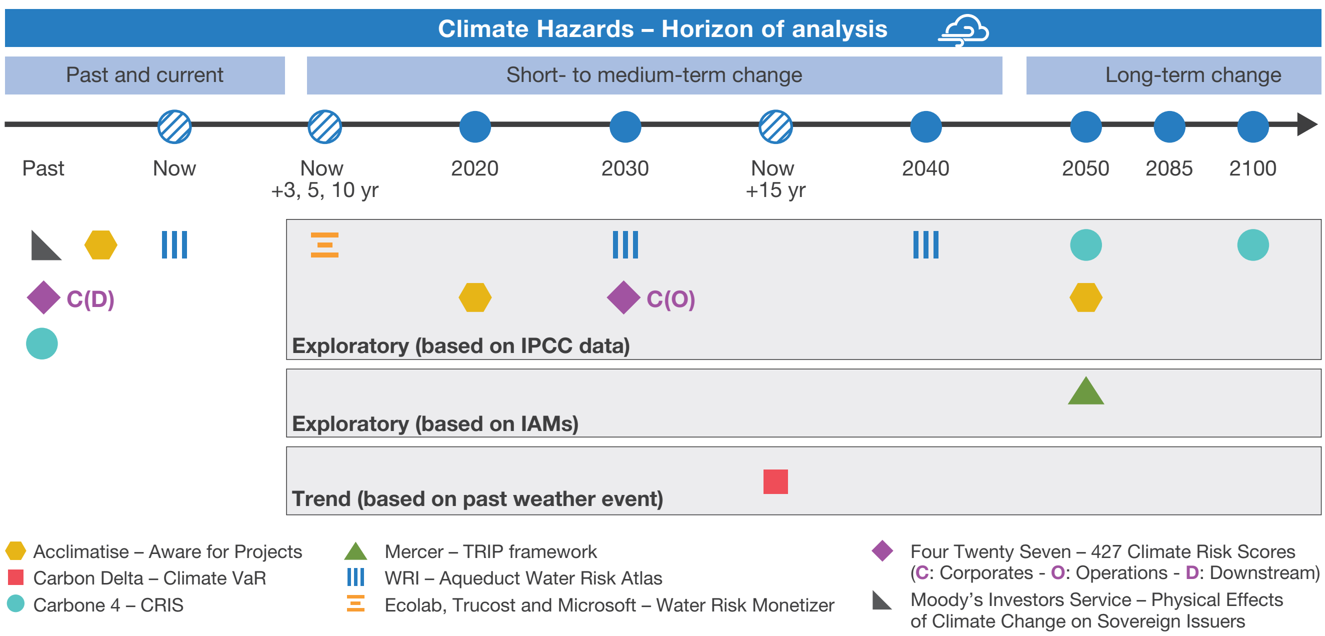
### 2.7.3. Implementing socio-economic scenario-based analysis

**The characterization of impacts to socio-economic agents could integrate more forward-looking aspects to reflect that socio-economic systems are evolving in terms of exposure, sensitivity and adaptive capacity.**

On the one hand, as shown on **Figure 12**, scenarios on socio-economic aspects can serve to understand how socio-economic potential futures will affect the climate. The approaches that use scenario analysis generally integrate this aspect. When approaches use IPCC's climate scenarios, this means implicitly that the scenario accounts for future socio-economic choices in terms of GHG trajectories. Additionally, the WRI defines water hazards themselves with specific reference to socio-economic drivers (*e.g.* water stress depends on the demand for water in different sectors, projected with variables of IPCC's SSP scenarios). Methodologies using IAMs also take future GHG trajectories as input to determine climate impacts.

On the other hand, there is limited integration of how the socio-economic evolutions will affect exposure, sensitivity

**FIGURE 13. TIME HORIZON AND APPROACHES TO FORWARD-LOOKING ANALYSIS**




*Source: Authors (2018)*

and adaptive capacity as pictured on **Figure 12**. Several approaches use expert judgment to prioritize some assumptions in future evolutions of socio-economic agents' sensitivity and capacity to adapt (Mercer analyses sensitivities based on current-day evidence complemented with qualitative judgment). Otherwise, there is currently little integration of prospective structural changes in the economy, or prospective change in the sensitivity and adaptive capacity of the socio-economic agents. This may be linked to data limitations or the relatively high level of uncertainty on socio-economic change. Instead, historical data is often used to characterize the current functioning of socio-economic agents (*e.g.* economic and financial data) and their sensitivity and capacity to adapt to climate impacts (*e.g.* Four Twenty Seven using historical weather sensitivity of sectoral sales for market risk, or using some aspects of economic consequences of major historical hazards; Carbone 4; Moody's Investors Service). Acclimatise's Aware for Projects lets the end-user characterize a project's coping capacity against historical and forward-looking dimensions (this depends on the end-users who are asked to select a project's sensitivities to climate-related indicators based on data that have had pre-determined thresholds applied, and which reflect a project's ability to cope with climate change or weather-related events). Acclimatise's Aware for Projects also lets the end-user decide whether they characterize a project coping capacity with historical or forward-looking dimensions (indeed this depends on the end-users who is asked to select thresholds on climate variables for the project to cope with climate change or weather events). IAMs simulating climate impacts may have limited capacity to include these socio-economic aspects. These models use damage functions to translate climate variables (generated from GHG trajectories) usually into a variation of GDP in a certain domain. There is heterogeneity in the studies used to produce the damage functions in the different domains of impacts (Diaz and Moore, 2017) which makes it difficult to track inclusion of these aspects in estimates of GDP loss.

### 2.7.4. Different sources of data

Data used to analyze physical climate risks are generated in a number of ways: observation data sometimes complemented with statistical processes (*e.g.* extrapolation in time; inference of conclusions to a broader population; down-scaling); data provided by end-user; modelling (*e.g.* weather and climate modelling; economic modelling; climate and economic modelling coupled in Integrated Assessment Models); expert judgment. Service providers use diverse sources to access this information, including public sources and paid databases. The sources are listed in the summary table for each approach whenever service providers accept to disclose them. These sources and methodologies to produce information may not have the same quality. However, discussion on this point is out of the scope of this report.

## 2.8. Operational strategies to deal with the granularity of climate change impacts

### 2.8.1. Challenges to acquire data with appropriate granularity depend on counterparty and users

The availability of data on counterparties has been a key issue for the production of information dedicated to financial actors. This is paramount since counterparties to portfolios constitute most of the exposure of financial institutions to physical climate risks. The following section defines further aspects of the data challenge.

#### Appropriate level of data granularity ranges from local to macro

**The data needs to catch the local and specific determinants of a counterparty's risk as well as the macro-context.** The physical climate risk arising from a counterparty has local or specific determinants in all the components of risk, that is, hazards, exposure, sensitivity and adaptive capacity of the counterparty.[31] It also has some broader scale elements.

Climate hazards can vary substantially at a local scale, as illustrated at the scale of observed meteorological events. Some climate hazards are also defined depending on the characteristics of the local environment (*e.g.* inland flooding is generated from the level of the river waters but it depends also on the height of the riverbed at certain locations).

The exposure of the counterparty to a climate hazard depends on the location of assets and other means of production that it depends on. It also depends on existing adaptation measures with potential macro-determinants (*e.g.* dykes reducing the exposure to flooding episodes).

Sensitivity and adaptive capacity may depend on the specific characteristics of the counterparty and specific interactions in its value chain. They may also depend on broader scale elements such as the characteristics of the activity sector, or elements of the macro environment such as the country level (*e.g.* the capacity of a country to adapt to climate hazards may create a context that influences the business environment of the counterparty).

Acquiring information that catches these different levels creates challenges to service providers.

31 As detailed in section 1, this is the resulting impact from all these elements that informs on the capacity of the counterparties to meet financial institutions' expectations (*e.g.* capacity to find liquidity to pay back debt; capacity to generate profits to provide financial return on equity).

### The data challenge depends on the type of portfolio counterparty and target user

**In operational terms, the data challenge to service providers varies depending on the type of counterparty and the end-user.**

Analyzing corporate counterparties may require in particular multiple layers of granular information. Corporates can comprise multiple entities and cumulate several activities. They potentially have multiple assets immobilized in large geographic perimeters, but also complex exposure through their networks of suppliers and market outlets. Financial institutions typically do not have detailed information on the assets and composition of the value chain. Moreover, they can potentially manage portfolios that involve multiple corporate counterparties, which saturates their ability to access and process this information on a case-by-case basis.

Analyzing physical climate risk to projects is challenging although it may face lesser data barriers. Usually it covers a limited number of specific sites that can be located more easily and analysis can be done at a higher resolution. The financial institution that engages in project finance is typically in a position where project officers can find the most information. The challenge remains on defining the type of hazard, but also the sensitivity to these hazards and adaptive capacity.

Analyzing sovereign counterparties is challenging in terms of combining analytical frameworks. The current approach is to produce climate risk profiles that are compatible with existing analytical frameworks on sovereign risks. These are essentially macro frameworks with indicators on economic, financial and social strength. The challenge is then to catch indicators that reflect correctly the local exposures and to make them compatible with the broader indicators on sovereign risk profiles. Financial institutions typically work with information from rating agencies and they may not produce such information by themselves.

The service providers have developed a range of strategies to accommodate for this granularity challenge.

## 2.8.2. Tackling the issue of granularity of the exposure to climate hazards

### The component of exposure defined by climate hazards location

The characterization of exposure to climate hazards can make use of different scales of climate information, from global to local (up to a resolution in the order of 10 km). Climate models used to understand global warming cover the entire globe and do not provide information at the scale of individual countries or sub-countries. Two types of methodologies exist to downscale information to a local level. Dynamic downscaling resolves explicitly the physics and dynamics of the regional climate model. This is done with models that were designed to target a specific region (*e.g.* the ALADIN-Climat model covers France with a 12 km resolution) or with global models that are able to zoom in on a given region (*e.g.* the Meteo-France ARPEGE-Climat model has a 12 km resolution on France and neighbouring countries, 50 km on the Atlantic, Africa and part of Asia, 150 km in other regions). The other methodology to downscale information is statistical. It uses data from global models and statistical relationships between global parameters calculated in the model and local variables to be determined (*e.g.* the NASA has downscaled all IPCC model data to 25 km resolution globally[32]).[33] The selected approaches may use different types of methodologies to generate information on climate hazards, but the complete exploration of data generation is out of the scope of this report.

In order to characterize exposure to climate hazards, some approaches are also using regional information on non-climatic components. For instance, exposure to river floods may vary substantially depending on geophysical parameters (*e.g.* topography of the riverbed) and location of socio-economic agents near the locally exposed area. This information may be necessary to characterize some climate-related hazards at a local scale, with geophysical proxies or population exposure data. In some instances, such information may be indicated at asset-level (Four twenty Seven for corporate assets and infrastructure, Carbone 4 for infrastructure).

As shown in section 2.4.2, the final risk information is often aggregated across hazards. In some instances, this is a consequence of the methodology. For instance, Four Twenty Seven identifies the exposure of corporate supply chain at country scale using a country risk indicator. This indicator encompasses the risk of the country to several hazards at the same time.

### The component of exposure defined by counterparty value chain location

The exposure of counterparties to a climate hazard also depends on the location of their physical assets, the location of their upstream and downstream value chain, and logistics, as shown in **Figure 14**.

**Only a few approaches explicitly address the exposure of upstream value chain. When it is considered, the exposure of suppliers appears at sectoral and country level.** Four Twenty Seven approaches supply chain networks at sectoral and country level. They start with the counterparty's country and sector of activity, and approach their supply chain using trade-flow data. This allows reconstituting the network of

32 https://cds.nccs.nasa.gov/nex-gddp/.
33 http://www.meteofrance.fr/climat-passe-et-futur/projections-climatiques.

countries involved in the supply chain of a counterparty's activity, based on activity sector and location of operations in a given country.

**Some approaches use asset specific methodologies to locate facilities of each counterparty**. This is where big data currently makes its larger contribution. Four Twenty Seven and Carbon Delta use large databases to map physical assets of the corporate counterparties company at a longitude-latitude coordinate level (*e.g.* Four Twenty Seven uses an 800,000-facility database). Carbone 4 locates the assets at a scale depending on available data. Trucost also employs user inputs to inform their model on how the counterparty interacts with the water resource at facility level.

**Some approaches also use asset or revenue specific methodologies to locate downstream value chain of corporates.** Four Twenty Seven, Carbone 4 and Carbon Delta are able to identify the country of sales with databases such as Factset for example.

**Some approaches also use top-down methodologies to provide aggregate picture of impacts to the counterparty, at sectoral level.** Mercer starts from sectoral activity of the counterparty to identify the counterparty with a sectoral sensitivity profile and combine it with a climate scenario. This avoids identifying datasets on exposure of counterparties and their value chain.

### 2.8.3. Tackling the issue of differences of sensitivity and adaptive capacity depending on specific agents

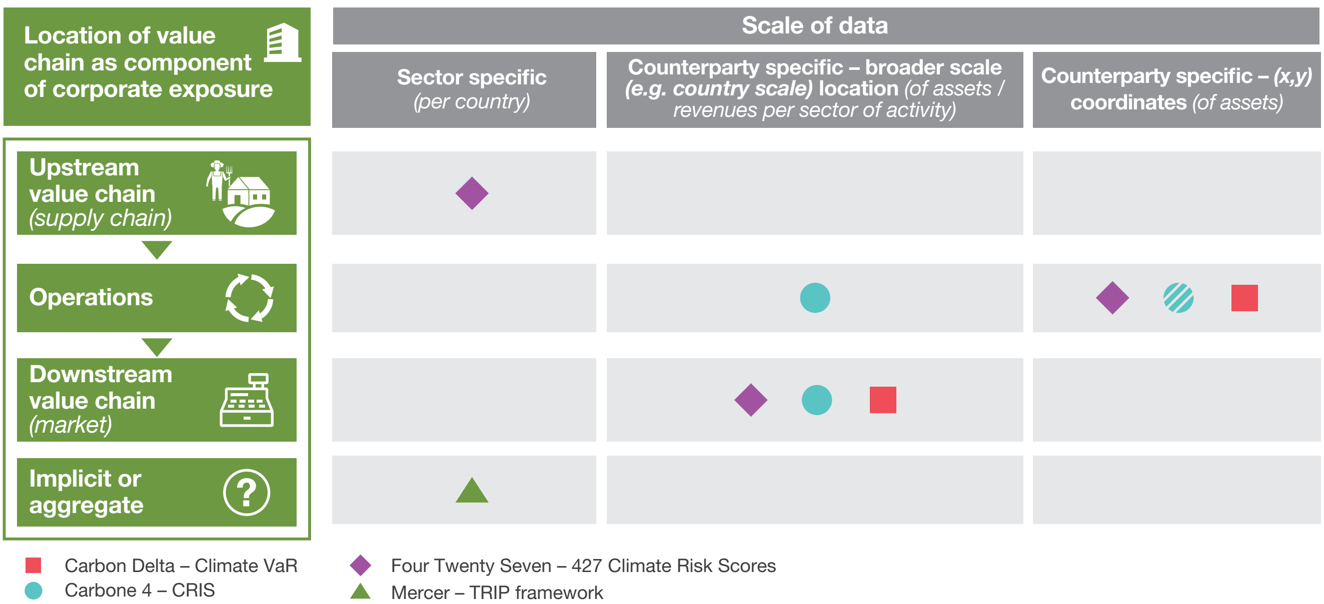
The characterization of impacts to a given counterparty may also benefit from different scales of information. The sensitivity and adaptive capacity of a counterparty may depend on its macro environment, its sector of activity, or more specific information about the counterparty and its value chain.

#### Characterizing the sensitivity of counterparties remains a major challenge

**The sensitivity of counterparties is currently a highly challenging parameter, approached most of all at sectoral level and accounting for variable scopes.**

For a given counterparty, one could ideally characterize several sensitivity parameters specific to the combination of: a hazard; its impact on an aspect of the counterparty value chain (*i.e.* upstream, operation, downstream); and further defined over a certain economic aspect (*i.e.* macro determinants of the business environment, labor, natural resource, different types of immobilized capital in the form of warehouses, factories, machines, etc.). In addition, the characterization of the counterparty sensitivity may depend on its macro environment, its sector of activity, or more specific information about the counterparty and its value chain.

**FIGURE 14. GRANULARITY OF CORPORATE COUNTERPARTY'S EXPOSURE**



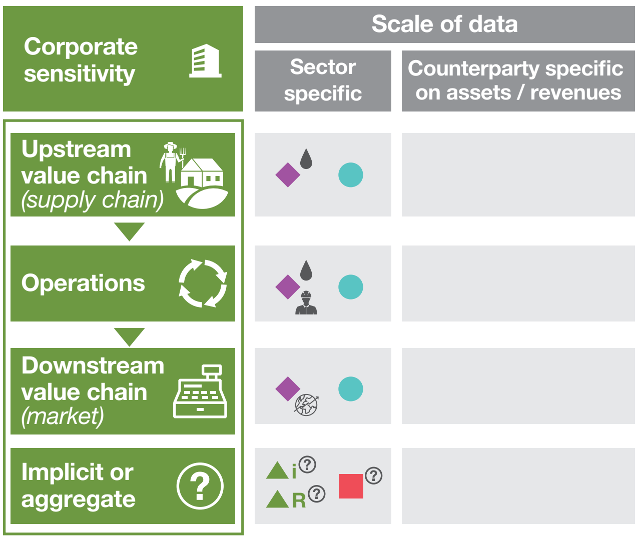

*Source: Authors (2018)*

While the characterization of counterparty sensitivity may benefit from different scales of information, in practice it is approached through **sectoral analysis** for some approaches focusing **on corporates** (as shown on **Figure 15**) **and otherwise** it is approached with **less granular data.** Current practices show that **sensitivity parameters cover variable scopes in terms of aspect of the counterparty value chain and economic aspects**.

The methodology and sources to generate these sensitivity parameters varies across approaches. This is particularly visible in corporate risk analysis as shown on **Figure 15**:

- Carbone 4 chooses to cover a wide range of sensitivity parameters per sector that are hazard-specific and that account for a number of financial items with a value chain approach. To do so, Carbone 4 uses a correlation matrix at sectoral level (60 sectors), that discusses the intensity of impact to a number of explicated financial items with a value chain approach and specifically to a type of hazard. The sources for this are based on a broad literature review.
- Four Twenty Seven chooses to produce sensitivity factors per element of the value chain, with some focus on a selection of economic aspects.

