

# Environmental risk analysis by financial institutions – a review of global practice

An input paper for the  
G20 Green Finance Study Group

September 2016



**Inquiry:** Design of a  
Sustainable Financial System



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More information on the Inquiry is at: [www.unep.org/inquiry](http://www.unep.org/inquiry) and [www.unepinquiry.org](http://www.unepinquiry.org) or from: Ms Mahenau Agha, Director of Outreach [mahenau.gha@unep.org](mailto:mahenau.gha@unep.org).

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This input paper has been prepared by the authors as a contribution to the G20 Green Finance Study Group (GFSG) but has not been endorsed by it nor does it represent the official views or position of the GFSG or any of its members.

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G20 Green Finance Study Group

September 2016

# Executive Summary

**Under its first Presidency of the G20, China established a Green Finance Study Group (GFSG), reporting to Finance Ministers and Central Bank Governors.** The GFSG's objective has been to identify institutional and market barriers to green finance and, based on country experiences and best practices, analyse options on how to enhance the ability of the financial system to mobilise private green investment, thereby facilitating the green transformation of the global economy.

To deliver this objective, the GFSG has been addressing a set of interrelated challenges across five areas of research, three of which have a sectoral focus ('greening the banking system', 'greening the bond market', 'greening institutional investment') and two of which are cross-cutting ('risk analysis' and 'measuring progress').

The Cambridge Centre for Sustainable Finance, hosted by the University of Cambridge Institute for Sustainability Leadership (CISL), was asked to serve as a Knowledge Partner to the GFSG, leading the research on the subject of 'risk analysis'.

Specifically, the GFSG asked the Cambridge Centre for Sustainable Finance for a global stocktake of the tools and techniques that financial institutions are developing to analyse environmental risks so that it could understand whether further action is needed to ensure such tools are developed and deployed efficiently and consistently in mainstream financial decision-making.

This paper presents the findings of this stocktake, which drew on CISL's ability to cross boundaries between multiple fields of expertise and engage deeply with its global network of institutions right across the financial system.

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**The GFSG asked the Cambridge Centre for Sustainable Finance for a global stocktake of the tools and techniques that financial institutions are developing to analyse environmental risks.**

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## Foundations

### **Why does effective ‘environmental risk analysis’ by financial institutions matter?**

If risks arising from environmental sources are being inadequately incorporated into financial decision-making, this is of strategic significance to G20 financial systems – including banking, institutional investment and insurance sectors – for at least two reasons:

1. Managing risk is central to the effective functioning and stability of financial institutions. Inadequate understanding of growing environmental sources of risk could allow threats to financial institutions to accumulate and limit progress towards sustainable global growth associated with a green transition.
2. All capital is deployed on the basis of expected ‘risk-adjusted’ returns. If environmental risk is being underestimated, capital can be over-allocated to higher risk activities. Improving environmental risk analysis can therefore support more efficient allocation of capital for long term stability; addressing any mis-pricing of risk will trigger demand for green finance solutions by mainstream actors.

**History has shown that ‘environmental’ events can affect the efficiency and effectiveness of markets, the safety and soundness of financial institutions and even the performance of wider financial and economic systems.** Further, efforts to address environmental threats can also create financial risks.

**Financial institutions have been addressing environmental sources of risk for many years.** There is a growing recognition, however, that traditional approaches to incorporating environmental factors into risk management systems are insufficient in the face of environmental sources of risk which now exist at new levels of scale, likelihood and interconnectedness.

**Social justice issues are often intrinsically linked with risks arising from environmental sources.** The use of the word ‘environment’ should not be interpreted narrowly; the risks arising from what may be termed ‘environmental sources’ such as food, atmospheric or water systems are often of concern precisely because of their social impacts, frequently felt disproportionately by those least able to withstand them.

**Today’s risk environment is increasingly seeing impacts that were previously considered by financial institutions to be externalities becoming, or threatening to become, more material.** At the same time, increased inter-dependencies within the global financial system both open up new opportunities and increase vulnerability to second-order effects through such interlinkages.

**A range of risk analysis tools and techniques are already being developed across key financial sectors to enhance understanding of environmental source of risk.** At the international level, relevant government-backed initiatives on relevant data disclosure are also underway. However, various possible challenges may prevent the effective incorporation of environmental sources of risk into mainstream decision-making by financial institutions.

The GFSG therefore decided to take stock of the tools and techniques that financial institutions are developing and understand whether further action is needed to ensure they are developed and deployed efficiently and consistently in mainstream decision-making.

## What do we mean by ‘environmental sources of financial risk’?

This research uses a long-established typology of financial risks to categorise the ways in which financial institutions can be exposed to environmental sources of risk, covering market, credit, counterparty, underwriting, business, operational and legal risk. For simplicity, in this research ‘business risk’ and ‘operational risk’ are combined into one category, labelled ‘business risk’. Similarly ‘underwriting risks’ that are faced by insurers and ‘counterparty risks’ are collated into the category of ‘credit risks’.

This research then uses two broad categories now commonly used in market practice for how environmental threats, and efforts to address them, can create financial risks.

1. **Physical.** Risks which arise from the impact of climatic (i.e. extremes of weather) or geologic (i.e. seismic) events or widespread changes in ecosystem equilibria, such as soil quality or marine ecology. As the Financial Stability Board notes (FSB, 2016), they can be event-driven (‘acute’) or longer-term in nature (‘chronic’).
2. **Transition.** Risks which arise from efforts to address environmental change, including but not limited to abrupt or disorderly introduction of public policies, technological changes, shifts in investor sentiment and disruptive business model innovation.

An analytical framework derived from these common typologies has been developed to underpin this research.

		Financial risks			
		Business	Credit	Market	Legal
Environmental sources	Physical				
	– Climatic				
	– Geologic				
	– Ecosystems				
	Transition				
	– Policy				
– Technology					
– Sentiment					

## Are environmental sources of risk a new type of risk for financial institutions?

This research is based on the premise that ‘environmental risks’ are not fundamentally new categories of risk for financial institutions. Rather, environmental threats, and efforts to address them, manifest as types of risk already experienced by financial institutions.

Many of the environmental threats, and efforts to address them, that trigger the risks faced by financial institutions in the 21st century exhibit new characteristics, namely increasing scale, likelihood and interconnectedness. Historic experience can no longer be relied upon to predict future risks arising from environmental sources; further, the possibility of abrupt transitions adds a layer of complication to environmental risk management.

Each one of these three characteristics is testing in its own right but in combination they can result in environmental sources of risk being material to financial institutions within traditional time horizons and demand new tools and techniques to understand and manage them.

## On which mainstream risk management practices does this research build?

The traditional risk management process proceeds along several widely-recognised stages, including risk identification, risk exposure, risk assessment and risk mitigation.

One risk assessment tool that has been mentioned by numerous financial institutions during the course of this research, but means different things to different parties, is ‘stress testing’. Stress testing has its roots in scenario analysis, which helps decision-makers assess the impacts of plausible, extreme futures. Stress testing is broader in application than regulatory assessments of threats to financial stability; in this research, financial institutions are found to be using stress testing mainly to model impacts at the client/ investee or portfolio level.

## What methodology underpins this research?

In light of the preliminary nature of work in this area, the approach taken is one of stocktaking of existing tools and techniques, particularly those being developed by financial institutions. The research was conducted in four related stages.