**FIGURE 15. GRANULARITY OF CORPORATE COUNTERPARTY'S SENSITIVITY**




- Carbon Delta – Climate VaR
- Carbone 4 – CRIS
- Four Twenty Seven – 427 Climate Risk Scores
- i Mercer – TRIP framework / Physical Impact factor
- R Mercer – TRIP framework / Resource Availability factor
- Impact on natural resource
- Impact on macro business environment
- Impact on labor
- Focus on certain types of impacts not made explicit

*Source: Authors (2018)*

  - Four Twenty Seven characterizes the sensitivity of the counterparty to its upstream value chain exposure at sectoral level, with a focus on natural resources. Operationally, Four Twenty Seven's Natural Resources indicator analyzes the intensity and efficiency of the sector when using resource inputs that are climate sensitive (*e.g.* water, energy and land use).
  - Four Twenty Seven characterizes the sensitivity of the counterparty's operation based on facility level characteristics and sectoral level analysis (including sectoral resource intensity) and it is hazard-specific. The sensitivities capture energy intensity, labor sensitivity to heat, and water intensity.
  - Four Twenty Seven characterizes downstream sensitivity with a specific focus on weather sensitivity of sectoral sales based on historical data.
- Carbon Delta chooses to provide sensitivity parameter with no specific focus on a particular element of the value chain or economic aspect. This is linked to the underlying methodology that focuses on business interruption, which can arise from any economic aspect along the value chain. Operationally, Carbon Delta provides sensitivity when calibrating a sectoral cost function with news database that informs on business interruption.
- Mercer chooses to analyze sensitivities with no specific focus on a particular element of the value chain but with separation on the type of economic impact. It produces a sectoral sensitivity profile on physical impacts (the "I" factor in Mercer's framework) and another one on resource availability (the "R" factor). The methodology is essentially top-down, starting from GDP losses simulated with damage functions of the FUND IAM. The sectoral sensitivity builds on judgmental allocation per economic sector of GDP losses. The simulated losses in FUND model arise in several domains of impacts that are not necessarily economic sectors. Hence the need to allocate impacts to the different economic sectors. For each factor, the sectoral sensitivity also reflects the sensitivity of the economic sector to different perils that have a different weight in the I or R factors. The FUND IAM does not necessarily allow to make explicit link on a specific hazard and the sensitivity of a counterparty. This model is not hazard-centric and it covers the macro-economic consequences of climate-related hazards as framed in IAM-generated scenarios. Such scenarios identify explicitly some of the physical climate hazards that may trigger adverse consequences to the GDP, and otherwise they mention directly a type of impact with no explicit mention of the underlying climate hazards.

In terms of project analysis, the regular version of Aware for Projects by Acclimatise also uses climate-sensitivity ratings at the scale of sub-sectors (19 primary sectors and over

130 sub-sectors) and the advanced functionalities allow users to define the climate-sensitivity at the asset level.

Generally, any type of methodology incorporates some expert judgment to complement the analysis of the counterparty's sensitivity.

Few approaches also treat explicitly how corporate counterparties are sensitive to the broader socio-economic context at the country scale (Four Twenty Seven mentions this aspect with exposure to country risk in each part of the value chain. We mentioned this aspect of Four Twenty Seven's methodology as a component of counterparty exposure to countries.) while it is necessarily the case for sovereign counterparties (Four Twenty Seven, Carbone 4, Moody's Investors Service).

#### Adaptive capacity is integrated only for sovereign counterparties

**Adaptive capacity is little integrated in existing approaches with major challenges on corporates as opposed to sovereigns and projects.**

Adaptive capacity has been integrated in the analysis of sovereign counterparties (Carbone 4, Four Twenty Seven and Moody's Investors Service) for instance through indicators of development level, fiscal flexibility, government policies. Acclimatise Aware for Projects also shows integration of this aspect in the analysis of infrastructure projects. The coping capacity is predefined at sectoral level or it builds on user inputs for asset-level information (*i.e.* the user is asked to select sensitivities to climate-related indicators – data that have had pre-determined thresholds already applied –, that define the limit of the project coping capacity to this variable). There has been lesser integration of adaptive capacity on the side of corporate counterparties.

Already existing adaptation measures may also affect the exposure, sensitivity and adaptive capacity of the counterparties. These are difficult to account for explicitly in terms of data, unless end-users have inputs to provide. The use of expert judgments is also a way to complement the analysis of the counterparty's adaptive capacity.

More generally, the focus on a type of impact or specificities of the counterparties did not always appear transparent in our research, sometimes for methodological reasons. For instance, damage functions in IAMs provide information on categories of impacts at a global level or at a regional level for FUND. These functions are generated and calibrated on a range of studies that may be representative of specific contexts.

### 2.8.4. A categorization of approaches based on analysis scale and tools

#### The scale of analysis could separate top-down and bottom-up methodologies

**It is not obvious to put each approach in a single box based on their strategy to deal with the granularity of climate impacts.**

Previous sections show that a given approach can use different scales of analysis for different aspects of risk. In addition, the scale of analysis may result from the combination of data with heterogeneous granularity. This occurs because the data challenges are different for each counterparty (*i.e.* project, sovereign, corporate) but also for each aspect of risk to a given counterparty (*i.e.* exposure, sensitivity, adaptive capacity).

Several scales of socio-economic analysis appear in existing approaches: micro/bottom-up; sectoral; macro/top-down. Micro analysis uses data from physical asset level to counterparty level. It can also be bottom-up when it aggregates micro results for instance up to a sectoral level. Sectoral analysis uses data and provides analysis at the level of an economic sector. Macro analysis uses data at country or regional level. Top-down approaches allocate impacts to economic sectors or counterparties.

To put things shortly, the overall methodology of existing approaches could be categorized as follows: Four Twenty Seven, Carbone 4, Carbon Delta, WRI, Trucost and Acclimatize provide essentially bottom-up approaches, while Moody's Investors Service and Mercer provide essentially top-down analyses. However, previous sections of this report show that several approaches carry out a combination of sophisticated analyses on various types of counterparties, with different datasets for each element of risk to a counterparty. Therefore, each approach listed in this report can potentially combine several scales of analysis as further illustrated below:

- **Elements of macro analysis:** Macro analysis is used on sovereigns (Moody's Investors Service, Four Twenty Seven, Carbone 4). Some country-level elements may also be incorporated into the analysis of other types of counterparties. For instance, Four Twenty Seven integrates the climate resilience of the country where the company sells its products, as a macro element of the company's exposure.
- **Elements of top-down analysis:** The methodology can also start from a macro analysis reallocated at a smaller scale, such as sectoral scale. For instance, Mercer uses estimates of GDP loss that are ventilated across economic sectors to build sectoral sensitivity profiles to physical impact and to resource availability impacts.

- **Elements of sectoral analysis:** Some sectoral elements feed the analysis of individual corporate counterparties. For instance, Carbone 4 includes sectoral considerations to analyze the climate sensitivity of corporate counterparties' financial statements. Four Twenty Seven also includes sectoral sales weather sensitivity in market risk analysis, sectoral dependence on climate-sensitive resource in supply chain risk analysis, or sectoral resource intensity in operation risk analysis. The regular version of Aware for Projects by Acclimatise also uses climate-sensitivity ratings at the scale of sub-sectors and coping capacity is predefined at this level.
- **Elements of micro analysis:** The advanced functionalities of Aware for Projects by Acclimatise allow users to define the climate-sensitivity and coping capacity at the asset level, based on the sub-sector the asset operates in. Four Twenty Seven also uses company's revenues per country to identify the exposure of sales to country climate risk. Carbone 4 also analyzes exposure of corporate counterparties at the scale of business units (defined as geographic and sectoral pairs) and it is hazard specific. The methodology identifies per country the location of fixed assets or revenues depending on sectoral capital intensity.
- **Elements of bottom-up analysis:** The approaches may also aggregate information on assets, business units, facilities or companies up to a broader object. For instance, Carbone 4 generates the risk rating of a company through aggregation of the hazard-specific risk rating to each business unit of the company (meaning aggregation across activities, countries and hazards). Carbon Delta calculates a company's exposure to climate impacts on revenues based on company's facility data and location of sales data. Vulnerability to revenue impacts is calculated based on facility level data per type of climate hazard. The vulnerability to specific hazards is presented as a sectoral cost function. It is calibrated based on a historical news database showing how past weather events interrupted businesses. Four Twenty Seven analyzes operation risk to a company based on identification of all the facilities of the company. This exposure is combined with sensitivity factor that includes specific details on the facility and type of hazard.

### The data treatment tools can also separate the methodologies

The methodologies can also be categorized depending on the strategy chosen to generate information on impacts through combination of different datasets. Since these strategies are the nexus of these proprietary approaches, it is no easy task to provide completely transparent picture for competitive reasons. Broadly speaking, the following categorization can apply:

- **Mixed correlation matrix:** Some methodologies (Four Twenty Seven, Carbone 4) create correlations between hazards and types of impacts with a combination of different sources. Service providers may use this strategy in different ways. Four Twenty Seven prioritizes data analysis regardless of data intensity. They carry out site-specific modelling of climate risk at the facility level for operations. The correlations can focus for example on the use of a climate-sensitive resource by the counterparty, or also on the susceptibility of its value chain to physical damages. This type of approach can also help some bottom-up approaches reduce their data intensity by working on priorities about the types of risks that should receive detailed attention. For instance, Carbone 4 looks for data depending on the correlation between hazards, economic impacts along the value chain and sector of activity. They also focus on locating sales or operations depending on the capital intensity of the counterparty's activity.
- **User-driven parameters:** Some methodologies are user-driven, they use sensitivities as declared by the end-user (Acclimatise).
- **Statistical treatment:**
  - Some methodologies rely on **statistical regressions to project variables. This is based on estimation of the variable depending on other variables**. For instance, the WRI estimates water demand as a function of other variables (*e.g.* GDP, urbanization). The function is estimated based on past data and projection is based on projections of the other variables (*e.g.* IPCC projections of GDP).
  - Some methodologies rely on **damage functions** that provide a link between a climate variable and its impacts on different socio-economic aspects (*e.g.* % GDP loss as a function of temperature). The quantification of the link between the variable and the impact requires calibration based on diverse sources of data (Carbon Delta, Mercer).
  - Some methodologies use **environmental economics techniques to monetarize** losses in the natural capital. For instance, Trucost internalizes the systemic consequences of the facility using water. This is done in the form of an additional water cost to the facility. The methodology builds on the Total Economic Value Framework (TEV) adapted from environmental economics.
- **Financial modelling:** Several service providers add a further step of **financial modelling** (Carbon Delta, Mercer). This consists in plugging impacts to the counterparty into a financial valuation model. This yields for example a correction of securities' market price due to physical climate impacts. These models belong to the

widespread family of Discounted Cash-Flows models. Climate impacts factor in the model through correction of the cash-flow sequence, or through correction of the risk premium into the discounting factor (which integrates risk in terms of return volatility, but not in terms of structural changes).

Service providers characterize impacts in different ways for they use various scales of analysis and various methodologies to acquire and combine the data. The same methodology is not always applied to the same type of impact on a given counterparty. This creates **differences in the nature of information within and across types of counterparties**.

## 2.9. Strategies to deal with the long-term uncertainty of future climate

### 2.9.1. The question of uncertainty is unavoidable in risk frameworks

The current state of scientific knowledge leaves no doubt about the existence of current and future climate change and the potential for large impacts. However, a certain amount of uncertainty[34] remains in climate futures – due to its prospective nature, and the way socio-economic systems may contribute to such a change and adapt to it over the next decades. The likelihood of alternative futures is therefore difficult to estimate, which characterizes uncertainty as defined in this report. Starting from this, what can be done with this uncertainty when analyzing potential impacts from climate change?

In a risk framework, the place of uncertainty poses questions since, by definition, uncertainty does not appear directly in the formulation of risk. However, the uncertainty remains and any risk framework will have to address it even in a passive way.

**In a nutshell, uncertainty is naturally present in forward-looking issues such as climate change. In this field, uncertainty on physical climate change has the advantage to be well understood, while the bigger challenge remains "usual" uncertainty on socio-economic evolutions. All the approaches on physical climate risk analysis necessarily face this issue. Existing approaches from service providers include some first steps to address uncertainty in a more active way than in a pure probabilistic risk framework.**

34 For more information about the links between risk and uncertainty, see the Thematic glossary in appendix of this report.

### 2.9.2. Tackling uncertainties regarding physical climate change

The sources of uncertainty on climate change have the advantage to be well documented. Climate uncertainty arises from different sources depending on the time, spatial scale and variable under analysis. Following the conclusions of the IPCC's CMIP5 project, in the case of global temperature projections, internal variability of the climate and inter-model uncertainty are dominant in the short-term, while factors such as GHG emissions are dominant in the end of the century.[35]

Current approaches treat this uncertainty in several ways that reckon some well-known patterns of decision-making under uncertainty as defined by economic scholars (Etner, Jeleva and Tallon, 2012).

Uncertainty on future climates can be treated by considering the worst-case scenario (*e.g.* Four Twenty Seven; Acclimatise), or a range of climate change scenarios consistent with different scenarios of GHG emissions (Carbone 4, WRI). In order to bypass uncertainty on climate futures, some approaches also make use of observed weather data to extrapolate some scenarios of future weathers (Carbon Delta). This goes in pair with a short-term horizon of analysis (15-year time horizon).

Model uncertainty also receives special treatment in several approaches. Several service providers use a multi-model approach for climate projections (*e.g.* Carbone 4, Four Twenty Seven, Acclimatise, WRI). Acclimatise uses an indicator on Global Climate Model agreement. This indicator is integrated when weighting the exposure to location-specific climate hazard data. Carbone 4 provides information on the confidence about data quality for climate projections. Mercer also carries out a review of FUND damage functions that have critical contribution to damages in the study period. They are reviewed for reasonability and directional accuracy based upon current research and expert judgment. When the results were not satisfying, Mercer provided corrections with additional data and modeling.

### 2.9.3. Tackling uncertainties regarding socio-economic impacts

As usually encountered in finance, there is large uncertainty about socio-economic vulnerability (to climate hazards in the frame of this report). The vulnerability of today's socio-economic systems is uncertain due to data constraints. The evolution of socio-economic systems themselves is also uncertain but important to analyze. Indeed, the vulnerability to future climate conditions may integrate the joint variation of climate hazards and of socio-economic systems in terms of adaptation measures or evolution of exposure, sensitivity and adaptive capacity.

35 https://www.climate-lab-book.ac.uk/2013/sources-of-uncertainty/.

At this stage, the service providers essentially deal with uncertainty on how the counterparties in their current state are vulnerable to climate hazards. This relies on a range of analyses as explained in the previous **paragraph 2.8** on sensitivity and adaptive capacity. More specifically, Acclimatise makes an active treatment of the uncertainty of the project vulnerability to climate hazards. Their strategy relies on absolute thresholds on climate variables that define the situations that are broadly unbearable for projects across within a wide range of sub-sectors (*i.e.* outside of the coping capacity of the project). The thresholds are pre-defined by Acclimatise through post-processing of climate-related data sets. Carbone 4 uses literature review and expert judgment to select sources and indicators considered critical at sectoral level. Carbon Delta calibrate their cost functions with impacts observed at counterparty level. Mercer uses expert judgment directly to allocate GDP impacts across economic sectors when building sensitivity profiles. Subjective judgments are used as a classic manner to provide a unified discourse where it is necessary to provide synthesis of complex and fragmented knowledge.

Mercer is the only example that addresses explicitly the evolution of socio-economic systems. However, they go with the assumption that socio-economic systems do not undergo major structural change (Mercer motivates this choice by the current state of financial practices). The literature on vulnerability and impacts provides scenarios but they are not used at the moment, possibly because their scope of application does not fit current methodologies or maybe because this is not the primary purpose of the analysis.

**The approaches in this mapping reveal that uncertainty on physical climate impacts is present anyhow even in risk frameworks. The approaches in this mapping show diverse active ways to address it, with focus on climate futures. Analytical frameworks on potential impacts of climate change could find benefits in addressing uncertainty more centrally in the analysis**.

As a summary of this comparative analysis of the state-of-the-art in physical climate risk analysis for financial actors, existing approaches demonstrate the current capacity to develop methodological options that target a range of financial practices. However, the methodologies include different choices in terms of data inputs, scope of impacts and analytical approaches.

# 3. Concluding remarks and the way forward to develop physical climate risk analysis in finance

**KEY MESSAGES OF SECTION 3**

- While financial institutions get more aware of the pressing climate issue, they still need to integrate physical climate risks in their decision-making.
- Service providers have the potential to develop further services but face challenges in terms of data availability and imperatives of commercial business models.
- Further development of climate services may benefit broadly from a co-design process between scientists and financial actors in a general interest configuration.

## 3.1. Physical climate risk is a pressing issue that financial actors are still to integrate

Physical impacts from climate change are occurring now and will continue to increase in the near term regardless of GHG emission scenarios. Physical climate risks arise from chronic or acute changes related to temperatures, winds and water cycles or combinations of these different aspects. Their consequences may propagate to financial institutions and their counterparties through complex channels. The direct exposure of a counterparty's or financial institution's operation (through physical assets, labor or dependence to natural resources) may represent only a fraction of their exposure to the risk. Consequences of climate change to a counterparty may also arise from exposure of its value chain (*i.e.* supply chain and market) or through consequences in the macro business environment (*e.g.* raise in insurance premiums). This justifies the need for a specific analysis of physical climate risks.

Financial actors are getting aware of the subject, as they start to mention this issue in their reporting. Yet they do not necessarily take action, or it is an experimental exercise at this stage often relying on external services.

## 3.2. Service providers are developing sophisticated methodologies but face barriers to exploit their full potential

The service providers contribute to the dynamics of the momentum on climate-related risk integration into financial decisions. Existing approaches demonstrate the capacity of specialized service providers to mobilize a diversity of methodologies and data to deliver targeted analysis of physical climate risk. Taken together, they allow covering a wide range of hazards, impacts, counterparties and sectors at different scales and horizons.

However, existing approaches show the difficulty to provide information that meets all of the TCFD recommendations at the same time, namely: quantified; with direct link to financial impacts; transparent; relevant and comparable across a wide spectrum of counterparties; addressing impacts from future climate and relying on forward-looking socio-economic data.

In line with the motivations for building the TCFD in the first place, it can be noted that data gaps still hamper the development of more complete and granular analysis of physical climate risk to financial actors. Data availability is challenging especially on corporate counterparties. Information would be needed at macro and sectoral scale on the business environment but also at counterparty or asset scale to define exposure, sensitivity and adaptive capacity to diverse types of impacts:

- Exposure depends on the location of assets and sales along the value chain of the counterparty and the local characteristics of hazards.
- The sensitivity may depend on sectoral aspects such as the dependence to natural resources or the conditions of offer and demand along the value chain and the bargaining power of the company, but also specific characteristics at the asset level (*e.g.* the characteristics of buildings may impact their sensitivity to climate hazards).
- The capacity of the company to cope with impacts when they arise also depends on multiple aspects at various scales. It involves specific behavior at the counterparty (*e.g.* the diverse sources of liquidity or the insurance cover; risk management process; a management style that enables companies to better process and assimilate new information; a culture of innovation; proactive engagement in responsible corporate adaptation), sectoral capacity, as well as the very broad characteristics of the socioeconomic system that influence the functioning of the counterparty. In this frame, the evolution of the insurance cover is also a major stake with difficulties on the data side.

There is currently a challenge to gather counterparty-specific data on these different aspects. The data gap also affects the capacity to provide monetarized financial estimates of climate impacts to a counterparty. Monetarization techniques use damage functions and data on the cost of past natural catastrophes. These are still limited to some hazards and some geographies, and disseminated in several studies each covering a small but detailed climate change impact. Estimation of financial impacts also requires the macro and micro information to reveal counterparty-specific impacts.

In addition to the data gap, service providers may face challenges in terms of business environment. The most mature analytical approaches have been developed so far in a configuration where financial institutions are potential subscribers. This may hamper thorough exploration of potential developments. While the inclusion of financial institutions takes various forms in the development process of existing approaches, this configuration may constrain the ability of service providers to propose some gradual steps towards innovative solutions with existing data and thorough developments as much as they would want.

## 3.3. ClimINVEST and the way forward: a co-design approach for the general interest

Relevant developments can be undertaken right now, while acknowledging that one research project cannot solve the entire concern on data availability. Ideally, many actors call for counterparties to disclose the sets of information on their exposure to physical climate risks, following the FSB's TCFD. Such disclosure may become available progressively, but not shortly. Another complementary option would be to rely on big data methodologies to acquire this data from other public databases as much as possible, but counterparty's disclosure might remain necessary for specific information.

The ClimINVEST project proposes an alternative pathway to develop physical climate risk analysis, and further build capacity of financial institutions and service providers to produce actionable information. The ClimINVEST project aims at developing actionable action with a co-design approach that creates a bilateral link between climate scientists and diverse financial actors without the stakes of commercial offer and demand. This co-design process will consist in developing methodologies and tools in the coming two years to answer – at least some of – the tailored needs for information at financial institutions'. It will of course build on existing methodologies to provide missing pieces of physical climate risk analysis and will provide transparent and publicly available outputs. The idea is to provide information that is scientifically relevant and that can contribute to actual integration of physical climate risk in financial decision-making.

This non-commercial co-design process will lead to explore concrete financial decision-making contexts. This may help understand how each context creates seeming barriers to integrate completely physical climate risks. For example, existing literature shows in general that financial actors may perceive some barriers to integrate climate risks in decision-making due to lack of "materiality". This may link to focus on short-term horizons and larger impacts; to the prevalence of past events in the analyses; or to specific ways to manage uncertainty (*e.g.* with static probability distributions and trade-offs to account for events with low likelihood and large impacts). Understanding better these specificities will help define solutions to produce actionable information on physical climate risks.

This non-commercial co-design process will also lead to explore thoroughly the available analytical frameworks on the side of scientists, as well as the richness of scientific data and indicators. Scientific analytical approaches may help overcome seeming barriers arising from financial decision-making frameworks. With the same example of "materiality" concerns, scientists may propose analytical frameworks. Robust decision-making is a technique that can help reduce the focus on short-term and likelihood of events.[36] Designing tales of future weather could also help financial actors make a link between concrete impacts they want to avoid, their connection with a future climate and their potential of occurrence in cooperation with climate scientists.[37] The co-design process can also help scientists provide a broader picture of the available climate data, to define further climate hazards or combinations of unprecedented climate hazards and to use further forward-looking analysis (*e.g.* through designing tales of future weather).

36 The decision-maker recognizes the existence of uncertain scenarios, but does not have to pick one. Instead, he chooses the potential situation he considers unbearable for example in case of project finance. Then he observes if the project is robust against the range of alternative scenarios. Thus, the focus is on the range of impact magnitude and not necessarily on the likelihood of impacts or the expected horizon of materiality.

37 A tale of future weather is a description of weather conditions that could typically occur in future climate conditions. They are generated in weather models, where the future climate conditions are used to set the boundary conditions of the model. It is also possible for financial actors to define the type of impacts they want to avoid from given weather conditions, and then scientists can help understand if it plausibly matches with a set of climate conditions. This can be a complement to robust decision analysis, to help financial actors define the types of climate futures they consider unbearable. Starting from concrete weather events is also a good way for financial actors to launch the discussion with counterparties on the conditions that may trigger their vulnerabilities. This methodology is also interesting to think about combinations of weather events that may occur in a future climate. (Hazeleger *et al*, 2015).

The ClimINVEST research project will also foster the production of actionable information on physical climate risk thanks to a general interest approach. The project will provide financial institutions with transparent methodology based on publicly available information with the control from climate scientists. Together with the co-design process, this will help disseminate the methodologies and potential indicators to a large panel of financial institutions. In addition, this general interest research project may also help prioritize developments that require large teams and combined expertise over longer periods. Depending on the results of the co-design process, this could be for example decadal information or framing the future climate in the frame of potential weather conditions.

# Annex 1: Glossary



This thematic glossary clarifies the meaning of terms as used in this report. IPCC definitions are used directly when relevant, or they are compatible with this glossary.

## Defining Risk

**Risk:** following the approaches listed in this report, risk is the potential consequences (negative – *i.e.* downside risk – or positive – *i.e.* upside risk) arising to a specific system – such as an ecosystem, a company, a country – exposed to a hazard, and depends on the specific vulnerability to this hazard of the system assessed.

**Risk and Uncertainty:** this report integrates uncertainty as part of climate risk analysis.

Economic and financial theories distinguish risk and uncertainty based on Frank Knight (1921):

- Following Knight, **risk** refers only to situations where the observer can **objectively** identify and quantify precisely each hazard and, for each of them, characterize the potential impact they might trigger. In other words, the situation can be described fully with probabilities on the likelihood of hazards and quantification of their consequences. This concerns situations where the theoretical statistical law is known in advance (*e.g.* when rolling a perfect six-face dice, you know in advance that you have 1/6 chance to obtain each face and nothing else can happen) or inferred from past experience (*e.g.* riskiness of young male population on a scooter extrapolated from long series of past observations).
- By complementarity, **uncertainty** applies to every other situation. According to the IPCC, it is a state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, or uncertain projections of human behavior (Agard *et al.*, 2014).

In practice, uncertainty is present in most situations and requires an interpretation from decision-makers. In particular, one option to make decisions in a context of uncertainty is to treat it in a risk framework. The decision-maker identifies and quantifies **subjectively** the hazards and their potential impacts. Other decision-making rationales can be used to deal with uncertainty out of a risk framework (*e.g.* robust decision-making).

## Analyzing Risk

### Risk broken down

According to the IPCC, risk results from the interaction of **vulnerability**, **exposure**, and **hazard**. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the **impacts** if these events or trends occur (Agard *et al.*, 2014).

**Hazard**: the potential occurrence of the trend or event that has adverse consequences to the system of interest. It comprises a description of the likelihood and magnitude of the event or trend.

**Exposure**: the presence of the system of interest in a place and setting that could be adversely affected.

**Vulnerability**: the propensity or predisposition of the system to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

**Sensitivity:** the degree to which a system of interest is affected, either adversely or beneficially, by a change.

**Adaptive capacity:** the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (Agard *et al.*, 2014). The adaptive capacity may increase or decrease over time. This may arise with changes in available resources to conditions in the system of interest, or with cumulative effects of more frequent critical events. A catastrophic event may also reduce permanently the coping range of the system if the system is not able to recover its functionality over time (*i.e.* limited resilience). (Smit and Wandel (2006))

**Coping capacity:** the ability of people, institutions, organizations, and systems, using available skills, values, beliefs, resources, and opportunities, to address, manage, and overcome adverse conditions in the short to medium term (Agard *et al.*, 2014).

**Resilience:** the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (Agard *et al.*, 2014).

**Impact** refers to the negative consequences of a hazard exposure that triggers a specific aspect of the system's vulnerability (*i.e.* one hazard may trigger several aspects of vulnerability and thus several impacts to the system).

**Adaptation:** the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to "moderate or avoid harm" or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Adaptation occurs through an array of actions that can be categorized in different ways:

- Incremental (Adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale) vs. Transformational (Adaptation that changes the fundamental attributes of a system in response to climate and its effects);
- Spontaneous (in response to experienced climate and its effects, without planning explicitly or consciously focused on addressing climate change) vs Planned;
- Soft (information, prevention or organisational changes) or Hard (protection infrastructure, re-dimensioning of networks, etc.);
- Reactive (implemented once changes have been recorded) or anticipating changes;

(Agard *et al.*, 2014; I4CE *et al.*, 2015).

**Hotspot:** a geographical area characterized by high vulnerability and exposure to climate change (Agard *et al.*, 2014).

### Risk Analysis and Management process

**Risk analysis:** this is the process of identifying and assessing risks.

**Risk identification:** the listing of the combinations of hazards, exposure and vulnerability that may create a risk to the object of interest. This can comprise a pre-screening that identifies key risks in order to prioritize further risk assessment.

**Risk assessment:** the qualitative and/or quantitative scientific estimation of risks (Agard *et al.*, 2014).

**Risk management:** plans, actions, or policies to reduce the likelihood and/or consequences of risks or to respond to consequences (Agard *et al.*, 2014). The main categories of risk management strategies are: risk transfer; risk retention; risk mitigation; risk avoidance.

- **Risk transfer:** the practice of formally or informally shifting the risk of financial consequences for particular negative events from one party to another (Agard *et al.*, 2014).
- **Risk retention:** the practice of accepting to bear a risk and deciding that bearing this risk does not deserve active risk management strategy.
- **Risk mitigation:** the lessening of the potential adverse impacts of physical hazards (including those that are human-induced) through actions that reduce hazard, exposure, and vulnerability (Agard *et al.*, 2014).
- **Risk avoidance:** the practice of refusing to bear a risk by limiting exposure to the system at risk. In the case of financial portfolio, avoiding the risk born by an asset means avoiding to bear the asset in portfolio.

**Risk monitoring:** the process of monitoring the implementation of the risk management strategy, and the relevance of the risk management strategy depending on the updates from risk analysis.

## Analyzing Physical Climate Risk

### Defining climate and climate change

**Climate**: the statistical distribution of all the possible **weathers** over long periods and large geographies. In other words, the weather is what you get in a specific date and geography whereas climate is what you expect over time and in large geographies.

**Climate change:** a change in the state of the climate that can be identified (*e.g.*, by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings (including human-made forcings such as GHG emissions) (Adapted from Agard *et al.*, 2014).

### Physical Climate risk broken down

**Acute physical climate risk:** climate risk that is event-driven such as increased severity of extreme weather events (*e.g.*, cyclones, droughts, floods, and fires) (TCFD, 2017a).

**Chronic physical climate risk:** climate risk that relates to longer-term shifts in precipitation and temperature and increased variability in weather patterns (*e.g.*, sea level rise) (TCFD, 2017a).

**Climate Impacts** (Consequences, Outcomes): effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called **physical impacts** (IPCC (2014) WGII Glossary: “impact” entry).

**Climate hazard**: the potential occurrence of a natural or human-induced physical climate event or climate trend that may cause harmful impacts to natural and socioeconomic systems. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts (Adapted from IPCC (2014) WGII Glossary).

**Emergent risk:** a risk that arises from the interaction of phenomena in a complex system, for example, the risk caused when geographic shifts in human population in response to climate change lead to increased vulnerability and exposure of populations in the receiving region (Agard *et al.*, 2014).

## Climate hazards (illustrative list, including physical impacts)

The following list provides examples of potential harmful trends and events that may become more frequent and intense with climate change.

### Wind

**Storm:** violent winds (in the order of 100 km/h) in an extended area. (*Source: Météo France* - http://www.meteofrance.fr/prevoir-le-temps/phenomenes-meteo/les-tempetes#)

### Water

**Drought:** a period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term; therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, shortage of precipitation during the growing season impinges on crop production or ecosystem function in general (due to soil moisture drought, also termed **agricultural drought**), and during the runoff and percolation season primarily affects water supplies (**hydrological drought**). Storage changes in soil moisture and groundwater are also affected by increases in actual evapotranspiration in addition to reductions in precipitation. A period with an abnormal precipitation deficit is defined as a **meteorological drought**. A mega drought is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more. For the corresponding indices, see WGI AR5 Box 2.4 (Agard *et al.*, 2014).

**Flood:** the overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas not normally submerged. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods, and glacial lake outburst floods (Agard *et al.*, 2014).

**Tsunami:** a wave, or train of waves, produced by a disturbance such as a submarine earthquake displacing the sea floor, a landslide, a volcanic eruption, or an asteroid impact (Agard *et al.*, 2014).

### Temperature

**Cold wave:** a period of abnormally cold wave for a given region and lasting for at least two days. *Source: Météo France* - http://www.meteofrance.fr/prevoir-le-temps/meteo-et-sante/grands-froids)

**Heat wave:** a period of abnormally and uncomfortably hot weather (Agard *et al.*, 2014).

### Wind and Water

**Extratropical cyclone:** a large-scale (of order 1000 km) storm in the middle or high latitudes having low central pressure and fronts with strong horizontal gradients in temperature and humidity. A major cause of extreme wind speeds and heavy precipitation especially in wintertime (Agard *et al.*, 2014).

**Tropical cyclone:** a strong, cyclonic-scale disturbance that originates over tropical oceans. Distinguished from weaker systems (often named tropical disturbances or depressions) by exceeding a threshold wind speed. A tropical storm is a tropical cyclone with 1-minute average surface winds between 18 and 32 m s–1. Beyond 32 m s–1, a tropical cyclone is called a hurricane, typhoon, or cyclone, depending on geographic location (Agard *et al.*, 2014).

**Storm surge:** the temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place (Agard *et al.*, 2014).

### Water and Temperature

**Sea Level Rise (SLR):** the sea level can change both globally and locally due to changes in the shape of the ocean basins; a change in ocean volume as a result of a change in the mass of water in the ocean; and changes in ocean volume as a result of changes in ocean water density (Adapted from Agard *et al.*, 2014).

## Data and tools for physical climate risk analysis

**Scenario:** a plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (*e.g.*, rate of technological change, prices) and relationships. Note that scenarios are neither predictions nor forecasts, but are useful to provide a view of the implications of developments and actions (Agard *et al.*, 2014). Different types of scenarios exist, including: climate scenarios (*e.g.* **CMIP** simulations); GHG concentration scenarios (*e.g.* Representative Concentration Pathways "**RCP**s"); emission scenarios; socio-economic scenarios (*e.g.* Shared Socio-Economic Pathways "**SSP**s"); GHG emission scenarios with socio-economic assumptions (*e.g.* **SRES**); etc.

**CMIP3 and CMIP5:** phases three and five of the Coupled Model Intercomparison Project (CMIP3 and CMIP5), coordinating and archiving climate model simulations based on shared model inputs by modeling groups from around the world. The CMIP3 multi-model data set includes projections using SRES scenarios. The CMIP5 data set includes projections using the Representative Concentration Pathways (Agard *et al.*, 2014).

**Climate scenario:** a plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, often serving as input to impact models. Climate projections often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as the observed current climate (Agard *et al.*, 2014).

**Climate projection:** a climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative-forcing scenario used, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized. See also Climate scenario (Agard *et al.*, 2014).

**Climate prediction:** a climate prediction or climate forecast: is the result of an attempt to produce (starting from a particular state of the climate system) an estimate of the actual evolution of the climate in the future, for example, at seasonal, interannual, or decadal time scales. Because the future evolution of the climate system may be highly sensitive to initial conditions, such predictions are usually probabilistic in nature. See also Climate projection, Climate scenario, and Predictability (Agard *et al.*, 2014).

**Representative Concentration Pathways (RCPs):** scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases and aerosols and chemically active gases, as well as land use/ land cover (Moss *et al*., 2008). The word *representative* signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. The term *pathway* emphasizes that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome (Moss *et al*., 2010).

RCPs usually refer to the portion of the concentration pathway extending up to 2100, for which Integrated Assessment Models produced corresponding emission scenarios. Extended Concentration Pathways (ECPs) describe extensions of the RCPs from 2100 to 2500 that were calculated using simple rules generated by stakeholder consultations, and do not represent fully consistent scenarios.

Four RCPs produced from Integrated Assessment Models were selected from the published literature and are used in the fifth IPCC Assessment Report as a basis for the climate predictions and projections in WGI AR5 Chapters 11 to 14:

- **RCP2.6.** One pathway where radiative forcing peaks at approximately 3 W m-2 before 2100 and then declines (the corresponding ECP assuming constant emissions after 2100).
- **RCP4.5** and **RCP6.0.** Two intermediate stabilization pathways in which radiative forcing is stabilized at approximately 4.5 W m-2 and 6.0 W m-2 after 2100 (the corresponding ECPs assuming constant concentrations after 2150).
- **RCP8.5.** One high pathway for which radiative forcing reaches greater than 8.5 W m-2 by 2100 and continues to rise for some amount of time (the corresponding ECP assuming constant emissions after 2100 and constant concentrations after 2250) (Agard *et al.*, 2014).

**Downscaling:** downscaling is a method that derives local- to regional-scale (10 to 100 km) information from larger-scale models or data analyses. In all cases, the quality of the driving model remains an important limitation on quality of the downscaled information (Agard *et al.*, 2014).