1. A review of available expert literature
2. An open invitation to countries, financial institutions and private sector stakeholders to submit examples of leading practice
3. A deeper look at a subset of illustrative examples, and the analytical techniques therein, from around the world
4. A synthesis of common lessons, challenges and options which were tested and refined with private sector representatives through webinars and workshops

The selection of case studies was designed to demonstrate a variety of evolving risk management tools and approaches worldwide from different financial sectors and relating to different environmental sources of risk.

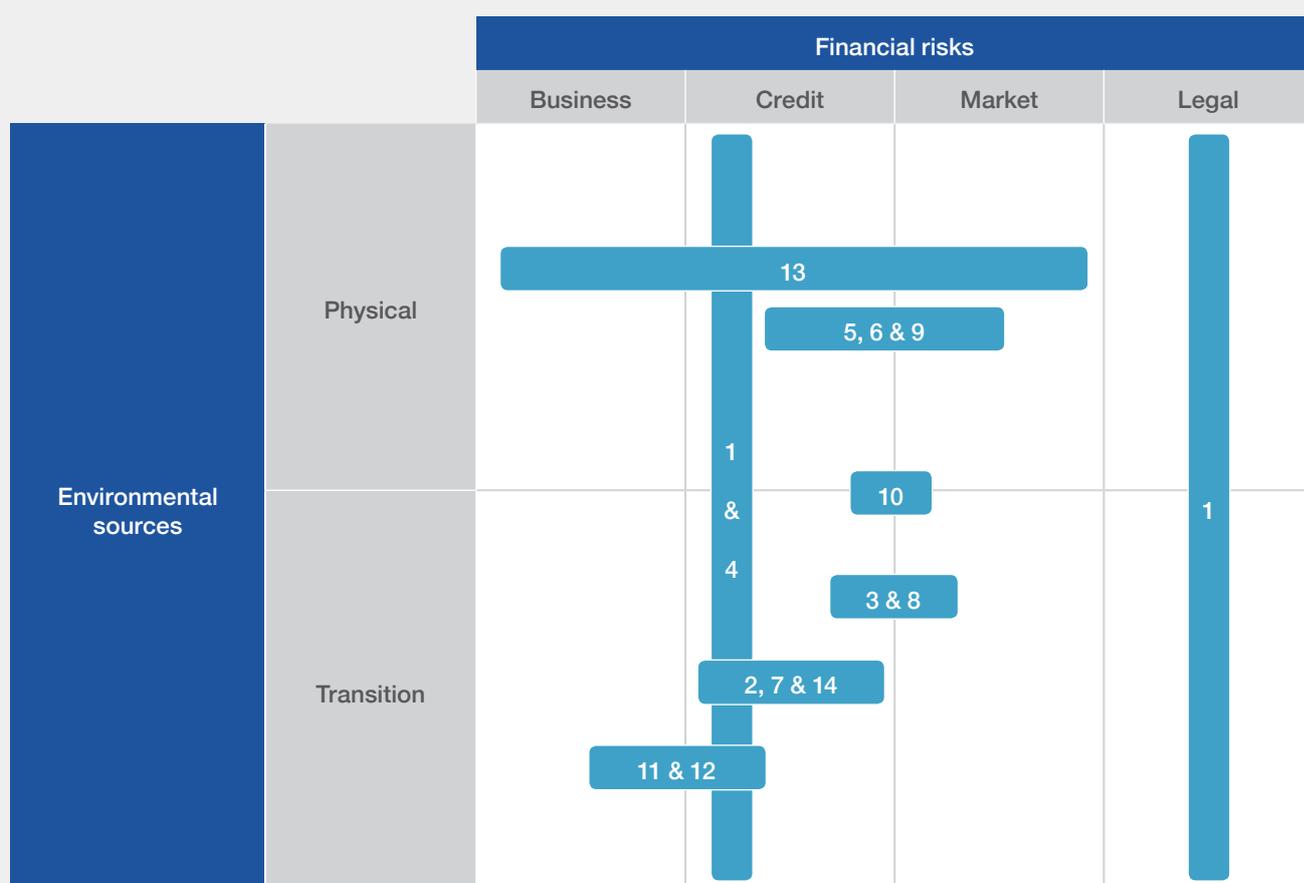
## Lessons

A range of illustrative case studies has been developed through this research process to demonstrate innovative market practice across geographies, financial sectors and risks:

Country	Sector	Focus
1 <b>Brazil</b>	Banking	Measuring the exposure of the Brazilian banking system to environmental risks
2 <b>China</b>	Banking	Stress testing the impact of environmental factors on a Chinese commercial bank's credit risk
3 <b>Germany</b>	Investment	Using scenario-analysis to assess the impact of different carbon and energy regulation in equity analysis
4 <b>India</b>	Banking	Measuring and managing an Indian bank's exposure to natural capital risks
5 <b>International</b>	Ratings agency	Integrating the impacts of climate change into sovereign debt ratings
6 <b>International</b>	Banking & investment	Integrating water stress into corporate bond analysis
7 <b>Italy</b>	Banking	Using stress testing and ratings models to align risk analysis with a 2°C climate scenario
8 <b>Netherlands</b>	Financial sector	The Dutch Central Bank's review of sectoral exposure to energy transition risks
9 <b>South Africa</b>	Insurance	Understanding the impact of climate change on a locality in South Africa
10 <b>Switzerland</b>	Banking	Stress testing balance sheet and client vulnerability to climate change risks
11 <b>United Arab Emirates</b>	Banking	Integrating environmental risk, including technology change, into credit approval processes in the Gulf
12 <b>United Kingdom</b>	Banking	A scorecard approach to integrating environmental performance into pricing decisions for real estate
13 <b>United Kingdom</b>	Insurance	A realistic disaster scenario of the micro- and macro-economic effects of a global food system shock
14 <b>United States</b>	Banking	Stress testing a US bank's energy clients against regulation and incentives driving the energy transition