# Annex 2: Sample of financial actors and reports for the preliminary review

| Name of financial player | Type | Presence of climate information | Link |
|---|---|---|---|
| Amundi | Asset manager | yes | http://legroupe.amundi.com/ezjscore/call/ezjscamundibuzz::sfForwardFront::paramsList=service=ProxyGedApi&routeId=_dl_ZTdiYzc1MjkxZTc2NGRjN2NlZjBlMmRkNzI2Nzg5YWE |
| Blackrock | Asset manager | yes | https://www.blackrock.com/corporate/literature/whitepaper/bii-climate-change-2016-us.pdf |
| BNP Paribas Cardif | Asset manager | yes | https://www.bnpparibascardif.com/documents/583427/923987/RAPPORT-LTE-ART173-V4-VFR.pdf/02e9a635-2b17-40b2-8e70-7bb989aac776 |
| Candriam | Asset manager | yes | https://www.candriam.fr/en/private/market-insights/article-173/risques-esgclimat/ |
| CM CIC Asset management | Asset manager | yes | https://www.cmcic-am.fr/fr/particuliers/notre-presentation/qui-sommes-nous/pdf/ESG-article-173.pdf |
| Coninco | Asset manager | yes | http://www.coninco.ch/SiteF/Investissements/Solutions.asp |
| Covea | Asset manager | yes | https://www.covea.eu/wp-content/uploads/2017/07/rapport_esg_covea_finance-1.pdf |
| De Pury Pictet Turrettini | Asset manager | no | |
| Demeter | Asset manager | yes | http://demeter-im.com/mentions-legales/ |
| Edmond de Rothschild Asset Management | Asset Manager | yes | http://www.edmond-de-rothschild.com/SiteCollectionDocuments/asset-management/isr/EDRAM-FR-Declaration-art-173.pdf |
| Eiffel investment group | Asset manager | no | |
| Erste AM | Asset manager | yes | https://www.erste-am.de/en/private-investors/responsible-investing/impact-analysis |
| Groupama AM | Asset manager | yes | http://www.groupama-am.com/wp-content/uploads/2016/11/Article-173_Investisseur_version-EML_2_modifi%C3%A9_en-cours_AMM_v5-5-2.pdf |
| IdInvest | Asset manager | yes | http://www.idinvest.com/pdf/rapport_esg_2017.pdf |
| J. Safra Sarasin | Asset manager | yes | https://www.jsafrasarasin.ch/internet/ch/en/imagebroschuere_nachhaltigkeit.pdf |
| Janus Henderson | Asset manager | yes | https://www.janushenderson.com/henderson/content/responsible-investment |
| Kempen | Asset manager | yes | https://www.kempen.com/fr/asset-management/responsible-investment/climate-change |
| La Banque Postale Asset Manager | Asset manager | yes | https://www.labanquepostale-am.fr/media/LTE_Lengagement%20de%20LBPAM.pdf |
| Lyxor Asset Management | Asset Manager | yes | http://www.lyxor.com/fileadmin/user_upload/pdf/Lyxor_Article_173_June_2017_EN.pdf |
| Meridiam | Asset manager | no | |
| Myria AM | Asset manager | no | |
| NN Investment Partners | Asset manager | yes | https://www.nnip.com/web/file?uuid=c9e962a4-6d90-410f-ac0e-ffdd5815cd8f&owner=f23032d2-df50-4d07-915b-6143862fa2ea&contentid=9854 |
| Nordea | Asset manager | yes | https://www.nordea.com/Images/35-98072/Nordea%20Asset%20Management%20-%20Our%20Approach%20on%20Climate%20Change.pdf |
| OFI AM | Asset manager | yes | https://www.ofi-am.fr/corporate/pdf/RSE_rapport-LTE.pdf |
| Raiffeisen Capital Management | Asset manager | yes | http://www.rcm-international.com/cs/Satellite?blobcol=urldata&blobheadername1=content-type&blobheadername2=Content-Disposition&blobheadername3=Cache-Control&blobheadername4=Pragma&blobheadername5=Expires&blobheadervalue1=application%2Fpdf&blobheadervalue2=attachment%3B+filename%3D%22investirdurablement_no16.pdf%22&blobheadervalue3=must-revalidate%2C+post-check%3D0%2C+pre-check%3D0&blobheadervalue4=public&blobheadervalue5=0&blobkey=id&blobnocache=true&blobtable=MungoBlobs&blobwhere=1371727375924&ssbinary=true |
| RobecoSAM | Asset manager | yes | http://www.robecosam.com/images/Climate_change_policy.pdf |
| Roche Brune Am | Asset manager | yes | https://www.roche-brune.com/media/upload/file/68/edito-beta-carbone.pdf |
| Schroders | Asset manager | yes | http://www.schroders.com/en/sysglobalassets/digital/insights/2017/pdf/sustainable/climate-change-dashboard/climatedashboard-july2017.pdf |
| Sparinvest | Asset manager | yes | http://www.sparinvest.lu/~/media/international/downloads/ri/jan2016_si%20ri%20review.ashx |

| Name of financial player | Type | Presence of climate information | Link |
|---|---|---|---|
| Swisscanto | Asset manager | yes | https://www.swisscanto.com/ch/fr/po/swisscanto-invest/durabilite.html |
| Sycomore | Asset manager | yes | https://www.sycomore-am.com/59672298-Article_173_Sycomore_AM_SSR.pdf |
| Vanguard | Asset manager | yes | https://www.vanguardfrance.fr/documents/investment-stewardship-mcnabb-letter-fr.pdf |
| Vontobel | Asset manager | yes | https://www.vontobel.com/en-int/asset-management/equities/thematic-investing-boutique/sustainability/ |
| Bank of America | Bank | yes | https://about.bankofamerica.com/assets/pdf/Bank-of-America-Programme-Response-Climate-Change-2017.pdf |
| Bank of China | Bank | no | |
| Barclays | Bank | yes | https://www.home.barclays/citizenship/our-approach/environmental-risk-in-lending.html |
| BPCE | Bank | yes | https://groupebpce.fr/Engagements/Un-groupe-responsable/Developpement-durable/Reduire-l-empreinte-carbone |
| CA -CIB | Bank | yes | https://www.ca-cib.fr/sites/default/files/2018-03/Cr%C3%A9dit%20Agricole%20CIB_DDR%202017_vdef_0.pdf |
| Crédit mutuel | Bank | yes | https://www.creditmutuel.com/sites/default/files/uploads-wysiwyg/RSE%20au%20national/fichier-pdf/RA-2016-RA-RSE_12-07-2017.pdf |
| Crédit Suisse | Bank | yes | https://www.credit-suisse.com/corporate/en/responsibility/banking/risk-management.html |
| Deutsche Bank | Bank | yes | https://de.download.dws.com/download?elib-assetguid=955c249b93014f8abf8f0b7097c1faa6&publishLocationGuid=c6279a92ca1042498a4b15eae68f085c |
| Goldman Sachs | Bank | yes | http://www.goldmansachs.com/citizenship/environmental-stewardship/market-opportunities/climate-and-weather-risk-solutions/ |
| HSBC | Bank | yes | https://www.hsbc.com/our-approach/building-a-sustainable-future/sustainable-finance |
| JP Morgan | Bank | yes | https://am.jpmorgan.com/uk/institutional/library/sustainable-investing-climate-risk |
| La Banque Postale | Bank | yes | https://www.labanquepostale.com/legroupe/banque-et-citoyenne/engagement-citoyen/rse.enbref.html |
| Morgan Stanley | Bank | yes | https://www.morganstanley.com/pub/content/dam/msdotcom/articles/fossil-fuels/A-Changing%20Climate_The%20Fossil_Fuel_Debate.pdf |
| Natixis | Bank | yes | https://www.natixis.com/natixis/upload/docs/application/pdf/2017-03/natixis_ddr2016_-_21_03_2017.pdf |
| Petercam | Bank | no | |
| RBC | Bank | yes | http://www.rbc.com/collectivites-durabilite/environment/environmental-footprint-reduction.html |
| Santander | Bank | yes | https://www.santander.com/csgs/Satellite/CFWCSancomQP01/en_GB/Corporate/Sustainability/Sustainable-activity/Environmental-footprint-and-energy-saving-plan.html |
| Société Générale | Bank | yes | https://www.societegenerale.com/rapport-rse/files/SG-RSE2016-2017-FR.pdf |
| Triodos Finance | Bank | yes | http://www.annual-report-triodos.com/en_us/2016/management-report/environmental-report.html |
| UBS | Bank | yes | https://www.ubs.com/global/en/about_ubs/investor_relations/annualreporting/2016/_jcr_content/par/teaserbox_f1a7/teaser/linklist/link_a6d4.0036442955.file/bGluay9wY-XRoPS9jb250ZW50L2RhbS9zdGF0aWMvZ2xvYmFsL2ludmVzdG9yX3JlbGF0aW9u-cy9hbm51YWwtcmVwb3J0LzIwMTYvdWJzLWdyb3VwLTIwMTYtZW4ucGRm/ubs-group-2016-en.pdf |
| AFD | Development Bank | yes | https://www.afd.fr/sites/afd/files/2018-03-02-12-49/cadre-intervention-climat-developpement-2017-2022.pdf |
| BERD | Development Bank | yes | http://www.ebrd.com/cs/Satellite?c=Content&cid=1395270079951&pagename=EBRD%2FContent%2FContentLayout&rendermode=live%3Fsrch-pg |

| Name of financial player | Type | Presence of climate information | Link |
|---|---|---|---|
| KfW | Development Bank | yes | https://www.kfw.de/nachhaltigkeit/PDF/Nachhaltigkeit/ESIA_KfW-Development-Bank_KfW-IPEX-Bank_DEG_2016-06.pdf |
| CNP | Insurance | yes | http://www.novethic.fr/fileadmin/templates/novethic/img/static/colloque-2017/RIR-2016-CNP-Assurances-VF.pdf |
| AG2R | Insurance | yes | https://www.ag2rlamondiale.fr/files/live/sites/portail/files/pdf/Groupe/AG2R-LA-MONDIALE-groupe-rapport-article-173-2016%20.pdf |
| Allianz | Insurance | yes | https://www.ag2rlamondiale.fr/files/live/sites/portail/files/pdf/Groupe/AG2R-LA-MONDIALE-groupe-rapport-article-173-2016%20.pdf |
| Aviva France | Insurance | yes | https://www.aviva.fr/documents/corporate/nous-connaitre/rapports-annuels/RAPPORT_ESG_CLIMAT_VDEF-compresse.pdf |
| Axa | Insurance | yes | https://www-axa-com.cdn.axa-contento-118412.eu/www-axa-com%2Ff570ad25-6178-47a0-afb9-59a5b7d3d70a_changementclimatique_rapport_risqueinvestissement_vf_30.08.17-b.pdf |
| Crédit agricole assurance | Insurance | yes | https://www.ca-assurances.com/espace-investisseurs/rapports-extra-financiers-0 |
| Generali | Insurance | yes | http://institutionnel.generali.fr/sites/default/files/rapport_art_173_fr_vdef_12.05.17_com.pdf |
| MACIF | Insurance | yes | https://www.mutavie.fr/portal/rest/jcr/repository/collaboration/sites/rpm/web%20contents/pages/pdf/MACIF_RIR_2016.pdf |
| MAIF | Insurance | yes | https://entreprise.maif.fr/files/live/sites/entreprise-maif/files/images/entreprise/performances-et-recompenses/Rapports-annuels/Rapport-MAIF_ESG-Climat_VF.pdf |
| Nord Europe Assurance | Insurance | yes | https://www.acmnvie.fr/fr/document/RapportLTE2016.pdf |
| SMA BTP | Insurance | yes | http://www.groupe-sma.fr/SGM/upload/docs/application/pdf/2017-07/rapport_lte_placements_sma_2016_def.pdf |
| Suravenir | Insurance | yes | https://www.suravenir.fr/wp-content/uploads/2017/05/2017-05-18-Rapport-LTE-Suravenir.pdf |
| ERAFP | Pension fund | yes | https://www.rafp.fr/sites/rafp_fr/files/publication/file/ra2016exe-06-planches.pdf |
| FRR | Pension fund | yes | http://www.fondsdereserve.fr/documents/Rapport-2016-article-173-lte-2.pdf |
| Groupe Malakoff Médéric | Pension fund | yes | http://www.malakoffmederic.com/groupe/blobs/medias/s/326248d416e00eb7/Rapport-RSE-Malakoff-Mederic-2016-VFext.pdf |
| Humanis | Pension fund | yes | https://humanis.com/sites/default/files/doc5107-rapport-esg-climat2016.pdf |
| Ircantech | Pension fund | yes | https://www.ircantec.retraites.fr/sites/default/files/public/actionsclimat17_0.pdf |
| MGEN | Pension fund | yes | https://www.mgen.fr/fileadmin/documents/5_Le_groupe_MGEN/Publications_2017/MGEN_Rapport_investissement_responsable_2016.pdf |
| Union Mutualiste Retraite | Pension fund | yes | https://umr-retraite.fr/sites/default/files/2017-10/rapport-esg-placements-2016_0.pdf |
| BEI | Public Bank | yes | https://institute.eib.org/wp-content/uploads/2017/05/SciencePo-Presentation-v.1.pdf |
| Caisse des Dépôts | Public Bank | yes | http://www.caissedesdepots.fr/fileadmin/sites/ra2016/assets/file/CDC-RADD2016-FR_02.pdf |
| BpiFrance | Public Bank | yes | https://www.bpifrance.fr/content/download/62900/679368/version/2/file/2016%20-%20Rapport%20RSE%20Bpifrance%20SA%20-%20extrait%20du%20rapport%20annuel.pdf |
| CCR | Reinsurance | yes | https://www.ccr.fr/documents/23509/113740/Rapport+ESG-Climat+CCR+2016.pdf/61683a3c-ba2e-4baa-a141-79bd70084989 |
| SCOR SE | Reinsurance | yes | https://www.scor.com/sites/default/files/scor_esg_2016_vf_mel.pdf |

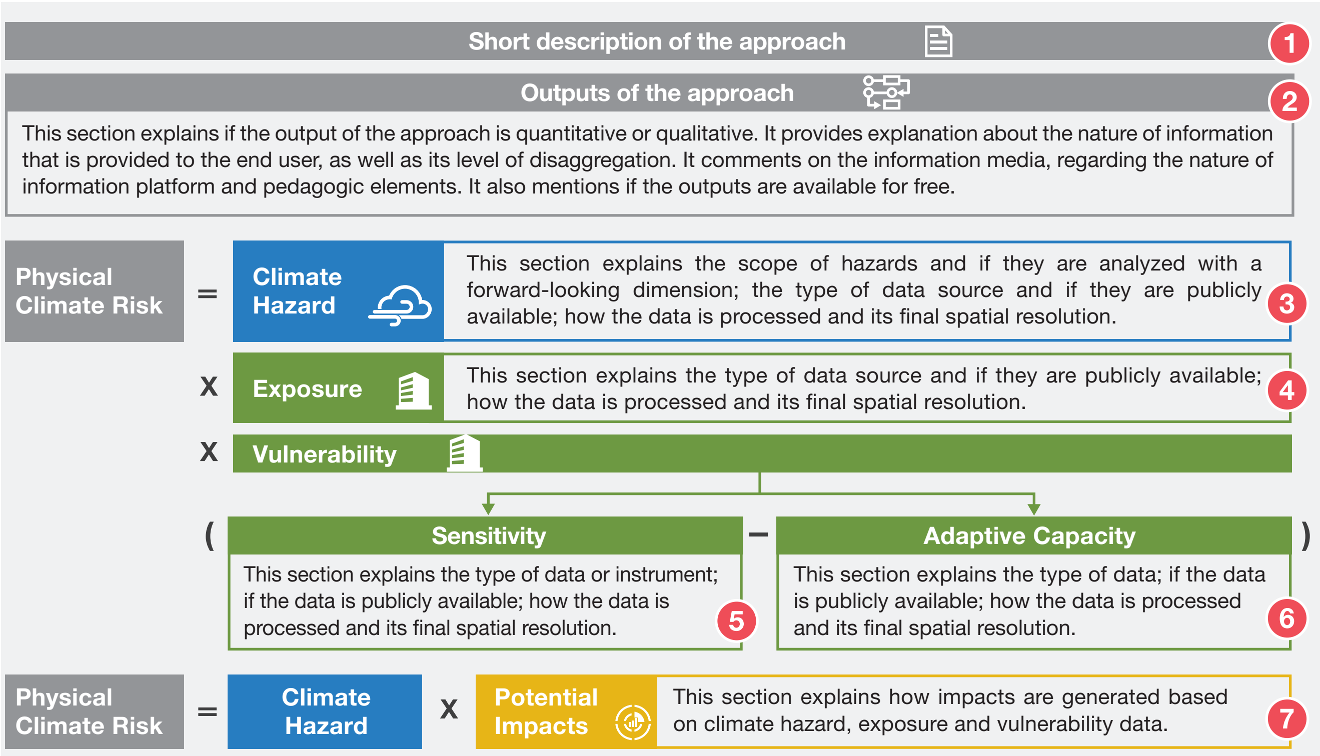
# Annex 3: Summary tables of available approaches

This annex provides detailed information on each of the approaches analyzed in the frame of this report. It was collected from publicy available documents and bilateral interviews with the service providers. The Figure below illustrates the structure of the annex for each approach, in **seven blocks of information**.

For each approach, the annex provides a short summary of the approach 1 and a description of its outputs 2. It also provides details on the underlying methodology, following the analytical blocks of the risk equation (*i.e.* hazards 3; exposure 4; sensitivity 5; adaptive capacity 6; impacts 7).

These details focus on: the perimeter of analysis, the data sources and granularity, the methods to process the data.

Some of the approaches apply distinct methodologies to analyze different aspects of a given type of counterparty (*e.g.* one methodology for corporate supply chain risks; another methodology for corporate operation risks). When this is the case, the specific perimeter is further detailed for the relevant blocks of information.