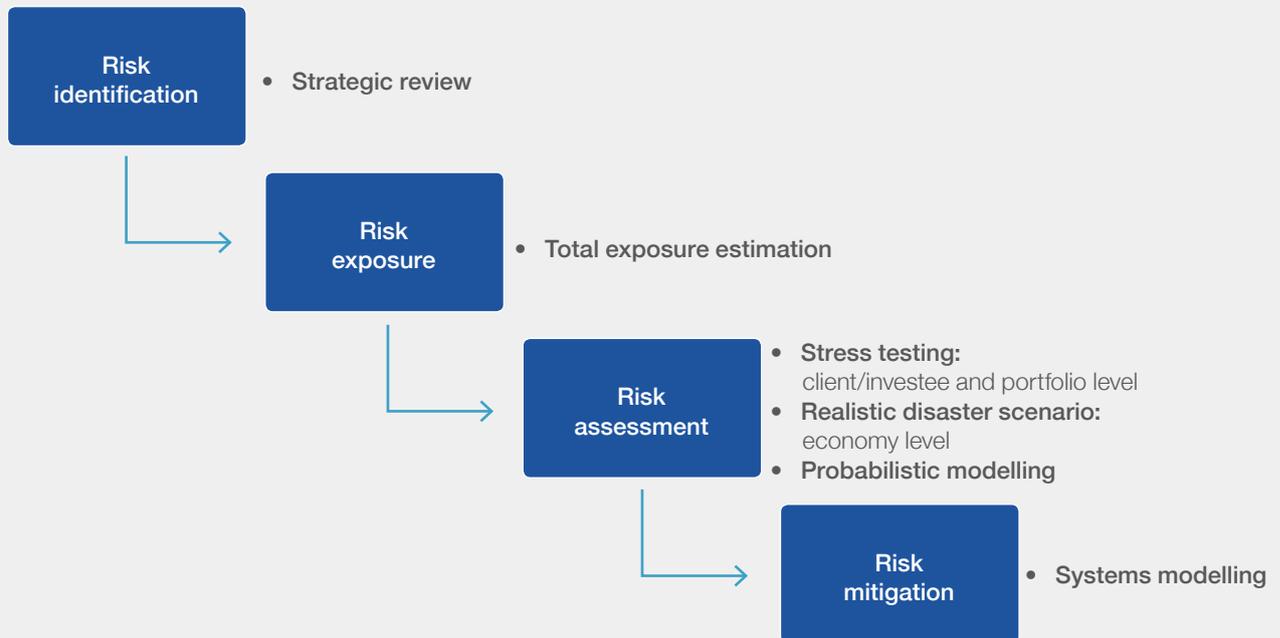
## Cross-cutting lessons

The stocktake has revealed innovative practices focusing on a variety of different environmental sources, and the financial risks arising from them, emerging across geographies and sectors. Qualitative approaches are the starting point; quantitative analysis is a common goal. Innovation focused on physical sources of risk is clustered around climatic events. Innovation focused on transition sources of risk is clustered around policy or regulatory change. The focus of the illustrative case studies is as follows:



Key			
Country	Sector	Country	Sector
1 Brazil	Banking	8 Netherlands	Financial sector
2 China	Banking	9 South Africa	Insurance
3 Germany	Investment	10 Switzerland	Banking
4 India	Banking	11 United Arab Emirates	Banking
5 International	Ratings agency	12 United Kingdom	Banking
6 International	Banking & investment	13 United Kingdom	Insurance
7 Italy	Banking	14 United States	Banking

A variety of tools and techniques are emerging, across every stage of traditional risk management:



Strategic reviews are common first steps. To estimate total exposure, either at the firm or industry level, proxies are being used.

**For risk assessment, different scenario-based tools are being evolved according to the context.** Where financial institutions are trying to assess the potential impact of risks on individual clients or investees and subsequently aggregate the results to a portfolio level, stress-testing techniques are being adapted. To analyse impacts that may propagate through entire economies, realistic disaster scenarios have been deployed. Where data allows, probabilistic modelling can help to navigate uncertainty.

For risk mitigation, an important innovation is the use of systems modelling to identify ‘no-regrets’ actions that institutions can prioritise in the context of complexity.

**Credit and market risks are receiving the most attention and analysis is revealing some material impacts.** A realistic disaster scenario developed by an international insurance market found that a global food price shock caused by a deep El Niño phase could suppress European stock markets by 10 per cent, and US stocks by 5 per cent, over a sustained period. Meanwhile, one group of investors concluded from its analysis that the margins of poorly prepared energy intensive companies in different markets could be reduced by more than 10 per cent in a strong carbon price scenario. In Brazil, analysis estimated that 33 per cent of the country’s top ten banks’ corporate lending is to sectors exposed to high levels of environment-related legal risk.

Early-stage evidence exists of financial institutions acting on the findings of such risk analysis in their financial decision-making. Anecdotal insights surfaced by this research include integration in the calibration of institutions’ risk appetites and pricing structures.

## Sector trends

The insurance industry has the deepest experience of innovation in analysing the physical sources of risk, having developed coherent metrics, methodologies and models to manage the financial impacts of natural catastrophes such as hurricanes, storms and floods. One key question for the sector relates to the fact that it is less clear whether these tools and techniques are being applied to transition sources of risk.

Investor innovation appears most focused on transition sources of risks, specifically as they impact heavy polluting and energy intensive sectors. One key question for the sector is whether techniques to analyse market risks associated with shifts in energy commodity prices (e.g. oil) are being adapted for broader application with transition sources of risk, for instance around prices being attached to carbon.

In the banking industry, transition sources of risks affecting energy intensive sectors are also a focus, with some broader innovation too, for example around water stress and 'natural capital' exposure. One key question for the sector is whether physical sources of risk are already incorporated into mainstream decision-making, for example for lending, or whether collaboration with the insurance industry might be fruitful.

## Possible gaps in current practice

While attention is widely being applied to transition risks, the possibility of abrupt shocks is rarely considered in practice. Limited work to assess interlinkages between sectors and subsequent aggregation appears to be happening. Market risk from fluctuations in commodity prices is well addressed, however more work is needed if such tools are to be adapted for use assessing the impact of carbon pricing. Of all the financial risks, the biggest knowledge gap may be around legal risk.

## Challenges and options

### Four challenges to mainstream integration

The illustrative case studies highlighted in this stocktake show that innovation in risk analysis is emerging, but is far from integrated into mainstream decision-making. Challenges relating to each stage of the standard risk management cycle have been identified by market participants.

1. **Lack of capacity:** developing credible analyses on how environmental sources can create financial risks is complex and requires expertise that is often not found in one institution. For example, understanding the effects of food price spikes caused by extreme weather events requires input from climate scientists, agricultural experts and economists. As another example, estimating borrowers' credit default risk arising from environmental policy changes requires collaboration among financial, environmental and policy specialists. Forming such partnerships can be costly and time consuming.
2. **Knowledge gaps:** fragmented or absent policy signals are a major distraction from efforts to develop more holistic analysis of the risks that financial institutions are exposed to. For example, relatively little is known about how the impacts of different environmental sources of risks can aggregate, how interlinkages between sectors may allow risks to propagate and how abrupt shocks may impact different pools of capital.

3. **Inadequate data:** data is a critical input to risk analysis. The lack of comprehensive and consistent data dissuades financial institutions from investing in tool development. To understand exposure to water stress, for instance, a financial institution needs data relating to the threat itself (e.g. probability of drought), how that threat may spread through a region (e.g. ownership rights) and the exposure of companies to the threat (e.g. water intensity of operations).
4. **Lack of a level playing field:** if risk is being systematically under-priced, a competitive market may force a ‘race to the bottom’. Widespread anecdotal evidence exists of entities suffering adverse market reactions if they disclose greater exposure to environmental risks than the market previously understood. The City of Norfolk, Virginia, for example, experienced a credit rating downgrade when it published results of analysis of its exposure to sea-level rise. Separately, short termism may mean that risks are not sufficiently being taken into account by financial institutions. One of the case studies in this report highlights work done by a credit rating agency to understand the impact of climate change on sovereign credit ratings. While the increased damage potential of climate-related natural catastrophes are seen to be material, the likelihood of such an event happening within the ratings horizon (5–10 years) is considered small. The result is that this risk factor is unlikely to be factored into the ratings that so many users depend on.

## Four response options

In response to each of these four challenges, an option has been identified as a priority for next steps.

1. To build capacity, national G20 regulators could convene multi-sector, multidisciplinary fora to develop environmental risk scenarios that represent priorities in their context.
2. To plug knowledge gaps, the G20 could support industry and academic research that helps to advance more holistic risk analysis on questions that are priorities across the G20.
3. To improve data, the G20 could ensure that work to improve data disclosure focuses on all types of data required for effective risk analysis.
4. To help level the playing field, the G20 could signal the importance of this issue by sponsoring an international forum in conjunction with the private sector and academic partners to facilitate knowledge sharing and develop common methodologies for environmental risk analysis in the finance sector.

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# 1.

# Introduction

**The proposal to launch a G20 ‘Green Finance Study Group’ (GFSG) under the Finance track of the G20 was made by the Chinese Government as it took on its first G20 Presidency in 2016.** The proposal was accepted by G20 Finance Ministers and Central Bank Governors and the study group was established with two co-chairs, the People’s Bank of China and the Bank of England, on behalf of the Chinese and UK Governments respectively. The United Nations Environment Programme (UNEP) serves as secretariat.

The GFSG’s objective has been to identify institutional and market barriers to green finance and, based on country experiences and best practices, analyse options on how to enhance the ability of the financial system to mobilise private green investment, thereby facilitating the green transformation of the global economy.

To deliver this objective, the GFSG has been addressing a set of interrelated challenges across five areas of research, three of which have a sectoral focus (‘greening the banking system’, ‘greening the bond market’, ‘greening institutional investment’) and two of which are cross-cutting (‘risk analysis’ and ‘measuring progress’).

**The Cambridge Centre for Sustainable Finance, hosted by the University of Cambridge Institute for Sustainability Leadership (CISL), was asked to serve as a Knowledge Partner to the GFSG, leading the research on the subject of ‘risk analysis’.** Specifically, the GFSG asked the Cambridge Centre for Sustainable Finance for a global stocktake of the tools and techniques that financial institutions are developing to analyse environmental risks so that it could understand whether further action is needed to ensure such tools are developed and deployed efficiently and consistently in mainstream financial decision-making.

**This paper drew on CISL's ability to cross boundaries between multiple fields of expertise and engage deeply with its global network of institutions right across the financial system.** The paper has been developed with GFSG and private sector contributions and feedback throughout, but serves as an input to the GFSG rather than as a formal G20 paper.

**This paper is structured around three core sections:**

1. 'Foundations' covers the practical and theoretical starting point for this work'
2. 'Lessons' summarises the trends emerging from the stocktake
3. 'Challenges and Options' presents the major obstacles preventing uptake of innovative practice by mainstream actors and offers ways forward

**This paper has been written for a variety of audiences: financial institutions, regulators, governments and scientists.** Each may have different expertise and use different vocabularies. The main body of the paper is intended to be as concise as possible. Appendices provide further detail which may be of value to particular audiences.

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**This paper drew on CISL's ability to cross boundaries between multiple fields of expertise and engage deeply with its global network of institutions right across the financial system.**  
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# 2.

# Foundations

## 2.1 Why does effective ‘environmental risk analysis’ by financial institutions matter?

**If risks arising from environmental sources are being inadequately incorporated into financial decision-making, this is of strategic significance to G20 financial systems – including banking, institutional investment and insurance sectors – for at least two reasons:**

1. Managing risk is central to the effective functioning and stability of financial institutions. Inadequate understanding of growing environmental sources of risk could allow threats to financial institutions to accumulate and limit progress towards the sustainable global growth associated with a green transition.
2. All capital is deployed on the basis of expected ‘risk-adjusted’ returns. If environmental risk is being underestimated, capital can be over-allocated to higher risk activities. Improving environmental risk analysis can therefore support more efficient allocation of capital for long term stability.

Work on this issue is all the more important given that the way in which the world’s infrastructure investment is deployed over the next 15 years or so will determine the future of the climate system (New Climate Economy, 2014).

**History has shown that ‘environmental’ events can affect the efficiency and effectiveness of markets, the safety and soundness of financial institutions and even the performance of wider financial and economic systems.** A range of historical experiences illustrating the first and second-order effects of such events on financial institutions and economies is detailed in Appendix A. Examples include the impacts of dust bowls, hurricane activity, geological disasters such as earthquakes and volcanoes, heatwaves and droughts across a range of geographies.

**Further, efforts to address environmental threats can also create financial risks.** For instance, investors and lenders may be exposed to liability for environmental damages according to the evolving interpretation of local laws (a situation notably highlighted by the Comprehensive Environmental Response, Compensation and Liability Act in the United States, but relevant across a range of developed and developing economies). More broadly, the Governor of the Bank of England has drawn attention to the fact that the policy

and technology changes required to deliver a lower-carbon economy could “prompt a reassessment of the value of a large range of assets as costs and opportunities become apparent...the speed at which such re-pricing occurs is uncertain and could be decisive for financial stability” (Carney, 2015).

**Financial institutions have been addressing environmental sources of risk for many years.** For instance, spurred by series of major natural catastrophes in the late 1980s and early 1990s that posed a threat to its solvency, the global (re)insurance industry, supported by scientific and modelling expertise, encoded resilience to extreme natural catastrophes into its capital regime. Meanwhile, market norms in the institutional investment and banking industries have evolved such that consideration of environmental and social risks is increasingly integrated into the decision-making of fund managers and project financiers respectively (the latter catalysed by initiatives such as the Equator Principles in the banking industry).

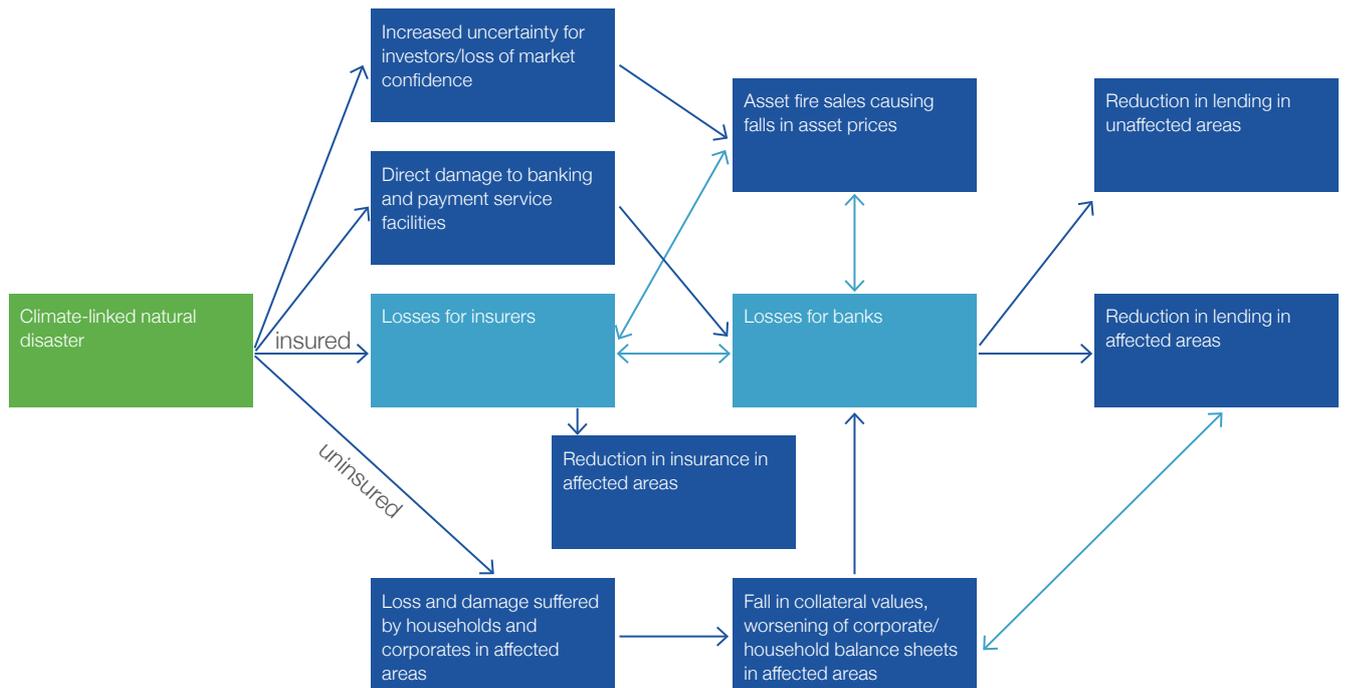
**There is a growing recognition, however, that traditional approaches to incorporating environmental factors into risk management systems are insufficient in the face of environmental sources of risk which now exist at new levels of scale, likelihood and interconnectedness.** In acknowledging this, the intention is not to undermine the value of such traditional approaches – far from it. It is arguably this set of tools and approaches that has enabled the recognition of new, potentially disruptive challenges that require an evolution in risk management practice. Challenges identified by countries and financial institutions contributing to this research include environmental conditions deteriorating at an accelerating rate, shifting market expectations, technological breakthroughs and tightening environmental policy requirements.