ANNEX 3: SUMMARY TABLES OF AVAILABLE APPROACHES

### 1. 427 CLIMATE RISK SCORES – BY FOUR TWENTY SEVEN

| SHORT DESCRIPTION OF THE APPROACH | |
|---|---|
| Name of approach | 427 Climate Risk Scores |
| Service provider | Four Twenty Seven |
| Targeted user | Financial institutions and corporations |
| Targeted use | Investment strategies; shareholder corporate engagement; risk management; Art. 173/TCFD disclosures |
| Summary of the approach | • Four Twenty Seven provides company risk scores based on facility-level risk assessment leverages corporate facility database of over 1,000,000 sites, where each site is assessed individually for its exposure to local climate hazards.<br>• Methodology includes both exposure and sensitivity factors at the facility and company level.<br>• Scores capture climate impacts on the value chain of companies: market, operations and supply chain of companies.<br>• Expanded scope of impacts including consideration on climate impacts to the macro environment of the business.<br>• Allows for comparison between companies and benchmarking of equities and indices. |

| OUTPUTS OF THE APPROACH | |
|---|---|
| **Type of output available** | |
| Scoring of companies | |
| Detail | For each company, data may also be disaggregated by country of operations or type of facility. |
| **Type of aggregation of information available** | |
| **Per hazard** | Detail and aggregation per hazard |
| **Per counterparty** | Per counterparty (or sub level such as business unit); per element of value chain; per sector; per portfolio; per geography. |
| **Per type of impact** | All impacts combined |
| **Per scenario** | No |
| **Per time horizon** | Restricted to one horizon |
| **Information media** | |
| Nature of platform | Online platform (Under development) |
| Visual architecture (*e.g.* mapping, storyline) | Data feed with detailed breakdown of scores, risk drivers and sectoral and regional benchmarks<br>Interactive visualizations: maps with detailed assessment of operational risk, analytics charts for company risk drivers and portfolio results, scorecards, etc.<br>Custom portfolio analysis for reporting and engagement including narrative |
| Customization by the user | For real assets (infrastructure, real estate) only |

| Pedagogy by displaying background information on | | | |
|---|---|---|---|
| **Hazards** | Perimeter | | selection of acute and chronic hazards with global coverage |
| | Period of analysis | | 2030-2040 |
| | Granularity of primary data | | 25x25 km for climate data, parcel level for floods (inland and coastal) |
| **Counterparty** | Perimeter of | Exposure | Operations, upstream, downstream, and macro |
| | | Sensitivity (assets; natural resource; labor; sales; etc.) | Asset level: natural resources and labor; downstream: resources intensity; Upstream: weather sensitivity |
| | | Adaptive capacity | Under development |
| | Granularity of primary data on | Exposure | Asset specific (lat/long) |
| | | Sensitivity | By facility type (sic code) |
| **Impact** | Perimeter of impacts | Socio-economic | Macro |
| | | Financial | Under development |
| Methodological assumptions and data gaps | | | Available for clients only |
| Explaining treatment of climate and socio-economic uncertainties | | | No |

| Accessing outputs of the approach | |
|---|---|
| Available for free | No |

### 427 CLIMATE RISK SCORES – BY FOUR TWENTY SEVEN (CONTINUED)

## CLIMATE HAZARD

### Corporates (operation risk)

#### Scope of hazards

*Acute:* Extreme water stress; Extreme precipitation; Extreme heat stress; Hurricanes and Typhoons; Wildfires; Inland floods
*Chronic:* Sea Level Rise; Long-term trends in water stress; Long-term trends in precipitation; Long-term trends in heat stress
The acute hazards are studied on Frequency, intensity and duration aspects. The dataset characterizes the increase in hazardous phenomena (relative: compare projected change to current conditions / absolute: exceedance of a statistical threshold for a particular area).

| Forward-looking dimension | |
|---|---|
| Time horizon | 2030-2040 |
| Nature of data (projection; forecast; historical data; trend scenario; exploratory scenario) | Projection (2020-2040 compared with 1985-2005 period) |
| Alternative futures (unique or multiple) | Unique Worst case scenario (RCP8.5) |
| **Type of source** | |
| Public, private, non disclosed sources | Public sources (IPCC; WRI) and proprietary sources |
| **Processing climate data** | |
| Treatment | Relevant raw climate data for each site is extracted from 5 climate models and processed statistically to identify relevant phenomena (duration / intensity of heat waves, rainfall events, etc.) then normalized to a score of 0 to 100 for purpose of comparison across locations and across hazards. |
| Final spatial resolution | 25x25 km (most granular resolution) |

### Corporates (downstream risk)

The dataset covers chronic phenomena (temperature and precipitation patterns). It defines hazards in absolute levels extracted from past weather variability, using non disclosed historical data.

### Sovereigns

The dataset covers acute (heat stress; extreme rainfall; water stress) and chronic (sea level rise) phenomena. The acute hazards are studied on frequency, intensity and duration. The dataset characterizes the increase in hazardous phenomena in relative terms (as the change between historical conditions and projected climate change). The climate hazards dataset has a 2030-2040 time horizon based on climate projection, but also historical data. There is one climate scenario.

## EXPOSURE

| Type of data | Type of source | Type of processing | | |
|---|---|---|---|---|
| | Public, private, not disclosed | Scale of data | Treatment | Final scale of exposure |
| **Corporates (upstream risk)** | | | | |
| Sectoral activity of the counterparty | Public sources (company financial data) and private sources (Trucost) | Company | For a counterparty in a given country and sector, trade flow data show the network of supplying countries. It is combined with country risk indicator to show exposure of the company upstream value chain to the country **(Country of Origin indicator)** | Sectoral at country level |
| Likely location of suppliers through sectoral trade flow data | Public sources (UN Comtrade) | Sectoral at country level | | |
| Indicator on climate risk in countries that contribute to sector production or re-export | Private sources (Indicators from 427's Country Climate Risk Index) | Country level | | |

### *427 CLIMATE RISK SCORES – BY FOUR TWENTY SEVEN (CONTINUED)*

| | | | | |
|---|---|---|---|---|
| **Corporates (operation risk)** | | | | |
| Location of corporate facilities | Private sources | Facility level | Each facility is analyzed and scored for six hazards through multiple risk indicators | Aggregated at company or company-country level |
| Indicator on country socio-economic risk to operations | Private sources (Indicators from 427's Country Climate Risk Index) | Country level | | |
| **Corporates (downstream risk)** | | | | |
| Location of sales | Public sources (reported and modeled company revenues); private sources (Factset) | Company | The combination of location of sales and country climate risk shows exposure of the company's dowstream value chain to a country. **(Country of Sales indicator)** | Aggregated at company or company-country level |
| Indicator on climate risk in countries that contribute to company's revenues | Private sources (Indicators from 427's Country Climate Risk Index) | Country level | | |
| **Sovereigns** | | | | |
| Composite index based on indicators about resilience (through political, environmental, social and economic stability); natural disaster risk (through major past events documented with public sources) and climate change exposure (with a focus on tail risk and densely populated areas) | | | | |

| **SENSITIVITY** | | | | |
|---|---|---|---|---|
| Type of data | Type of source | Type of processing | | |
| | Public, private, not disclosed | Scale of data | Treatment | Final scale of sensitivity |
| **Corporates (upstream risk)** | | | | |
| Intensity and efficiency of sector when using natural resource inputs: water, energy and land use. This is the **Resource Demand indicator**. | Not disclosed | Sectoral (NAICS 6 digits) | | Sectoral |
| **Corporates (operation risk)** | | | | |
| • Function of facility (*e.g.* manufacturing plant, distribution center, warehouse)<br>• Sectoral resource intensity<br>• Other data on materiality of impacts (how intensive a particular impact might be on a particular asset) | Public sources (peer-reviewed literature on heat and labor productivity, impacts of water scarcity and heat on corporate performance); private sources (for facility function) | Facility and sectoral | • Sensitivity to different impacts is analyzed depending on the type of facility and applied to overweight certain risk scores for relevant hazards<br>• Sensitivity analysis includes sectoral resource intensity and other indicators on materiality of impacts<br>• No more precision on the process | Sectoral |
| **Corporates (downstream risk)** | | | | |
| Historical sensitivity of sectoral sales to weather variability (temperature and precipitation patterns). This is the **Weather Sensitivity indicator**. | | Sectoral | | Sectoral |
| **Sovereigns** | | | | |
| Composite index based on indicators about resilience (through political, environmental, social and economic stability); natural disaster risk (through major past events documented with public sources) and climate change exposure (with a focus on tail risk and densely populated areas). | | | | |

### *427 CLIMATE RISK SCORES – BY FOUR TWENTY SEVEN (CONTINUED)*

| ADAPTIVE CAPACITY | | |
|---|---|---|
| Type of data | Type of source<br>Public, private, not disclosed | Type of processing |
| **Corporates** | | |
| Not included in the methodology. | | |
| **Sovereigns** | | |
| Indicators on a country's resilience (*i.e.* ability to withstand, prevent or recover from impacts) to climate impacts. Four types of indicators:<br>• political stability<br>• environmental stability<br>• social stability<br>• economic stability | Not disclosed | |

| IMPACTS | |
|---|---|
| **Corporates (upstream risk)** | |
| Type of processing | |
| Analytical steps | The methodology is not hazard-specific. There is not a hazard dataset to combine with:<br>1/ the sectorial natural resource sensitivity is the Resource Demand indicator.<br>2/ the combination of country exposures and 427's indicator on climate risk brings the Country of origin indicator<br>3/ combination of both indicators: no available information |
| Final scale of information | Company level |
| Type of financial impact | |
| Asset damage; loss of revenue (or production); rise of costs; implicit | Asset damage; loss of revenue (or production); rise of costs |
| **Corporates (operation risk)** | |
| Type of processing | |
| Analytical steps | The methodology is hazard-specific, there are different hazard indicators to combine with.<br>1/ Combination of hazard, facility exposure and natural resource sensitivity<br>2/ Introduction of Country climate risk indicators |
| Final scale of information | • Facility level<br>• Possibility to aggregate at parent company level |
| Type of financial impact | |
| Asset damage; loss of revenue (or production); rise of costs; implicit | Asset damage; loss of revenue (or production); rise of costs |
| **Corporates (downstream risk)** | |
| Type of processing | |
| Analytical steps | The methodology is not hazard specific.<br>1/ Combination of company's location of revenues and 427's Country climate risk indicator produces the Country of Sales indicator.<br>2/ Weather Sensitivity indicator is combined with Country of sales indicator to produce the indicator on downstream risk. |
| Final scale of information | Company level |
| Type of financial impact | |
| Asset damage; loss of revenue (or production); rise of costs; implicit | Asset damage; loss of revenue (or production); rise of costs |

### *427 CLIMATE RISK SCORES – BY FOUR TWENTY SEVEN (CONTINUED)*

| Sovereigns | |
|---|---|
| Type of processing | |
| Analytical steps | Composite index based on indicators about resilience (through political, environmental, social and economic stability); natural disaster risk (through major past events documented with public sources) and climate change exposure (with a focus on tail risk and densely populated areas) |
| Final scale of information | Country level |
| Type of financial impact | |
| Asset damage; loss of revenue (or production); rise of costs; implicit | Asset damage; loss of revenue (or production); rise of costs |

### 2. AQUEDUCT WATER RISK ATLAS – BY WRI

| SHORT DESCRIPTION OF THE APPROACH | |
|---|---|
| Name of approach | Aqueduct - Water Risk Atlas |
| Service provider | WRI |
| Targeted user | Not defined - All financial institutions |
| Targeted use | Analysis of portfolio exposure to climate hazards |
| Summary of the approach | The Water Risk Atlas provides a mapping of scores on exposure to water-related hazards. These hazards are given for both current climate conditions and future climate conditions.<br>This summary tables focuses on a selection of hazards (*i.e.* annual water supply; seasonal variability; annual water demand; water stress) in future climate conditions, that are directly relevant to the scope of this report on risks arising from climate change potential impacts. |

| OUTPUTS OF THE APPROACH | | | |
|---|---|---|---|
| **Type of output available** | | | |
| Scoring of geographic areas | | | |
| **Type of aggregation of information available** | | | |
| **Per hazard** | Detail and aggregation per hazard | | |
| **Per counterparty** | NA (the methodology covers hazards only) | | |
| **Per type of impact** | NA (the methodology covers hazards only) | | |
| **Per scenario** | Presentation of several scenarios | | |
| **Per time horizon** | Detailed per horizons | | |
| **Information media** | | | |
| Nature of platform | Online Platform | | |
| Visual architecture (*e.g.* mapping, storyline) | Mapping of scores with textual context elements. | | |
| Customization by the user | Maps are interactive with possibilities to select indicators, timeframe and scenarios. | | |
| **Pedagogy by displaying background information on** | | | |
| **Hazards** | Perimeter | | selection of chronic hazards related to water stress |
| | Period of analysis | | Current (2014), 2020, 2030, 2040 |
| | Granularity of primary data | | Variable depending on datasets |
| **Counterparty** | Perimeter of | Exposure | NA (the methodology covers hazards only) |
| | | Sensitivity (assets; natural resource; labor; sales; etc.) | NA (the methodology covers hazards only) |
| | | Adaptive capacity | NA (the methodology covers hazards only) |
| | Granularity of primary data on | Exposure | NA (the methodology covers hazards only) |
| | | Sensitivity | NA (the methodology covers hazards only) |
| **Impact** | Perimeter of impacts | Socio-economic | NA (the methodology covers hazards only) |
| | | Financial | NA (the methodology covers hazards only) |
| Methodological assumptions and data gaps | | | Detailed in supporting documents |
| Explaining treatment of climate and socio-economic uncertainties | | | Detailed in supporting documents |
| **Accessing outputs of the approach** | | | |
| Available for free | Yes | | |

### AQUEDUCT WATER RISK ATLAS – BY WRI (CONTINUED)

## CLIMATE HAZARD

### Scope of hazards

*Chronic:* Annual water supply; Seasonal variability (*i.e.* intra-annual variability) of water supply; Annual water demand; Water stress (*i.e.* water use / water supply ratio)
The hazards are studied on their intensity. The dataset characterizes the both increase in hazardous phenomena (relative change in variable compared with historical conditions to 2020, 2030 and 2040) and absolute level of hazardous phenomena (in 2020, 2030, 2040).

### Forward-looking dimension

| | |
|---|---|
| Time horizon | Current (2014), 2020, 2030, 2040 |
| Nature of data (projection; forecast; historical data; trend scenario; exploratory scenario) | Projection (21-year periods centered around 2020, 2030, 2040) and historical data |
| Alternative futures (unique or multiple) | 3 scenarios: optimistic (RCP 4.5 and SSP2); Business as usual (RCP 8.5 and SSP2); Pessimistic (RCP 8.5 and SSP3) |

### Type of source

Public, private, non disclosed sources

All sources are public, and vary accross indicators:
- **Annual water supply:** IPCC (CMIP5 simulations from 6 GCMs); GLDAS-2 database for simulated historical runoff; NCAR Command Language resampling tool.
- **Seasonal variability:** IPCC, GLDAS-2 and NCAR Command Language
- **Annual water demand:** IPCC (CMIP5 simulations from 6 GCMs and socio-economic variables from SSP scenarios); historical data from FAO Aquastat; world Bank; UNDESA; Gassert et al (2013); GMIA v5 to estimate water withdrawal in the three sectors; data from Neumann et al (2011) on likelihood of irrigation expansion (LIE) for spatial distribution of the expansion of irrigated agriculture; SRES projections from IIASA (2009)
- **Water stress:** IPCC (CMIP5 simulations from 6 GCMs and socio-economic variables from SSP scenarios); Shiklomanov and Rodda (2004) for the calculation of industrial and domestic consumptive use

### Processing climate data

Indicator on Annual Water Supply

The water supply indicator is the total blue water (*i.e.* the approximative naturalized river discharge). Projected change in total blue water is equal to the 21-year mean around the target year divided by the baseline period of 1950-2010.
Detail on construction of the indicator:
The methodology starts from te annual runoff variable. It comes from 6 GCMs with various spatial resolutions (from 2.5°x2° to 1.25x0.9375). The simulated variable is bias corrected with historical data from the GLDAS-2 database using quantile-quantile matching. The runoff values from different GCMs are resampled to a higher 1°x1° resolution using the NCAR Command Language and summed into hydrological catchments. (Hydrological catchments are determined starting from the Global Drainage Basin Database (GDBD), and more finely resolved into sub-basin polygons with a recursive algorithm. The outlet of each resulting catchment is found using the GDBD digital elevation model.) The distribution of water runoff across catchments accounts for catchment connectivity, thanks to a catchment flow accumulation approach (with recursive summing of runoff from adjacent upstream catchments, ignoring instream storage or retention). The indicator is formated as a score (see sub-section below on "Formatting each indicator as a score").

Indicator on Seasonal Variability

The seasonal variability indicator approximates the the intra-annual (measured between months) variability of water supply. Higher value implies higher probability of droughts or flooding.The indicator of projected change in seasonal variability is computed as the ratio of:
- the variability of monthly total blue water over a year, averaged over a 21-year period centered on the target year,
- the variability of monthly total blue water over a year, averaged over the baseline period (from 1950 to 2010).

Indicator on Annual Water Demand

The water demand indicator is the water withdrawal, *i.e.* the total amount of water abstracted from freshwater sources for agriculture, domestic and industrial uses (this sectoral split is due to FAO Aquastat data). The indicator of projected change in water withdrawal is equal to the summarized withdrawals for the target year, divided by the baseline year (2010).
The methodology differs between the agricultural sector (Section A/ below) and industrial and domestic sectors (Section B/ below).

**A/ In the case of agriculture**, withdrawals are driven by climate and socioeconomic conditions.It consists of irrigation water withdrawals, measured as the ratio between irrigation water requirement (Step 1) and irrigation efficiency (Step 2).
- *Step 1:* Irrigation water requirement is the sum of non consumptive use (approached as water for rice irrigation and paddy lands) and consumptive use (see. Steps 1.1/ and 1.2/).

### AQUEDUCT WATER RISK ATLAS – BY WRI (CONTINUED)

- *Step 1.1/* Country-level projection of agricultural area actually irrigated (for each target year: 2020, 2030, 2040):
  The area equipped for irrigation per country for a given year is regressed on socioeconomic variables. The parameter estimates is done with historical data. The parameters are then projected using SSP variables on GDP, population and urbanization. The area equipped for irrigation is transformed into area actually irrigated projected at country level, using additional data from the Global Map of Irrigation Area (GMIA v5).
  The projected additional irrigated area is then distributed in space at a fine pixel scale, accounting for the area available for expansion classified by likelihood of irrigation expansion (LIE). The distribution rule of additional irrigated area is: 1/ among areas available for irrigation, that are already equipped but non irrigated yet, in decresaing order of likelihood 2/ among areas available for irrigation that are not equipped, in decreasing order of likelihood 3/ In other countries, which allows to account for the possibility of international agriculture trade.
- *Step 1.2/* Calculation of irrigation necessary for crops evapotranspiration:
  Consumptive use of water is the combination of area actually irrigated (calculated in step 1.1) and Irrigation necessary for crops evapotranspiration needs and that depends on climate conditions. Irrigation necessary for evapotranspiration needs is estimated as the difference between potential evapotranspiration (from the literature) and actual evapotranspiration (from climate estimates). The Irrigation necessary for evapotranspiration needs is derived from GCMs and bias corrected with quantile-quantile matching on GLDAS-2 data.

• *Step 2/* Irrigation efficiency:
Irrigation efficiency is regressed on socioeconomic varia bles. Historical values of irrigation efficiency come from FAO Aquastat and Rower et al (2007). The estimated equation is then projected with SSP data on socioeconomic variables.

**B/ In the case of industrial and domestic sectors**, estimates of water withdrawals are driven by socioeconomics and not climate.
Withdrawals at country level are regressed on socio-economic variables, and other effects (static variables, interactions, etc.). It uses historical estimates of withdrawals from FAO Aquastat and other historical data for socio-economic variables. The estimated equation is then projected using SSP variables on GDP, population and urbanization. The variability of projected yearly country effects is constrained with Winsorization process. Withdrawals are then distributed at a finer spatial resolution. The spatial disaggregation from country to pixel resolution was not available for SSP variables. Thus it uses 0.5° projections of SRES from IIASA (2009) that are matched with the SSP framework.

For all sectors: formatting as a score (see sub-section below on “Formatting each indicator as a score”).

| Indicator on Water Stress |
|---|
| Water stress is an indicator of competition for water resources. Water stress is the ratio between Withdrawals (see detail in indicator on Annual Water Demand) in target year and Available blue water. Available blue water is the flow-accumulated runoff minus upstream consumptive use computed over hydrological catchments. It is the difference between Total available blue water and consumptive use.<br>Consumptive use is the portion of withdrawn water that evaporates or is incorporated into a product and is thus no longer available for downstream use. Non-consumptive use is the difference between withdrawals and consumptive use. In the agricultural sector, consumptive use is calculated as in Step 1.2 of agricultural withdrawal indicator. In the domestic and industrial sectors, industrial and consumptive use were calculated for all target years by multiplying withdrawals by the 2025 projection of industrial and domestic consumptive use ratios (consumptive use / withdrawals), respectively, from Shiklomanov and Rodda.<br>The indicator on Projected water stress is the ratio of withdrawals in year t to available blue water average on 21-year centered on year t. The indicator on Projected change in water stress uses the 1950-2010 baseline period for available blue water.<br>The indicators are formated as a score (see sub-section below on “Formatting each indicator as a score”). |
| Formatting each indicator as a score |
| Indicators are normalized to a comparable 5-level scale: four thresholds are determined based on existing literature, the range and distribution of indicator values and expert judgment. The normalization functions vary by indicator but generally follow either a simple linear or a logarithmic form (formulas are given in Gassert et al (2014). The threshold methodology has tha advantage of being independent of the distribution of data and thus unaffected by extreme values. However, defining thresholds assigns meaning to specific indicator values. Transparency is provided with the normalization function and with access to raw indicator values. |

| Final spatial resolution of the four indicators | 1°x1° |
|---|---|

## EXPOSURE, SENSITIVITY, ADAPTIVE CAPACITY

Not included in the methodology.

## IMPACTS

Not included in the methodology.

### 3. AWARE FOR PROJECTS – BY ACCLIMATISE

| SHORT DESCRIPTION OF THE APPROACH | |
|---|---|
| Name of approach | Aware for Projects |
| Service provider | Acclimatise |
| Targeted user | Development project officers, Risk managers on projects at design/operation/maintenance stages |
| Targeted use | • Climate risk screening at early phase of an infrastructure project, to identify which project should be taken to the next stages of a detailed climate risk analysis.<br>• Launch discussion with the project designers or project developers on how they account for current and future climate impacts in the design of the project and make appropriate adaptation choices. |
| Summary of the approach | • Qualitative scoring of climate risk to infrastructure project.<br>• 3-level scoring based on qualitative indicators for climate hazards, exposure and sectoral sensitivity of the project.<br>• The methodology characterizes climate hazards with thresholds on specific climate variables and statistics for the project to cope with climate change or weather events.<br>• The objective is to drive the dialogue for adaptation choices with project sponsors or designers.<br>• User-focused approach, the Aware platform serves as basis for tailored analyses. |

| OUTPUTS OF THE APPROACH | |
|---|---|
| **Type of output available** | |
| Qualitative (scoring) | |
| Detail | • Rating of climate risk to the project (for separate and aggregate climate hazards) in three levels (low/medium/high risk).<br>• This is a screening of the project climate risk, not an in-depth impacts and vulnerability assessment of the project:<br>- *Express report:* automated, rapid option that utilizes pre-defined climate sensitivity ratings specific to the chosen sub-sector;<br>- *Full report:* requires the user to answer a series of climate sensitivity-related questions based on the user's knowledge of the project's design and operation. This option is recommended for a more detailed analysis based on the user's knowledge of the project.<br>• Information is qualitative (indicators are qualitative, the methodology does not estimate the monetary impacts to the socioeconomic objects). |
| **Type of aggregation of information available** | |
| **Per hazard** | Detail and aggregation per hazard |
| **Per counterparty** | Per project; per portfolio |
| **Per type of impact** | All impacts combined |
| **Per scenario** | No |
| **Per time horizon** | Restricted to one horizon |
| **Information media** | |
| Nature of platform | • Website returning a climate risk screening report (express report or manual report).<br>• PDF format printing |
| Visual architecture (*e.g.* mapping, storyline) | • Rating (low/medium/high risk categories at the project level and for individual hazards).<br>• Radar chart (low/medium/high risk at individual hazard level).<br>• Map of project locations.<br>• Textual information: it comprises detail of project information. It also comprises sections dedicated to a specific climate hazard comprises: detail on the level of exposure; reminder of the client-declared sensitivity of the project to the climate hazard considered in the section (when applicable); narrative on the nature of impacts in the current or future climate context; the level of model agreement on future climatic conditions; recommendation on the need to discuss with project designers about integration of climate change impacts in project design (by establishing critical thresholds on climate-related variables); list of questions as a starting point for discussion; additional resources (for in-depth analysis of climate impacts to a specific infrastructure; for latest news and information on the climate hazard of the section). |
| Customization by the user | Personal comments can be saved. |

### AWARE FOR PROJECTS – BY ACCLIMATISE (CONTINUED)

| Pedagogy by displaying background information on | | | |
|---|---|---|---|
| Hazards | Perimeter | | Selection of acute and chronic hazards |
| | Period of analysis | | Current, 2020 or 2050 depending on data |
| | Granularity of primary data | | 0.5° Grid (*i.e.* 50km x 50km at the equator) |
| Counterparty | Perimeter of | Exposure | Location of project component |
| | | Sensitivity (assets; natural resource; labor; sales; etc.) | Not detailed |
| | | Adaptive capacity | Through threshold on climate variable |
| | Granularity of primary data on | Exposure | Project component level |
| | | Sensitivity | Project component level |
| Impact | Perimeter of impacts | Socio-economic | No |
| | | Financial | No |
| Methodological assumptions and data gaps | | | Detail on sources |
| Explaining treatment of climate and socio-economic uncertainties | | | For model ucnertainty, use of indicator on multi-model agreement integrated when wheighting the exposure to location-specific climate hazard data; for climate uncertaity, use of scenario uncertainty; for socio-economic uncertainty, use of absolute threshold on climate variable reflecting the situation that is unbearable for the project. |

| Accessing outputs of the approach | |
|---|---|
| Available for free | No |

## CLIMATE HAZARD

### Scope of hazards

*Acute:* Wildifire; Flood; Landslide; Tropical storms.
*Chronic:* Temperature increase; Permafrost; Sea Ice (seasonal); Precipitation increase (seasonal increase); Snow loading; Precipitation decrease; Water availability.
The hazards are studied on Frequency and intensity aspects. The dataset characterizes the increase in hazardous phenomena (through absolute exceedance of a threshold).

| Forward-looking dimension | |
|---|---|
| Time horizon | Current; 2020 or 2050 depending on data |
| Nature of data (projection; forecast; historical data; trend scenario; exploratory scenario) | Projection and historical data |
| Alternative futures (unique or multiple) | Unique scenario |

| Type of source | |
|---|---|
| Public, private, non disclosed sources | Public sources: IPCC (CMIP5 (temperature increase, precipitation increase, precipitation decrease; other GCM projections (water availability, snow loading); UNEP/GRID-Europe (wildfire; landslide; tropical storms); US NSIDC (permafrost; sea ice; snow loading; Darmouth Flood observatory Colorado University (flood); Alcamo et al (2007) (water availability); Global Precipitation Climatology Centre (water availability). |

| Processing climate data | |
|---|---|
| Treatment | • Post processing of all data<br>• Resampling to a common grid the heterogenous initial resolutions<br>• Aware characterizes hazards as climate-related indicators, derived from data processed against pre-determined thresholds |
| Final spatial resolution | 0.5° grid (*i.e.* 50km x 50km at the equator) |

### AWARE FOR PROJECTS – BY ACCLIMATISE (CONTINUED)

| EXPOSURE | | | | |
|---|---|---|---|---|
| Type of data | Type of source | Type of processing | | |
| | Public, private, not disclosed | Scale of data | Treatment | Final scale of exposure |
| Location of project components | Private source (End-user) | Project component level | None | Project component level |

| SENSITIVITY | | | | |
|---|---|---|---|---|
| Type of data or instrument | Type of source | Type of processing | | |
| | Public, private, not disclosed | Scale of data | Treatment | Final scale of sensitivity |
| Aggregate information on project specific sensitivity | *Private:*<br>• End-user (aggregate information on project component specific sensitivity) or<br>• Acclimatise expertise | • Project component specific (from end-user) or<br>• Sub-sector specific (from Acclimatise matrix) | | Project component |

| ADAPTIVE CAPACITY | | |
|---|---|---|
| Type of data | Type of source | Type of processing |
| | Public, private, not disclosed | |
| Thresholds on climate variables, that define the coping capacity of the counterparty | Private (pre-determined in Aware) | |

| IMPACTS | |
|---|---|
| Type of processing | |
| Analytical steps | 1/ Score per individual hazards: as a combination of hazard specific sectoral sensitivity and exposure data<br>2/ Aggregation of hazard scores at project component level<br>3/ Aggregation of project component scores at project level |
| Final scale of information | Project level |
| Type of financial impact | |
| Asset damage; loss of revenue (or production); rise of costs; implicit | Asset damage |

### 4. CLIMATE VAR – BY CARBON DELTA

| SHORT DESCRIPTION OF THE APPROACH | |
|---|---|
| Name of approach | Climate VaR |
| Service provider | Carbon Delta |
| Targeted user | Financial Institutions, policy-makers and Corporations |
| Targeted use | The Climate VaR is used to understand the impact that climate change could have on the valuation of investment securities. Various use cases have been identified: Country level, ALM/Asset level, Portfolio or Weighted asset risk (for contribution of assets to the portfolio risk) or unweighted asset risk (for broader view of issues at portfolio companies). |
| Summary of the approach | Quantifies the financial impacts of climate risks and opportunities onto companies, which can be aggregated at portfolio level. Currently covering equity and corporate bonds but expanding in sovereign bonds as well. Physical risk analysis covers the impact of climate hazards on company locations, focusing on business interruption (*i.e.* subsequent loss of revenue) and asset damage.<br>Extreme weather scenario is based on 30 years of observed, historical trend data, extrapolated forward for extreme weather events. |

| OUTPUTS OF THE APPROACH | | | |
|---|---|---|---|
| **Type of output available** | | | |
| Climate Value at Risk (Climate VaR) is a quantitative estimate of the expected financial loss or gains from climate risks and opportunities. | | | |
| Detail | Possible to ask for climate cost estimates instead of complete Climate VaR. | | |
| **Type of aggregation of information available** | | | |
| **Per hazard** | All hazards combined | | |
| **Per counterparty** | Per counterparty, per sector; per portfolio; per geography. | | |
| **Per type of impact** | All impacts combined | | |
| **Per scenario** | Restricted to one scenario | | |
| **Per time horizon** | Restricted to one horizon | | |
| **Information media** | | | |
| Nature of platform | Carbon Delta has developed a software that delivers all of its climate risk/opportunity computations. Data can be delivered in various formats, *i.e.* .xlsx, .csv, .json, etc. Their proprietary software generates all data outputs and also produces portfolio and enterprise factsheets in pdf, which are used to explain the results of the scenario analysis. | | |
| Visual architecture (*e.g.* mapping, storyline) | Analytics factsheets | | |
| Customization by the user | The Climate VaR model is flexible for adjusting assumptions and input parameters. There are several steps in the computational chain, which leave room for modifications. | | |
| **Pedagogy by displaying background information on** | | | |
| **Hazards** | Perimeter | | Selection of acute hazards |
| | Period of analysis | | Coming 15 years |
| | Granularity of primary data | | 50Km x 50 km |
| **Counterparty** | Perimeter of | Exposure | Operation and sales sites |
| | | Sensitivity (assets; natural resource; labor; sales; etc.) | Operation and downstream |
| | | Adaptive capacity | Not included |
| | Granularity of primary data on | Exposure | Facility for operations and country per sector for sales |
| | | Sensitivity | Sectoral and calibration with news data |
| **Impact** | Perimeter of impacts | Socio-economic | Implicit scope along operations and downstream value chain |
| | | Financial | Asset damage and loss of revenue along operations and downstream value chain |
| Methodological assumptions and data gaps | | | |
| Explaining treatment of climate and socio-economic uncertainties | | | |
| **Accessing outputs of the approach** | | | |
| Available for free | No | | |

***CLIMATE VAR – BY CARBON DELTA (CONTINUED)***

## CLIMATE HAZARD

### Scope of hazards

*Acute:* Wildfire; Extreme temperatures (heatwave and coldwave); Extreme snowfall; Extreme precipitation; Extreme wind patterns; Tropical cyclones; Fluvial and coastal flooding (to be coverd in 2018).
The hazards are studied on frequency and intensity. The dataset characterizes hazardous phenomena in absolute levels, extracted from observed weather trends.

| Forward-looking dimension | |
|---|---|
| Time horizon | The coming 15 years |
| Nature of data (projection; forecast; historical data; trend scenario; exploratory scenario) | Scenario (trend) |
| Alternative futures (unique or multiple) | Unique scenario |
| **Type of source** | |
| Public, private, non disclosed sources | Public sources (ERA-Interim (extreme weather); ETH Zurich Climada model simulations; Exploration of satellite data (Sentinel 1&2 program) and earth obervation data. |
| **Processing climate data** | |
| Treatment | 35 years of observed data:<br>• statistically processed to be compatible with the 0.5°x0.5° grid<br>• statistical extrapolation of the trend updated on an annual basis. |
| Final spatial resolution | 0.5° grid (*i.e.* 50 km x 50 km at the equator) |

## EXPOSURE

| Type of data | Type of source: Public, private, not disclosed | Type of processing: Scale of data | Treatment | Final scale of exposure |
|---|---|---|---|---|
| **Corporates (operations)** | | | | |
| Location of facilities | Public (Google Maps, Linked In, Monster); private (Database on 35,000 companies: 600,000 production facilities in power sector, cement sector and other industries) | Facility level | None | Facility level |
| **Corporates (downstream)** | | | | |
| Location of sales | Private (Factset) | Counterparty (per sector and country) | None | Counterparty (per sector and country) |

## SENSITIVITY - CORPORATES (OPERATIONS AND DOWNSTREAM)

| Type of data or instrument | Type of source: Public, private, not disclosed | Type of processing: Scale of data | Treatment | Final scale of sensitivity |
|---|---|---|---|---|
| • News on impacts of past climate hazards on targeted companies (days of interruption and loss of revenue)<br>• Characteristics of facility<br>• Sectoral cost function | Public: satellite imagery (characteristics of facilities), Open street map (characteristics of facilities); private: news service; PIK Institute for cost function | Facility and sectoral level | Cost function is calibrated with the news data. The function is based on revenue per day and days of interruption from the event. | Facility level |

## ADAPTIVE CAPACITY

Not included in the methodology.

***CLIMATE VAR – BY CARBON DELTA (CONTINUED)***

| IMPACTS - CORPORATES (OPERATIONS AND DOWNSTREAM) | |
|---|---|
| Additional data and instruments | |
| Type of data | • Financial market data<br>• Financial valuation model: classical discounted dividend model for equity; classical bond valuation model |
| Type of source | |
| Public availability of sources; scale of information | Bloomberg, Reuters and Factset (financial market data); counterparty level |
| Type of processing | |
| Analytical steps | 1/ Combination of hazard, exposure and sensitivity<br>2/ Financial Valuation of impacts |
| Final scale of information | Counterparty level |
| Type of financial impact | |
| Asset damage; loss of revenue (or production); rise of costs; implicit | Asset damage; loss of revenue (or production) |

### 5. CRIS – BY CARBONE 4

| SHORT DESCRIPTION OF THE APPROACH | |
|---|---|
| Name of approach | CRIS – Climate Risk Impact Screening |
| Service provider | Carbone 4 |
| Targeted user | Financial actors (asset manager, asset owner, etc.) |
| Targeted use | Analysis of physical climate risk |
| Summary of the approach | Qualitative scoring of the climate risk level of different types of assets (sovereign, corporate, infrastructure) and portfolios, covering all business sectors in 210 countries. It accounts for 7 direct climate hazards and 9 indirect hazards, in 3 climate scenarios on two time horizons (2050 and 2100). Corporate exposure is defined at the scale of business units (defined as "geography-sector" couples for corporates). The methodology uses ectoral vulnerability to different hazards with a value chain approach based on correlations across hazard/potential max financial losses and sector sensitivity. |

| OUTPUTS OF THE APPROACH | |
|---|---|
| **Type of output available** | |
| | Scoring |
| Detail | The scoring is presented through a 5-class system (Lower, Moderate, Medium, High and Very High risk) and a 0 to 99 score. The scoring is relative (*i.e.* low score means the asset is part of assets that are least at risk, but absolute impact is not monetized). It is based on the combination of climate hazard exposure and sectoral/sovereign vulnerability, for each hazard. |
| **Type of aggregation of information available** | |
| **Per hazard** | Detail and aggregation per hazard |
| **Per counterparty** | Detail and aggregation per project; per counterparty and business unit levels; per sector; per geography; per portfolio. |
| **Per type of impact** | All impacts combined |
| **Per scenario** | Presentation of several scenarios |
| **Per time horizon** | Detail and aggregation per horizons |
| **Information media** | |
| Nature of platform | For corporate and sovereign assets, a web data platform is available for clients, comprising both scorings for our CRIS physical risk assessment, and our CIA transition risk assessment (http://www.carbon4finance.com/). A pre-screening tool is available for corporate analysis (https://c4mycris.com/). For real assets and private equity, specific tools are also available. |
| Visual architecture (*e.g.* mapping, storyline) | Scoring gauges / Linear trajectory of risk level over time for each scenario with normalized values allowing for comparison of risk levels across time horizons and scenarios / Scores allow comparison with sectoral best-in-class and average / Comments on main vulnerability components and main hazards projection for the most risky business units / Textual presentation of detailed outputs, inputs on asset information and methodology. |
| Customization by the user | Yes, through mycris website. |

| Pedagogy by displaying background information on | | | |
|---|---|---|---|
| **Hazards** | Perimeter | | Relevant hazards in a list of 7 direct hazards (both acute and chronic) and 9 indirect hazards (for sovereigns: uncertainty information), with geographic coverage. |
| | Period of analysis | | 20-year/30-year period projections compared to an historical 20-year/30-year reference period |
| | Granularity of primary data | | 25 to 100km2 raw resolution. Up to 8km for some countries (*e.g.* France) |
| **Counterparty** | Perimeter of | Exposure | All value chain |
| | | Sensitivity (assets; natural resource; labor; sales; etc.) | Generalized approach on value chain and financial impacts to the counterparty, based on 15 vulnerability factors assessed for each sector or country. |
| | | Adaptive capacity | Not included for corporates; included with detailed components for sovereigns |
| | Granularity of primary data on | Exposure | Variable granularity depending on data availability (from asset level to country-level information) |
| | | Sensitivity | Sector specific |
| **Impact** | Perimeter of impacts | Socio-economic | Generalized approach on value chain and impacts to the counterparty |
| | | Financial | Generalized approach on value chain and impacts to the counterparty (on CAPEX, OPEX and sales for corporate, and Debt and GDP for sovereign, with more than 10 underlying components in total) |

### *CRIS – BY CARBONE 4 (CONTINUED)*

| | |
|---|---|
| Methodological assumptions and data gaps | Details on confidence about data quality and availability |
| Explaining treatment of climate and socio-economic uncertainties | Use of alternative climate scenarios and mentions multi-model approach for each scenario |

**Accessing outputs of the approach**

| | |
|---|---|
| Available for free | No |

## CLIMATE HAZARD

### Scope of hazards

*Acute:* Heatwaves (and aggravation as urban heat island intensification); Extreme rainfall (and aggravation as river and groundwater floods, landslides and mass movements); Extreme drought (and aggravation as water scarcity and wildfires); Storms.
*Chronic:* Average temperature (and aggravation as biodiversity migration and loss and air quality degradation); Rainfall patterns; Sea level rise (and aggravation as coastal floods and coastal erosion).
The acute hazards are studied on frequency, intensity and duration aspects. The dataset characterizes the increase in acute hazardous phenomena (as a relative increase in frequency and intensity compared with a reference period).