**Social justice issues are often intrinsically linked with risks arising from environmental sources.** The use of the word ‘environment’ should not be interpreted narrowly; the risks arising from what may be termed ‘environmental sources’ such as food, atmospheric or water systems are often of concern precisely because of their social impacts, frequently felt disproportionately by those least able to withstand them. Separate work focused on challenges more exclusively rooted in issues of social justice are being taken forward by the G20 through efforts such as the Global Partnership for Financial Inclusion.

**Today’s risk environment is increasingly seeing impacts that were previously considered by the financial institutions to be externalities becoming, or threatening to become, more material.** This may be due to tighter environmental policy requirements being enforced (for instance, new legislation to restrict air pollution from industry) or, quite simply, the growing scale and impact of environmental shock events (persistent regional droughts, for example).

**At the same time, increased interdependencies within the global financial system both open up new opportunities and increase vulnerability to second-order effects through contagion.** While the starting point for this research is the direct, first-order effects of environmental sources of risk on financial institutions, a range of second-order effects may exist. As demonstrated by Figure 1, the Bank of England, for example, has examined the second-order effects of natural catastrophes by identifying how losses not borne by the insurance industry due to underinsurance may go on to undermine the collateral values securing loans in the banking industry’s mortgage portfolios (Batten et al, 2016). Where such assets have been securitised, exposures could of course spread further into the financial system. Meanwhile, where at the national level shocks are sufficiently severe, the OECD has noted that the extent of international financial integration is now such that countries may suffer from shocks to other countries with which they have no direct economic or financial connection (OECD, 2012).

**Figure 1: A transmission map of natural disaster to financial sector losses; Source: Batten et al. (2016)**



**A range of possible challenges may prevent the effective incorporation of future environmental considerations into mainstream risk management by financial institutions such as banks, insurers and other institutional investors.** Potential issues may include information asymmetries, short termism, misaligned incentives, as well as inadequate expertise and underdeveloped risk assessment methodologies. In relation to information asymmetries, one prominent example played out in parallel to the GFSG's work. In 2015, New York State's Attorney General ruled that pure play coal producer Peabody Energy must stop making misleading disclosures about the financial risks it faces from any future legal changes associated with climate change that have the potential to reduce demand for coal and affect the company's financial performance. The firm has since filed for bankruptcy.

**Addressing the mis-pricing of risk will trigger demand for green finance solutions by mainstream actors.** As argued publicly by a representative of a major asset manager at the joint B20/City of London/UNEP event on 'The Future of Green Finance' in London in March 2016, as asset owners take steps to address the mis-pricing of risk, this will trigger new demand for intermediaries and innovators to bring forward financial instruments that offer solutions.

**A range of environmental risk analysis tools and techniques are already being developed across key financial sectors to better understand the financial implications of the increasing scale, likelihood and interconnected nature of these environmental sources of risk.** These include the use of scenarios – what may be termed 'environmental scenario risk analysis' – and cut across key financial sectors such as banking, insurance and investment. They cover a spectrum of environmental issues, such as air pollution, natural hazards and water stress, as well as efforts to address them.

**At the international level, relevant government-backed initiatives are also underway.**

The Financial Stability Board (FSB), for instance, is sponsoring a private sector task force on climate-related financial disclosures to ensure that the data available to financial institutions is consistent and sufficient for proper risk analysis. Meanwhile, through its Presidency of the Council of the European Union in the first half of 2016, the Dutch Government tabled for discussion the value of ‘carbon stress testing’ to strengthen investor awareness and promote financial stability.

**The GFSG therefore decided to take stock of the tools and techniques that financial institutions are developing and understand whether further action is needed to ensure they are developed and deployed as efficiently and consistently in mainstream decision-making.**

## 2.2 What do we mean by ‘environmental sources of financial risk’?

**At the heart of this research is the question of how environmental sources of financial risk can be more effectively integrated into mainstream decision-making by financial institutions.** In its own words, the G20 GFSG is interested in how a range of possible market and institutional failures may be preventing the effective incorporation of future environmental considerations risk management by financial institutions such as banks, insurers and institutional investors.

**This research uses a long-established typology of financial risks to categorise the ways in which financial institutions can be exposed to environmental sources of risk.**

1. Market risk refers to the “risk of losses in on- and off-balance-sheet positions arising from movements in market prices” (Basel Committee on Banking Supervision, 1996).
2. Credit risk is comprised of issuer and counterparty risk. Issuer risk is the possibility that an issuer/borrower is not able to fulfil its obligations due to its default. Counterparty risk comprises the risk that a counterparty defaults and is not able to fulfil its obligations (Christoffersen, 2003).
3. Underwriting risk is the risk of insured losses being higher than expected. In property and casualty insurance products, significant components of such risk are the reserve and premium risks. In life and health insurance products, biometric and customer behaviour risks are important (Bennett, 2004).
4. Business risk refers to the possibility that changes in circumstances undermine the viability of business plans and business models.
5. Operational risk is the risk of losses due to “physical catastrophe, technical failure, and human error in the operation of a firm, including fraud, failure of management, and process errors” (Christoffersen, 2003).
6. Legal risk is the risk of significant legal consequences that flow from actions attributable to business (Moorhead and Vaughan, 2016). These are the risks that may arise when parties suffer losses related to environmental change, or their failure to manage appropriately their contribution to it.

**Some risk taxonomies add liquidity, country and reputational risks to these categories.**

**For simplicity in this research, ‘business risk’ and ‘operational risk’ are combined into one category, labelled ‘business risk’.** Rapidly changing societal views of corporate behaviour relating to many environmental sources of risk mean that financial institutions often highlight reputational risk as a material factor in their decision-making. This research therefore includes reputational risk in the ‘business risk’ category.

**Similarly ‘underwriting risks’ that are faced by insurers and ‘counterparty risks’ are collated into the category of ‘credit risks’.** Thus, the category of credit risks would contain issuer and counterparty risks faced by banks and institutional investors and credit and underwriting risks faced by (re)insurance companies.

**This research then uses two broad categories commonly used in market practice for how environmental threats, and efforts to address them, can create financial risks.** There is a range of ways to conceptualise environmental sources of risk (e.g. Mercer’s ‘TRIP’ framework or the framework developed by the University of Oxford’s Sustainable Finance Programme – see Caldecott and McDaniels, 2014). The roots of the typology used in this research lie in the Bank of England’s Prudential Regulation Authority (PRA) 2015 report ‘The impact of climate change on the UK insurance sector’ (PRA, 2015), which has been widely built upon since.

1. **Physical.** Risks which arise from the impact of climatic (i.e. extremes of weather) or geologic (i.e. seismic) events or widespread changes in ecosystem equilibria, such as soil quality or marine ecology. These sub-categories are informed by the Cambridge Centre for Risk Studies ‘Taxonomy of Macro-threats’ (Coburn et al, 2014). As the Financial Stability Board notes, they can be event-driven (‘acute’) or longer-term in nature (‘chronic’).
2. **Transition.** Risks which arise from efforts to address environmental change, including but not limited to abrupt or disorderly introduction of public policies, technological changes, investor sentiment and disruptive business model innovation.