### Forward-looking dimension

| | |
|---|---|
| Time horizon | 2050 and 2100 |
| Nature of data (projection; forecast; historical data; trend scenario; exploratory scenario) | 20-year/30-year period projections compared to an historical 20-year/30-year reference period. |
| Alternative futures (unique or multiple) | 3 IPCC families based on SRES and RCP scenarios : low-emission (below 3°C); medium-emission (above 3°C); high-emission (above 4°C). |

### Type of source

| | |
|---|---|
| Public, private, non disclosed sources | Public sources (IPCC's CMIP3 and CMIP5 models; EM-DAT (disasters); PSMSL (sea level); WB, UNEP, etc. (aggravating factors). |

### Processing climate data

| | |
|---|---|
| Treatment | Statistical approach and normalization |
| Final spatial resolution | Country and infracountry (state, district, departments) based on 25 to 100km² raw resolution. Up to 8km for some countries (*e.g.* France) |

## EXPOSURE

| Type of data | Type of source | Type of processing | | |
|---|---|---|---|---|
| | Public, private, not disclosed | Scale of data | Treatment | Final scale of exposure |
| **Corporates (operation; downstream) and infrastructure** | | | | |
| Sectoral split of revenues<br>Sectoral capital intensity<br>Location of fixed assets<br>Location of revenues | Public databases (*e.g.* Factset) and disclosure of the company | Business unit (*i.e.* geography-sector couple): from asset level to country level depending on available information | Exposure is defined per business unit. The proxy is location of fixed assets or revenues depending on sectoral capital intensity. The level of geographic breakdown depends on available information and final result is at country scale. | Sectoral at country level, and company / infrastructure level |
| **Sovereigns** | | | | |
| Structural indicators or socio-economical evolving indicators | Worldwide databases | Country | The data treats different aspects altogether (infrastructure, natural resources, population, industrial means). Each indicator informs on a specific hazard or its aggravating factor. | Country |

### CRIS – BY CARBONE 4 (CONTINUED)

| SENSITIVITY | | | | |
|---|---|---|---|---|
| Type of data | Type of source | Type of processing | | |
| | Public, private, not disclosed | Scale of data | Treatment | Final scale of sensitivity |
| **Corporates (upstream; operation; downstream) and infrastructure** | | | | |
| Matrix on Sectorial sensitivity to hazard, as combination of:<br>• Hazard-specific information: potential impact as a correlation between hazard and financial items<br>• Sector-specific information: potential impact as a correlation between sectors and the hazard-specific information | Public documentation review and private expert opinion | Sectoral | The sectoral sensitivity combines the datasets to establish correlations between hazards and financial items at sectorial level, with a value chain perspective (that includes consideration on workforce, natural resource, logistics, sales; etc.) | Sectoral |
| **Sovereigns** | | | | |
| • Indicators on hazard impacts to the country | Public (WB, UNEP, etc.) and non disclosed worldwide databases | Country | Multi-indicator agreggation methods | Country |

| ADAPTIVE CAPACITY | | |
|---|---|---|
| Type of data | Type of source | Type of processing |
| | Public, private, not disclosed | |
| **Corporates and infrastructure** | | |
| Not included in the methodology. | | |
| **Sovereigns** | | |
| Indicators capturing the potential impacts on: infrastructure, natural resources, population, and industrial means that all impact the three main dimensions of the sovereign rating: economic strength, financial strength and social strength. | Public (*e.g.* World Bank, ND-GAIN) | Adaptive capacity indicators are weighted between each others. This creates a rating that moderates the gross vulnerability risk of the country. |

| IMPACTS | |
|---|---|
| **Corporates (upstream; operation; downstream) and infrastructure** | |
| Type of processing | |
| Analytical steps | 1/ *Climate hazard rating:* catching magnitude, frequency and duration of hazards, with larger weight on direct hazards and smaller on aggravating factors.<br>2/ *Vulnerability rating:* this is the sectoral vulnerability computed from sensitivity datasets.<br>3/ Climate-hazard risk rating: combination of climate hazard and vulnerability ratings per sector; and combination of sectors with weighting on company's revenues per sector.<br>4/ *Aggregate climate risk rating:* combination of climate-hazard risk ratings, with acute hazard overweigthed. |
| Final scale of information | Per hazard, business unit, time horizon, scenario. Aggregation is possible across business units, hazards. |
| Type of financial impact | |
| Asset damage; loss of revenue (or production); rise of costs; implicit | Asset damage; loss of revenue (or production); rise of costs |

***CRIS – BY CARBONE 4 (CONTINUED)***

| **Sovereigns** | |
|---|---|
| Type of processing | |
| Analytical steps | Sovereign risk ratings are calculated per country and per hazard. They are the combination of a location-specific hazard rating and a country vulnerability rating. The country vulnerability rating is calculated per hazard. For each hazard, it is the combination of exposure and sensitivity datasets, moderated by an adaptive capacity rating. |
| Final scale of information | Country; per hazard, time horizon, scenario. Aggregation is possible across hazards. |
| Type of financial impact | |
| Asset damage; loss of revenue (or production); rise of costs; implicit | Asset damage; loss of revenue (or production); rise of costs |

### 6. PHYSICAL EFFECTS OF CLIMATE CHANGE ON SOVEREIGN ISSUERS – MOODY'S INVESTORS SERVICE

| SHORT DESCRIPTION OF THE APPROACH | |
|---|---|
| Name of approach | Physical Effect of Climate Change on Sovereign Issuers |
| Service provider | Moody's Investors Service |
| Targeted user | Investors (sovereign portfolio) |
| Targeted use | This is not a new product to investors. |
| Summary of the approach | In-depth screening on the susceptibility to climate change risk of Moody's-rated sovereigns, based on illustrative data.<br>The screening encompasses mainly impacts of climate-related disasters on a country.<br>This serves to analyze how these susceptibility factors correlate with Moody's creditworthiness ratings based on Moody's existing scorecard.<br>This "susceptibility heat map" (in the sense it is formatted as a qualitative 4-point scale) is not a standalone sovereign rating product. |

| OUTPUTS OF THE APPROACH | |
|---|---|
| **Type of output available** | |
| | Scoring of sovereigns |
| Detail | • Susceptibility to climate change presented as a heatmap through a 4-point colored scale (labeled "Most Susceptible", "Susceptible", "Less susceptible", "Least Susceptible").<br>• Heat map is based on quantified indicators bucketed into two main indicators: "Exposure" to climate change risk and "Resilience" to climate change risk. |
| **Type of aggregation of information available** | |
| **Per hazard** | All hazards combined |
| **Per counterparty** | Per sovereign |
| **Per type of impact** | All impacts combined |
| **Per scenario** | No |
| **Per time horizon** | Restricted to one horizon |
| **Information media** | |
| Nature of platform | Moody's 2016's report titled "How Moody's Assesses the Physical Effects of Climate Change on Sovereign Issuers". |
| Visual architecture (*e.g.* mapping, storyline) | • Mapping of susceptibility to physical climate change of Moody's-rated sovereigns based on illustrative data, with a 4-point colored scale.<br>• Table on detail of quantified indicators (and with a 4-point colored scale) of exposure and resilience to climate change risk, for Moody's-rated sovereigns most susceptible to physical climate change based on illustrative data. |
| Customization by the user | NA |

| Pedagogy by displaying background information on | | | |
|---|---|---|---|
| **Hazards** | Perimeter | | Selection of acute hazards |
| | Period of analysis | | Historical (mainly 10-year horizon) |
| | Granularity of primary data | | Not mentioned |
| **Counterparty** | Perimeter of | Exposure | Indicators on economic diversification and geographic location |
| | | Sensitivity (assets; natural resource; labor; sales; etc.) | Specific indicator on sensitivity and additional integration into an indicator of impacts |
| | | Adaptive capacity | Specific indicator on adaptive capacity and integration into other indicators of resilience |
| | Granularity of primary data on | Exposure | Country level |
| | | Sensitivity | Country level |
| **Impact** | Perimeter of impacts | Socio-economic | Damage to infrastructure, impact on economic activity, social costs, population shifts |
| | | Financial | Asset damage, economic and social costs |
| Methodological assumptions and data gaps | | | Detail provided on scope and data sources |
| Explaining treatment of climate and socio-economic uncertainties | | | NA (historical approach) |

ANNEX 3: SUMMARY TABLES OF AVAILABLE APPROACHES

### PHYSICAL EFFECTS OF CLIMATE CHANGE ON SOVEREIGN ISSUERS – MOODY'S INVESTORS SERVICE (CONTINUED)

| Accessing outputs of the approach | |
|---|---|
| Available for free | • This is not a new product to investors.<br>• Specific information on physical climate impacts and sovereign ratings can be found in Moody's investors service 2016's report titled "How Moody's Assesses the Physical Effects of Climate Change on sovereign Issuers", accessed online the 02/20/2018 at: https://www.eticanews.it/wp-content/uploads/2017/01/Moodys-climate-change-and-sovereigns-November-7.pdf<br>• A specific study on the case of small island sovereigns and climate impacts can be found in Moody's investors service 2017's report titled "Small island credit profiles resilient to near term climate shocks, but climate trends pose longer-term risks" available to Moody's investors service subscribers.<br>• Broader information on ESG at Moody's can be found online at: https://esg.moodys.io/ |

## CLIMATE HAZARD

### Scope of hazards

*Acute:* Drought; Extreme temperatures; Floods; Landslide; Storms; Wildfire.
The hazards are studied on Frequency and intensity aspects. The dataset characterizes hazardous phenomena through absolute level of impacts from past disasters.

| Forward-looking dimension | |
|---|---|
| Time horizon | NA (Historical. No quantified forecast is included, but Moody's monitors the evolution of climate hazards) |
| Nature of data (projection; forecast; historical data; trend scenario; exploratory scenario) | Historical data |
| Alternative futures (unique or multiple) | NA (Historical) |
| **Type of source** | |
| Public, private, non disclosed sources | Public sources (EMDAT; National sources) and proprietary sources |
| **Processing climate data** | |
| Treatment | The datasets do not provide individual exposure to events. they provide:<br>• Number of annual climate change related Disasters (10-year average): represents the frequency of disasters related to climate change (which includes drought, extreme temperature, flood, landslide, storm and wildfire).<br>• Annual Damage (% GDP – over 10 years) represents the magnitude of natural disasters impacts. |
| Final spatial resolution | Country level |

## EXPOSURE

| Type of data | Type of source | Type of processing | | |
|---|---|---|---|---|
| | Public, private, not disclosed | Scale of data | Treatment | Final scale of exposure |
| Exposure is treated through indicators on economic diversification and geographic location:<br>• Economic diversification through:<br>- size of economy (nominal GDP);<br>- concentration of agriculture (agriculture employment as % labor force; Agricultural Total VA as %GDP);<br>• Geographic location through Indicator on exposure from ND-GAIN exposure | Public sources (IMF, Eurostat, AMECO, National Sources, International Labor Organization, World Bank, OECD; USDA; ND-GAIN) and private sources (Moody's) | Country | None | Country |

***PHYSICAL EFFECTS OF CLIMATE CHANGE ON SOVEREIGN ISSUERS – MOODY'S INVESTORS SERVICE (CONTINUED)***

| SENSITIVITY | | | | |
|---|---|---|---|---|
| Type of data | Type of source | Type of processing | | |
| | Public, private, not disclosed | Scale of data | Treatment | Final scale of sensitivity |
| **Corporates (upstream; operation; downstream) and infrastructure** | | | | |
| Sensitivity is treated specifically through a sensitivity index and integrated into an indicator of impacts:<br>• Sensitivity index is from the ND-GAIN vulnerability index - sensitivity component: this is the extent to which a country is dependent upon a sector negatively affected by climate hazard, or the proportion of the population particularly susceptible to a climate change hazard.<br>• Indicator of annual damage from natural disasters (as %GDP over 10 years) | Public sources (ND-GAIN, EMDAT, National sources) and private sources (Moody's) | Country | None | Country |

| ADAPTIVE CAPACITY | | |
|---|---|---|
| Type of data | Type of source | Type of processing |
| | Public, private, not disclosed | |
| Indicators make adaptive capacity and resilience interconnected. It includes:<br>• Development level through: wealth (GDP per capita); Resource available for adaptation (ND-GAIN Vulneravility Index - Adaptive capacity component)<br>• Fiscal flexibility through: debt burden, debt affordability; government fiscal strength (fiscal sub-indicators are: General government debt as %GDP; General Government Interest Payments/ General Government Revenues %; Government fiscal deficit as %GDP) | Public sources (IMF; OECD; Eurostat; AMECO; National Sources; ND-GAIN)<br>and private sources (Moody's) | None |

### *PHYSICAL EFFECTS OF CLIMATE CHANGE ON SOVEREIGN ISSUERS – MOODY'S INVESTORS SERVICE (CONTINUED)*

| **IMPACTS** | |
|---|---|
| Type of processing | |
| Analytical steps | Moody's has compiled a list of macroeconomic variables and independent indices to illustrate the relative susceptibility of rated sovereigns to the effects of physical climate change.<br>Exposure encompasses economic diversification and geographic location indicators. Both aspects of exposure factor in the description of hazards, their likelihood, the exposure of the country and population, the sensitivity of the country and a measure of magnitude of climate impacts in terms of GDP. Economic diversification includes size of economy (nominal GDP); concentration of agriculture (agriculture employment as % labor force; Agricultural Total VA as %GDP). Geographic location includes exposure (ND-GAIN exposure); hazards (number of annual climate change related disasters; annual damage; ND-GAIN sensitivity).<br>Resilience encompasses development level (it looks broadly at the resources available for adaptation to climate change), fiscal flexibility (it reflects a sovereign's capacity to carry extra debt to cope with any material physical damage) and government policies (it refers to those policies that address climate change risks, such as insurance of savings funds to mitigate against natural disasters) indicators. These aspects of resilience factor in the capacity of a country to recover form climate-related disasters once they occurred. Development level is included through wealth (GDP per capita); Adaptive capacity (ND-GAIN Vulneravility Index - Adaptive capacity component). Fiscal flexibility is included through: debt burden, debt affordability; government fiscal strength (General government debt %GDP; General Government Interest Payments/General Government Revenues %; Government fiscal debt as %GDP). No indicator was available to inform on government policies.<br>Indeed, what is considered important for credit risk is how climate impacts might affect the borrower's capacity and willingness to repay existing obligations. Thus the risk to the lender is in the exposure of the borrower to climate events and their capacity to maintain or improve their functional capacity (and capacity to repay debt) when such events occur, that is, their resilience.<br>In terms of analytical steps:<br>1/ Indicators are bucketed into Exposure and Resilience indicators;<br>2/ In each sub-category of Exposure and Resilience, the indicators are equal weighted. Where data for one indicator (*e.g.* agricultural employment) is missing, Moody's considers only other indicators in that sub-category;<br>3/ Moody's report analyzes the correlation between Moody's sovereign ratings and the susceptibility of sovereigns to phyical climate change. The susceptibility to physical climate change of Moody's-rated sovereigns is neither merged with Moody's sovereign credit risk ratings nor considered as a complement to them. |
| Final scale of information | Country level |
| Type of financial impact | |
| Asset damage; loss of revenue (or production); rise of costs; implicit | Primary credit risk from physical climate change:<br>• Impact on economic activity (*e.g.* crop yield, flooding, destruction of livelihoods);<br>• Damage to infrastructure (*e.g.* physical impact of cyclones, major floods);<br>• Social costs (*e.g.* health crisis, flood security concerns);<br>• Population shifts (*e.g.* forced displacements).<br>These primary impacts may influence Moody's key factors used for sovereign ratings. These key factors are:<br>• *Factor 1:* Economic Strength (rating sub-factors: growth dynamics; scale of the economy; national income; adjustment factors);<br>• *Factor 2:* Institutional Strength (rating sub-factors: institutional framework and effectiveness; policy credibility and effectiveness; adjustment factors);<br>• *Factor 3:* Fiscal Strength (rating sub-factors: debt burden; debt affordability; adjustment factors);<br>• *Factor 4:* Susceptibility to Event Risk (rating sub-factors: political risk; government liquidity risk; banking sector risk; external vulnerability risk);<br>(For further detail on matching between climate impacts and key sovereign rating factors, see Exhibit 3 of Moody's (2016) report entitled "How Moody's Assesses the Physical Effects of Climate Change on Sovereign Issuers"). |