**An analytical framework derived from these mainstream approaches to risk identification has been developed to underpin this research (Figure 2).** Pockets of expertise exist around the world in many of the cells of this matrix. The focus of this research is to gather experiences and learning from across this spectrum, without preference to any one in particular, in order to identify cross-cutting lessons.

**Figure 2: An analytical framework for understanding environmental sources of financial risks**

		Financial risks			
		Business	Credit	Market	Legal
Environmental sources	Physical				
	– Climatic				
	– Geologic				
	– Ecosystems				
	Transition				
	– Policy				
– Technology					
– Sentiment					

An illustrative description of just one or two examples of how each type of environmental source of risk could lead to the different types of financial risks is presented in Appendix B in an attempt to clarify how this analytical framework is intended to be understood. The distribution of these environmental sources of risk is not necessarily uniform across different financial sectors or indeed across different countries.

Importantly, interlinkages can emerge *between* different environmental stresses (e.g. extreme events triggering policy change) as well as between the risks that result for different financial sectors (e.g. the impact of uninsured losses on the collateral values of bank loans).

## 2.3 Are environmental sources of risk a new type of risk for financial institutions?

This research is based on the premise that ‘environmental risks’ are not fundamentally new categories of risk for financial institutions. Rather, environmental threats, and efforts to address them, manifest as types of risk already experienced by financial institutions. It is true that many of the sources of risk featured in this research are either accelerating or are new themselves. However, seeing these as sources of existing types of risk rather than fundamentally new types of risk is a critical distinction given the G20 GFSG’s interest in understanding how environmental risk analysis can be integrated into mainstream financial decision-making. This highlights the importance of understanding existing mainstream risk management analytical frameworks and practices.

**Many of the environmental threats, and efforts to address them, that trigger the risks faced by financial institutions in the 21st century exhibit new characteristics.**

The experiences submitted by financial institutions as part of this research point to at least three distinctions – larger scale, increased likelihood and deeper interconnectedness (further elaborated in Appendix C) – which evolutions in risk management tools and practices need to contend with.

**Each one of these three characteristics is testing in its own right but in combination they can result in environmental sources of risk being material to financial institutions within traditional time horizons.** The increasing scale, likelihood and interconnectedness of today's environmental sources of risk mean that they can no longer be considered peripheral to the risk management agenda and that traditional views that these are only long term threats beyond the time horizon of interest to financial institutions are increasingly open to challenge.

**Historic experience can no longer be relied upon to predict future risks arising from environmental sources; baseline averages are moving, and low probability, high impact extremes are becoming more likely.** In the risk management literature, these trends relate respectively to the 'skewness' and the 'fat tail' of probability distributions. Such trends are routinely studied in relation to physical and transition events, as well as potential liability claims arising from them. For example, Holland and Bruyère (2014) observe an upward trend in the global proportion of category 4–5 hurricanes, offset by a similar decrease in the proportion of category 1–2 hurricanes. Going forward, the Economist Intelligence Unit reports that the cost of 6°C global warming could lead to a present value loss worth US\$13.8trn, whereas keeping the warming under 2°C would cut such tail risks by three-quarters (Economist Intelligence Unit, 2015). Management of tail risks is particularly important for financial institutions, especially institutional investors who are tasked to manage their funds with the long term benefit of their beneficiaries in mind.

**Further, the possibility of abrupt transitions adds a layer of complication to environmental risk management.** Developments in technology and science (for instance, low cost battery storage at scale) can prompt an abrupt shift in investor sentiment about future climate trajectories, which in turn could lead to economic shocks, causing substantial losses in financial portfolio value within timescales that are relevant to all investors (CISL, 2015). An abrupt transition might also be spurred by sudden and potentially irreversible changes in Earth systems, such as the disappearance of summer Arctic sea ice or disruptions to monsoon circulations (King et al, 2015). Equally, interaction between large scale climate system changes might lead to a cascade of other events. In these circumstances, as detailed in a report to the European Systemic Risk Board (Gros et al, 2016), late adjustment would result in a "hard landing", which, exacerbated by a lack of technological progress, would amplify the physical costs of climate change.

## 2.4 On which mainstream risk management practices does this research build?

**The traditional risk management process proceeds along several widely-recognised stages.** Firstly, potential risk factors that could affect the portfolio or firm in question are identified, including the channels through which those risks could create financial impacts. Then, the overall significance of the risk factors on the portfolio or firm is calculated in order to come up with an exposure at risk. More detailed assessment of the

impact of different scenarios is performed for higher priority risks, which relies on sufficient availability or disclosure of risk exposure information. Finally, exposure at risk is compared to the firm's risk appetite and a risk mitigation action plan is composed and executed.

**To ensure that financial institutions are managing environmental sources of risk appropriately, regulatory authorities around the world have been conducting 'strategic reviews' of industry practices across all stages of this process.** Published findings include those of the National Association of Insurance Regulators (NAIC) in the United States, the Bank of England's Prudential Regulation Authority review of the impact of climate change on the UK insurance sector (PRA, 2015) and the European Systemic Risk Board's Advisory Scientific Paper 'Too late, too sudden: Transition to a low-carbon economy and systemic risk' (Gros, Schoenmaker, Langfield, & Matikainen, 2016). The Governor of the Banque de France, François Villeroy de Galhau, has announced intentions to perform similar analysis as part of France's 2015 Energy Transition Law (de Galhau, 2015).

**One risk assessment tool that has been mentioned by numerous financial institutions during the course of this research, but means different things to different parties, is 'stress testing'.** Various definitions of stress testing have been proposed. This paper will use the following comprehensive definition provided by the Committee on the Global Financial System: "stress testing is a risk management tool used to evaluate the potential impact on a firm of a specific event and/or movement in a set of financial variables. Accordingly, stress testing is used as an adjunct to statistical models such as value-at-risk ("VaR"), and increasingly it is used as a complement, rather than as a supplement, to these statistical measures (BIS, 2005)".

**Stress testing has its roots in scenario analysis, which helps decision-makers assess the impacts of plausible, extreme futures.** A scenario can be defined as "a script-like characterisation of a possible future presented in considerable detail, with special emphasis on causal connections, internal consistency, and concreteness" (Schoemaker, 1991). Based on a mixed methods research study of 13 financial institutions, Andreeva (2011) estimates that in addition to purely technical scenarios such as interest rate and oil price shifts, the most widely used scenarios by financial institutions include a major sovereign default, unrest in the Middle East, the financial crisis 2007–2009, a Japanese recession and a double dip recession. Some financial institutions routinely consider scenarios without significant recent precedent, such as the assassination of a head of state in a G20 country, water war in Africa, a large magnitude earthquake in the USA or the unification of (or war between) North and South Korea.

**Stress testing is broader in application than regulatory assessments of threats to financial stability; in this research, financial institutions are found to be using stress testing to model impacts mainly at the client/investee or portfolio level.** Stress testing in its current form has been used by the internationally active banks since the early 1990s (Sorge and Virolainen, 2006). The first official regulatory requirement for stress testing came in the form of the 1996 market risk amendment to the Basel I Accord. Banks were urged to perform sensitivity and historical scenario tests, as well as devise their own hypothetical scenarios. The first supervisory stress tests of financial system resilience were conducted by the US Supervisory Capital Assessment Program and the Committee of European Banking Supervisors in 2009.

**Much can be learned from the insurance industry's experience of what is required to ensure resilience to natural catastrophe events exhibiting characteristics of increasing scale, likelihood and interconnectedness over the last three decades.**

As stated in a Willis Research Network concept note (Douglas, 2014), following a period of unprecedented losses from natural catastrophes in the 1980s, culminating in those incurred by Hurricane Andrew in 1992, the global (re)insurance sector entered a period of crisis. There were many (re)insurer insolvencies in Europe, North America and elsewhere. Confidence in the global insurance risk sharing system was hit and all types of capital were being withdrawn or could not be expanded. Due to this lack of capital, natural disaster insurance and reinsurance became unavailable, severely restricted or excessively expensive.

Subsequently, a combination of capital sensitivity to natural disasters, a revolution in the scientific modelling world and reform of public policy and financial regulation brought about a fundamental transformation in the market. The insurance sector, with its academic and regulatory partners, has established a tried and tested operational system for competitively allocating capital to disaster risks at even at very extreme probabilities. Natural catastrophe modelling is now mandated by many rating agencies and provides the whole basis for the Solvency II regime for demonstrating that (re)insurers have enough capital in place to survive a 1 in 200 event – a regulation that could not be set without the support of such modelling. In spite of growing losses, natural disaster risk has become increasingly understood and more accurately evaluated. With sufficient amounts of capital being allocated to match risk levels on a more efficient basis, failures have become less frequent. Further the volatility in underwriting capacity and pricing in response to either high catastrophe losses or benign conditions steadily dampened.

## 2.5 What methodology underpins this research?

**In light of the preliminary nature of the G20's work in this area, the approach taken is one of stocktaking of existing tools and applications being developed by financial institutions in particular.** Such an approach is timely because financial institutions around the world, as well as a variety of experts working with them, are currently developing relevant tools and approaches, often triggered by broader policy and regulatory interventions. Some of the learning from this work is being made publicly available, but much of it is not. There is certainly no comprehensive global review of current practice, from which to derive lessons about the barriers to the effective incorporation of environmental sources of risk into financial decision-making and review options, concepts and potential methodologies for further development.

**The research was conducted in four related stages.**

1. A review of available expert literature
2. An open invitation to countries, financial institutions and private sector stakeholders to submit examples of leading practice
3. A deeper look at a subset of illustrative examples, and the analytical techniques therein, from around the world
4. A synthesis of common lessons, challenges and options which were tested and refined with private sector representatives through webinars and workshops

**The selection of case studies was designed to demonstrate a variety of evolving risk management tools and approaches worldwide from different financial sectors and relating to different environmental sources of risk.** The case studies are neither an exhaustive list of current practice, nor necessarily an indication of best practice. Rather, they are a selection from the submissions provided to the research team designed to reflect the diversity of experiences evident across markets of interest to the G20. They suffer from selection bias in that they illustrate the submissions received about what is currently happening, rather than what is not.

**The research process had to align with a compressed G20 meeting schedule.** This presented the research team with a challenging set of interim and final deadlines and inevitably meant that the breadth and depth of the work undertaken had to be shaped accordingly. Given that this is intended as an initial stocktaking exercise, this paper should be taken in the spirit of laying the groundwork for future, more specific research.

**The stocktake was informed by a variety of submissions from across the world, from institutions in countries such as Australia, Brazil, Canada, China, Colombia, France, Germany, India, Mexico, Netherlands, United Arab Emirates, United Kingdom, United States, Spain, Switzerland and South Africa as well as a variety of industry bodies and international organisations.** A full list of sources approached for information can be found in Appendix D.

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**Until now, there has been no comprehensive global review of current practice, from which to derive lessons about the barriers to the effective incorporation of environmental sources of risk into financial decision-making and review methodologies for further development.**

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## 3.

# Lessons

A range of illustrative case studies has been developed through this research process to demonstrate innovative market practice across a range of geographies, financial sectors and risks. They are detailed in Figure 3, listed in alphabetical order by country; a full profile of each is found in Appendix E.

**Figure 3: The illustrative case studies featured in this study**

Country	Sector	Focus
1 Brazil	Banking	Measuring the exposure of the Brazilian banking system to environmental risks
2 China	Banking	Stress testing the impact of environmental factors on a Chinese commercial bank's credit risk
3 Germany	Investment	Using scenario-analysis to assess the impact of different carbon and energy regulation in equity analysis
4 India	Banking	Measuring and managing an Indian bank's exposure to natural capital risks
5 International	Ratings agency	Integrating the impacts of climate change into sovereign debt ratings
6 International	Banking & investment	Integrating water stress into corporate bond analysis
7 Italy	Banking	Using stress testing and ratings models to align risk analysis with a 2°C climate scenario
8 Netherlands	Financial sector	The Dutch Central Bank's review of sectoral exposure to energy transition risks
9 South Africa	Insurance	Understanding the impact of climate change on a locality in South Africa
10 Switzerland	Banking	Stress testing balance sheet and client vulnerability to climate change risks
11 United Arab Emirates	Banking	Integrating environmental risk, including technology change, into credit approval processes in the Gulf
12 United Kingdom	Banking	A scorecard approach to integrating environmental performance into pricing decisions for real estate
13 United Kingdom	Insurance	A realistic disaster scenario of the micro- and macro-economic effects of a global food system shock
14 United States	Banking	Stress testing a US bank's energy clients against regulation and incentives driving the energy transition

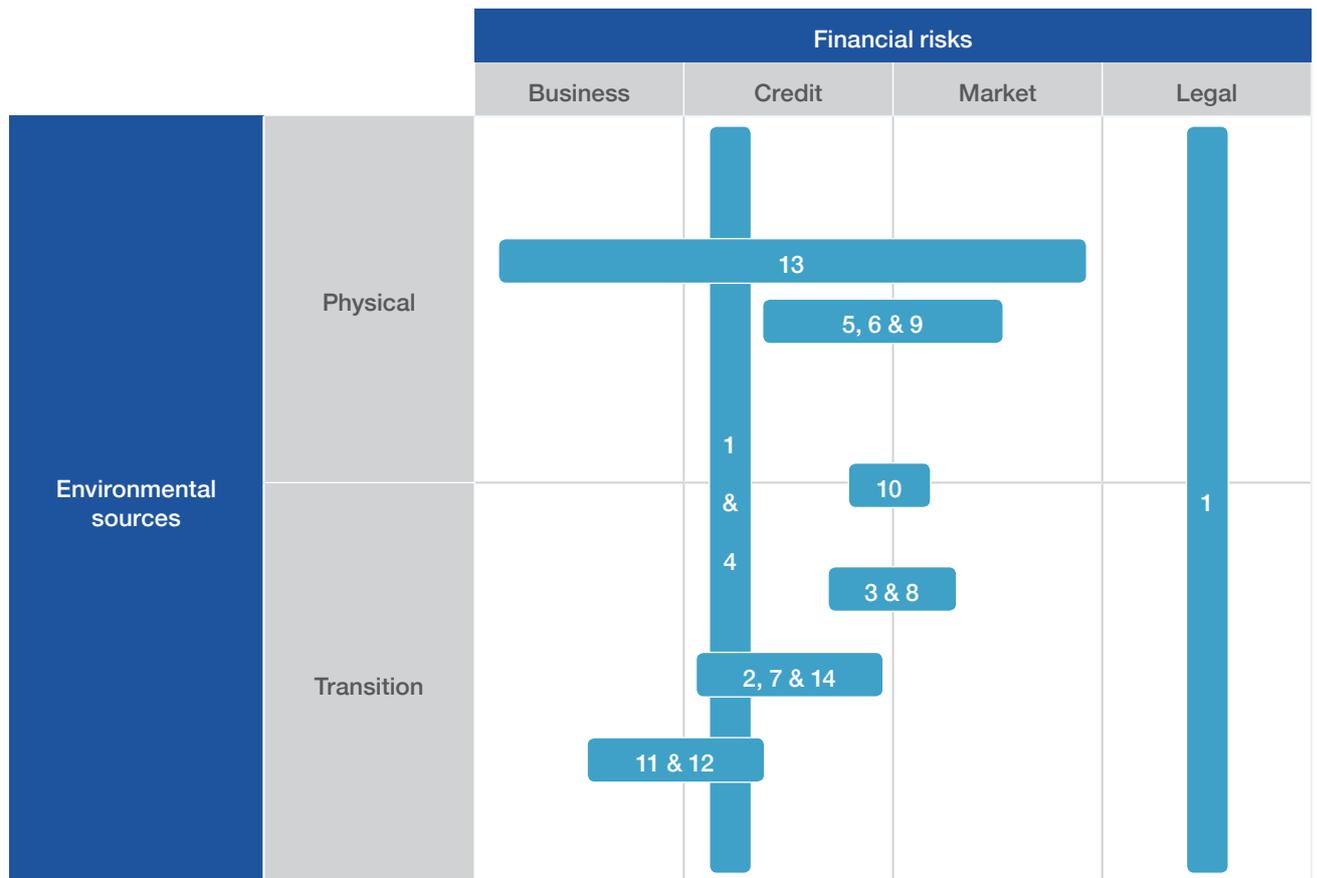
In combination, these illustrative case studies, together with the supporting material submitted to the study team, the literature review that has been conducted and the private sector consultation events that have been convened, provide a rich picture of current practice.