### 7. TRIP FRAMEWORK – BY MERCER

| SHORT DESCRIPTION OF THE APPROACH | |
|---|---|
| Name of approach | TRIP framework |
| Service provider | Mercer |
| Targeted user | Investors |
| Targeted use | Framework for investors to prioritize risks and opportunities during strategy setting, portfolio construction, and manager selection and monitoring. |
| Summary of the approach | • Quantified impact of climate risk on financial portfolio returns.<br>• Twofold indicator on climate impact to assets in the TRIP framework: I – Impact (physical impacts from short-term acute climate events) and R – Resource availability (impact of long-term shifts in climate patterns to sectoral resource inputs).<br>• 4 climate and socio-economic scenarios and 10- or 35-year time horizons.<br>• Portfolio analysis under classical asset class breakdown and under sectoral breakdown.<br>• Risk analyzed as downside risk and upside opportunities. |

| OUTPUTS OF THE APPROACH | |
|---|---|
| **Type of output available** | |
| Quantitative (financial estimate) | |
| **Type of aggregation of information available** | |
| **Per hazard** | All hazards combined |
| **Per counterparty** | Per sector; per asset class; per portfolio |
| **Per type of impact** | Separation of physical impacts ("I factor") and impacts from climate sensitive resources ("R factor") |
| **Per scenario** | Four different scenarios |
| **Per time horizon** | Restricted to one horizon |
| **Information media** | |
| Nature of platform | Not detailed |
| Visual architecture (*e.g.* mapping, storyline) | Visible in Mercer's reports:<br>• Circular diagram of portfolio and weighted constituent asset classes, with magnitude and direction (positive or negative) of impact from the TRIP factors to each constituent asset class.<br>• Bar chart of annual return impact per industry sector or asset class:<br>- Across scenarios, with minimum and maximum variation when change is unidirectional across scenarios, or with maximum variability when change goes is positive and negative across scenarios;<br>- In a given scenario.<br>• Heat maps on the sensitivity of asset classes or sectors for each TRIP factor.<br>• Textual information:<br>- Narrative of potential TRIP impacts in each scenario;<br>- Key indicators for investors for each TRIP factor in each scenario (*e.g.* magnitude of impacts depending on time horizon; global GDP loss). |
| Customization by the user | No |

| Pedagogy by displaying background information on (***) | | | |
|---|---|---|---|
| **Hazards** | Perimeter | | Selection of acute and chronic hazards |
| | Period of analysis | | Average impacts from 2015 to 2050 |
| | Granularity of primary data | | Not detailed |
| **Counterparty** | Perimeter of | Exposure | End user data |
| | | Sensitivity (assets; natural resource; labor; sales; etc.) | Implicit |
| | | Adaptive capacity | Included in fund damage functions (implicitly; or explicitly for agriculture and for SLR sector of impact) |
| | Granularity of primary data on | Exposure | End user data |
| | | Sensitivity | Sectoral |

### TRIP FRAMEWORK – BY MERCER (CONTINUED)

| | | | |
|---|---|---|---|
| Impact | Perimeter of impacts | Socio-economic | Capital and labor on implicit parts of value chain ("I factor"); natural resources on implicit parts of value chain ("R factor") |
| | | Financial | Implicit |
| Methodological assumptions and data gaps | | | Explanation on modelling damages based on FUND model |
| Explaining treatment of climate and socio-economic uncertainties | | | Concerning the uncertainty of the FUND model: damage functions that have critical contribution to damages in the study period are reviewed for reasonability and directional accuracy based upon current research and expert judgment.<br>Concerning the vulnerability of future socio-economic systems, some views on the markets are incorporated in the financial valuation of impacts, based on expert judgment. |
| **Accessing outputs of the approach** | | | |
| Available for free | No | | |

*(***) This section on information displayed to the end user is filled based on the information available in Mercer's 2015 report "Investing in a time of climate change».*

## CLIMATE HAZARD

### "I - Physical impacts factor"

#### Scope of hazards

*Acute:* (Extra) Tropical Storm; Coastal flood; Extreme temperature; Wildfire
The focus on a specific statistical dimension of hazards (*e.g.* frequency, intensity, duration) is not detailed. The dataset characterizes the increase in hazardous phenomena.

| Forward-looking dimension | |
|---|---|
| Time horizon | 2050 |
| Nature of data (projection; forecast; historical data; trend scenario; exploratory scenario) | Exploratory scenario (average impacts from 2015 to 2050) |
| Alternative futures (unique or multiple) | Four scenarios |
| **Type of source** | |
| Public, private, non disclosed sources | Climate scenarios from Mercer and partners largely informed by FUND model |
| **Processing climate data** | |
| Treatment | Not detailed |
| Final spatial resolution | Not detailed |

### "R - Resource availability factor"

#### Scope of hazards

*Acute:* Coastal flood.
*Chronic:* Average annual temperature; Average annual precipitation; Shifts in timing / duration of rainy seasons.
The focus on a specific statistical dimension of hazards (*e.g.* frequency, intensity, duration) is not detailed. The dataset characterizes the increase in hazardous phenomena.

| Forward-looking dimension | |
|---|---|
| Time horizon | 2050 |
| Nature of data (projection; forecast; historical data; trend scenario; exploratory scenario) | Exploratory scenario (average impacts from 2015 to 2050) |
| Alternative futures (unique or multiple) | Four scenarios |
| **Type of source** | |
| Public, private, non disclosed sources | Climate scenarios from Mercer and partners largely informed by FUND model |
| **Processing climate data** | |
| Treatment | Not detailed |
| Final spatial resolution | Not detailed |

### TRIP FRAMEWORK – BY MERCER (CONTINUED)

| EXPOSURE | | | | |
|---|---|---|---|---|
| Type of data | Type of source | Type of processing | | |
| | Public, private, not disclosed | Scale of data | Treatment | Final scale of exposure |
| The financial user provides its list of financial assets in portfolio, with sectoral breakdown. | User data | Sectoral | None | Sectoral |

| SENSITIVITY | | | | |
|---|---|---|---|---|
| Type of data | Type of source | Type of processing | | |
| | Public, private, not disclosed | Scale of data | Treatment | Final scale of sensitivity |
| • Damage functions in the FUND model<br>• Supplemented with additional analysis on damages for coastal flood, wildfires<br>• An additional scenario is developed where FUND damage estimates are on-leveled to match the estimates from the DICE global damage function. This is done to address the observation that FUND impact estimates are lower than in DICE or PAGE, driven especially by optimistic estimates in the agricultural sector. | Public (FUND; RMS and Risky business for coastal flood; costofcarbon.org for wildfire; ND-GAIN for extrapolation of loss estimates to different countries; DICE) | Focused on peril | The sectorial sensitivity is calculated for the I and the R factors. For each factor, the sectorial sensitivity reflects the sensitivity of the economic sector to different perils that have a different weight in the I or R factors.<br>Analytical steps to produce sectorial sensitivities:<br>1/ The GDP impact of each type of peril (averaged over four scenarios) is judgmentaly ventilated across the economic sectors.<br>2/ For each economic sector, the peril-weighted sensitivities are agregated across the different types of peril, to provide the aggregate sensitivity combined with GDP loss.<br>3/ Final step of normalization provides sectorial sensitivity on a [0;1] scale. | Focused on sectors |

#### ADAPTIVE CAPACITY

Adaptive capacity is not accounted for explicitly in the analysis.
NB: Diaz and Moore (2017):

- Existing adaptation measures are implicitly included in FUND damage functions, where functions are calibrated to econometric studies of net response to warming.
- Existing adaptation measures are explicitly included in FUND damage functions for agriculture sector (it includes lagged rate component that fades with adaptation) or for the SLR sector of impact (SLR assumes cost-effective adaptation with sea-walls or retreat).

| IMPACTS - "I - PHYSICAL IMPACTS FACTOR" AND "R - RESOURCE AVAILABILITY FACTOR" | |
|---|---|
| Additional data and instruments | |
| Type of data | Financial market data and model for the financial valuation of impacts |
| Type of source | |
| Public availability of sources; scale of information | Private data |

### TRIP FRAMEWORK – BY MERCER (CONTINUED)

| | Type of processing |
|---|---|
| Analytical steps | Creating quantified trajectories of TRIP impacts for each scenario:<br>• Trajectories of atmospheric GHG concentrations from socio-economic scenarios are translated into temperature change through climate sensitivity parameters in the IAMs.<br>• Temperature change is translated into economic damage (as %GDP loss) through damage functions in FUND and supplementary analysis by Mercer.<br>• Impact categories are bucketed into "I" and "R" factors based on established taxonomy of peril types from the (re)insurance industry.<br>• Bucketed impacts expressed as %GDP loss aggregate to total %GDP loss for each of the "I" and "R" factors.<br>Sectorial and regional impacts are calculated as a combination of:<br>1/ Regional climate-related impacts in a given scenraio, bucketed into the I or R factor<br>2/ Sectorial sensitivity factors<br>3/ This yields an impact to the I or R factor.<br>Asset class sensitivity is computed for each of the I and R factor:<br>Asset class sensitivity calculation depends on the type of asset class. In general, it consists in:<br>• Combining the sectoral sensitivity calculated in B.1 with the weight of the sector in the asset class (as observed in the relevant index universe, for listed assets).<br>• Integrating Mercer's own view on the market.<br>Modelling return impact to assets per industry or per asset class:<br>• The valuation model is run successively without and with each scenario on TRIP factors.<br>• The difference of return in the non-TRIP scenario and in a given TRIP scenario provides the TRIP impact on return.<br>• The valuation model is plugged with the asset sensitivities (as defined in B) and the quantification of the TRIP impact on GDP overtime (as defined in A).<br>• The valuation includes an assessment of the TRIP factor impact on volatility: initial sector and asset class volatility assumptions, based on historical averages, were adjusted for each scenario based on the variance of the TRIP factor values at 2050. This method accounts for the degree to which investment returns might be "pulled" in different directions by climate change, with greater potential volatility. The adjustment resulted in increases to historical volatility measures by as much as 20% for the coal sector, down to 0% for the health sector. |
| Final scale of information | Asset class and sectorial levels |
| | **Type of financial impact** |
| Asset damage; loss of revenue (or production); rise of costs; implicit | Implicit |

### 8. WATER RISK MONETIZER – BY ECOLAB, TRUCOST AND MICROSOFT

| SHORT DESCRIPTION OF THE APPROACH | |
|---|---|
| Name of approach | Water Risk Monetizer |
| Service provider | Ecolab together with Trucost and Microsoft |
| Targeted user | Companies |
| Targeted use | Analysis of physical climate risks |
| Summary of the approach | The Water Risk Monetizer provides monetary cost of water applicable at facility level and reflecting currently non-priced surface water risks in local context.The methodology provides a range of metrics on monetary costs to the facility and from a range of risk factors. Among the risk factors that affect monetary cost of water to the facility, climate change appears as an aggravating factor of future water stress, using WRI's Aqueduct indicators.<br>The aspects where future water stress is integrated are:<br>• The **lack of incoming water to the facility, with subsequent direct loss of revenue (deisgnated as revenue at risk)**. The metric is "**revenue at risk**" = water necessary to generate revenue / water available to the facility. It can combine with a **likelihood of impacts** being realized through a number of risk triggers that include future water stress on operations (but also legal and regulatory, reputational and marketing, financial factors).<br>• The **lack of incoming water to the facility, with subsequent indirect rise in operational cost.** The metric is "**Combined risk-adjusted price of incoming water**" = (projected water price + incoming water risk premium) x projected quantity of water. Future water stress is integrated in projections of incoming water risk premium. It is the total cost of incoming water. The rise of cost is valued as a potential pricing in water cost of the broad impacts that the facility causes when removing water from other uses. Such impacts are on human health and loss of ecosystem services. This makes use of valuation methods from environmental economics. It can combine with a likelihood of impacts being realized, including future water stress.<br>• The **cost of water outgoing from the facility**. The metric is "**Combined risk-adjusted price of outgoing water**". This is built similarly to the incoming water to the facility. In the same way, it can combine with a **likelihood of impacts** being realized, including future water stress. |

| OUTPUTS OF THE APPROACH | |
|---|---|
| **Type of output available** | |
| Quantitative (estimates of revenue at risk, total cost of water) | |
| Detail | Metrics at the facility level do not target specifically the impacts of future water stress to the facility. The available metrics are:<br>• Risk premium relative to price for incoming and outgoing water: shows the discrepancy between the current price paid for water and the additional cost of water that is currently unpriced at each facility;<br>• Potential revenue at risk due to water quantity risk: year one revenue at risk for the facility displayed as a percentage of total revenue;<br>• Rank based on water quantities, monetized risk and likelihood: this metric can be used to compare the relative water risk across a group of different facilities. |
| **Type of aggregation of information available** | |
| **Per hazard** | All hazards combined |
| **Per counterparty** | Per facility; per portfolio |
| **Per type of impact** | All impacts combined |
| **Per scenario** | No |
| **Per time horizon** | Restricted to one horizon |
| **Information media** | |
| Nature of platform | • Online tool<br>• Printing results in CSV format and PDF format |
| Visual architecture (*e.g.* mapping, storyline) | • Mapping of facility risk rank on two axes about:<br>- Water scarcity (including water quality and quantity);<br>- Growth (of facility revenue or output).<br>• The two levels in each axis draws four quarters on the mapping, associated with suggestion of action plan:<br>- High water scarcity/high growth: "Prioritize these locations for water reduction investment";<br>- High water scarcity/low growth: "Facilities for engagement with local water users and stakeholders to ensure continued license to operate.";<br>- Low water scarcity/high growth: "Monitor basin conditions and regional growth";<br>- Low water scarcity/low growth: "Maintain Operational Efficiency". |
| Customization by the user | Not disclosed |

***WATER RISK MONETIZER – BY ECOLAB, TRUCOST AND MICROSOFT (CONTINUED)***

| Pedagogy by displaying background information on* | | | |
|---|---|---|---|
| Hazards | Perimeter | | Water stress |
| | Period of analysis | | The coming 3,5 and 10 years |
| | Granularity of primary data | | See WRI's Aqueduct Water Risk Atlas |
| Counterparty | Perimeter of | Exposure | Facility |
| | | Sensitivity (assets; natural resource; labor; sales; etc.) | Direct focus on costs and revenues |
| | | Adaptive capacity | Not covered |
| | Granularity of primary data on | Exposure | User input |
| | | Sensitivity | User input |
| Impact | Perimeter of impacts | Socio-economic | Macro |
| | | Financial | Costs and revenues |
| Methodological assumptions and data gaps | | | Methodology available online |
| Explaining treatment of climate and socio-economic uncertainties | | | Partial integration of the vulnerability of the future socio-economic system |
| **Accessing outputs of the approach** | | | |
| Available for free | Yes (available online at https://www.waterriskmonetizer.com/) | | |

** The "pedagogy» section is filled out based on the details available in the methodological guidelines.*

## CLIMATE HAZARD

### Scope of hazards

*Chronic:* Water stress (*i.e.* water use / water supply)
The hazards are studied on Frequency and intensity. The dataset characterizes the increase in hazardous phenomena based on the WRI's Aqueduct Project.

| Forward-looking dimension | |
|---|---|
| Time horizon | The coming 3, 5 and 10 years |
| Nature of data (projection; forecast; historical data; trend scenario; exploratory scenario) | Projection |
| Alternative futures (unique or multiple) | Unique |
| **Type of source** | |
| Public, private, non disclosed sources | Public sources (WRI Aqueduct Project) |
| **Processing climate data** | |
| Treatment | No |
| Final spatial resolution | Not precised |

## EXPOSURE

| Type of data | Type of source | Type of processing | | |
|---|---|---|---|---|
| | Public, private, not disclosed | Scale of data | Treatment | Final scale of exposure |
| Location of facility | Private sources (End user) | Facility level | None | Facility level |

**WATER RISK MONETIZER – BY ECOLAB, TRUCOST AND MICROSOFT (CONTINUED)**

| SENSITIVITY | | | | |
|---|---|---|---|---|
| Type of data | Type of source | Type of processing | | |
| | Public, private, not disclosed | Scale of data | Treatment | Final scale of sensitivity |
| • Focus on costs (operational costs from incoming and outgoing water stress to facility):<br>no specific indication on the sensitivity of the facility cost to water stress. The methodology defines a complete cost of water based on impacts of using a certain amount of water to the broader socio-economic environment. These impacts depend on water stress (see the Impact section).<br>• Focus on revenues (loss of revenue from incoming water stress to facility): sensitivity of revenues through the amount of water necessary to generate revenues (based on user input) | Private sources (user input) | Facility | None | Facility |

| ADAPTIVE CAPACITY |
|---|
| Not included in the methodology. |

| IMPACTS | |
|---|---|
| Additional data and instruments and Type of source | |
| Type of data | • Academic literature on functions that explain dependance of socio-economic impacts from water use to the level of water stress.<br>• Other types of data to generate the metrics (including public sources and user data). |
| Type of processing | |
| Analytical steps | • Trucost has a dedicated team of analysts who analyze 13,500 companies every year. For each company, Trucost will calculate the direct (cooling and process water) and indirect (including purchased water) water use. If data are disclosed by companies through CDP Water or through Annual and CSR reports or through the Trucost engagement phase called the Trucost Environmental Register then Trucost would take that into account. If data are not disclosed, Trucost would estimate the water use using a bottom-up EEIO approach. Trucost would also collect other types of data including the type of water resources (rivers, groundwater etc.). That water data for each company is expressed in cubic meters and Trucost has historical data for large and mid caps since 2005. Trucost water data as well as Trucost carbon and natural resources data are available for investors and academics via the Eboard platform. Additional data from companies may be necessary to conduct the detailed assessment.<br>• The impacts from water stress to the facility costs are incorporated in broader metrics. The costs from incoming and outgoing water integrate a monetization of impacts on the broader socio-economic system from the facility that deviates water for its own use. These impacts include human-healt and environmental impact that are functions of water stress. The relationship arises from academic literature. These relations are projected using indicators on future water stress from WRI's Aqueduct Project.<br>• The impacts from incoming water stress to the facility revenue is more directly reflected in the final Revenue at risk metric. The metric formula is: Revenue at risk = water necessary to generate revenue / water available to the facility. The water availability is a function of basin-level water stress indicators from the WRI. This relation is projected using indicators on future water stress from WRI's Aqueduct Project.<br>• The likelihood of impacts integrates current and future water stress with the heaviest weight, for they are considered to be more likely to lead to an increase in operating costs. |
| Final scale of information | Facility level |
| Type of financial impact | |
| Asset damage; loss of revenue (or production); rise of costs; implicit | Loss of revenue (or production); rise of costs |



ANNEX 3: SUMMARY TABLES OF AVAILABLE APPROACHES

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