A range of lessons can be drawn. They are presented below in three sections: those that are cross-cutting, those that relate to specific financial sectors and those that relate to possible gaps in current practice.

### 3.1 Cross-cutting lessons

**The stocktake has revealed innovative practices emerging across geographies and sectors.** While national legal, market and environmental contexts give rise to local variations, a broad range of financial institutions across markets and sectors are demonstrating meaningful engagement and early progress on this topic. Figure 4 shows how this range of examples can be understood in the context of the analytical framework developed by this study. The primary focus has been at the firm level, however there are also examples of firms deferring at this stage to innovation being driven at the industry level, often in response to new regulations on environmental and social risk management (for instance in Bangladesh, Brazil, Colombia and Peru).

**Figure 4: The focus of the illustrative case studies featured in this report**



Key					
Country	Sector	Country	Sector		
1	Brazil	Banking	8	Netherlands	Financial sector
2	China	Banking	9	South Africa	Insurance
3	Germany	Investment	10	Switzerland	Banking
4	India	Banking	11	United Arab Emirates	Banking
5	International	Ratings agency	12	United Kingdom	Banking
6	International	Banking & investment	13	United Kingdom	Insurance
7	Italy	Banking	14	United States	Banking

**Innovation focused on physical sources of risk is clustered around climatic events.**

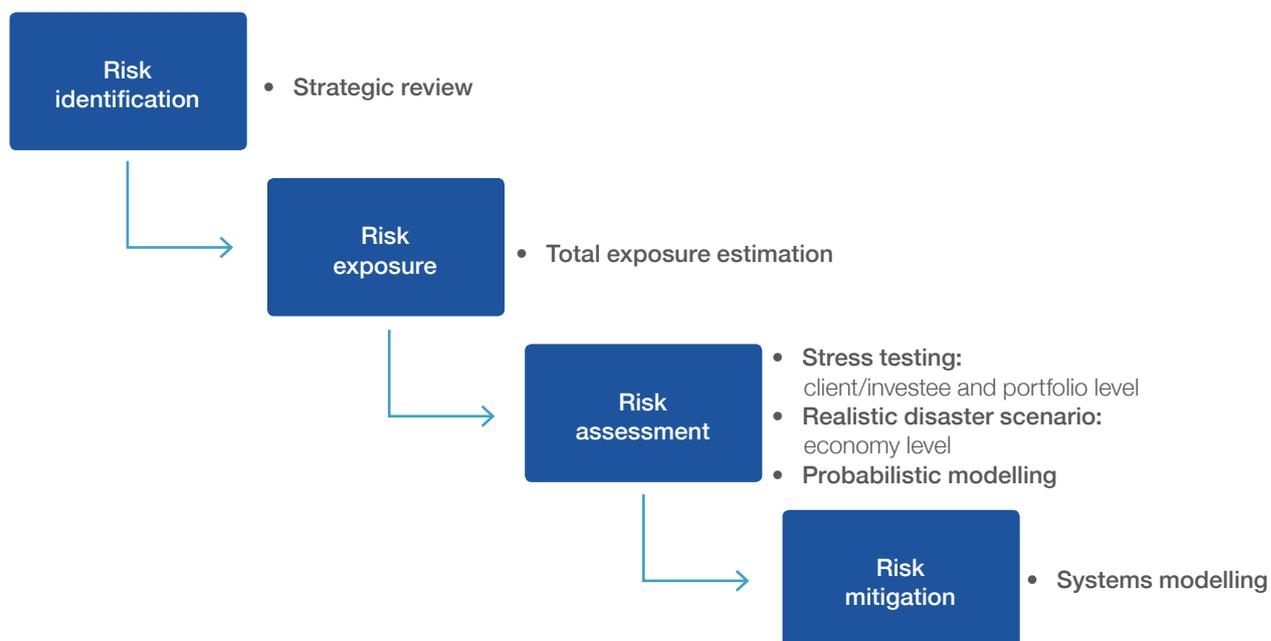
Illustrative examples include a global reinsurer collaborating with a ratings agency to analyse the impact of climate change on sovereign credit ratings (Case Study 5), an insurance market study on the micro- and macro-economic impacts of global food price shocks triggered by an intense El Niño phase (Case Study 13) and systems analysis led by a non-life insurer to understand the drivers of growing risk exposure in the context of climate change in a particular region (Case Study 9). One major international collaboration is focused on how to incorporate water stress into corporate bond analysis (Case Study 6), an example of an overlap between climatic and ecosystem sources of risk. None of the cases represented here deal with geologic sources of physical risk. However these sources of risk have long been analysed by insurance companies as part of their catastrophe modelling as well as by other financial institutions when considering their operational risks and business continuity plans.

**Innovation focused on transition sources of risk is clustered around policy or regulatory change.** Examples of innovation in China (Case Study 2), Germany (Case Study 3), Italy (Case Study 7), the Netherlands (Case Study 8) and the United States (Case Study 14) all focus on understanding the impact of policy change, either to achieve decarbonisation, cleaner air or both. One example from the United Arab Emirates was found of a financial institution explicitly considering the role of technology change (Case Study 11), although the impact of this specific analysis on financial decision-making so far has been modest.

**Qualitative approaches are the starting point; quantitative analysis is a common goal.** Virtually all of the private and public submissions received indicated that financial institutions are already engaged in some sort of qualitative assessment and management of the impact of environmental sources of risk. Approaches include, but are not limited to, strategic reviews, upgrades to risk governance structures and the tightening of internal risk management policies, including adopting international principles-based frameworks. Some early progress is being made with respect to innovative approaches to quantifying these impacts, which is clearly the direction of travel for risks to be properly managed.

**A variety of tools and techniques are emerging, across every stage of traditional risk management.** Figure 5 sets out four common stages of a risk management process, starting with risk identification, moving through risk exposure and risk assessment and concluding with risk mitigation actions. Within each stage, this study has found examples of innovation emerging.

**Figure 5: Key innovations across all stages of a common risk management process**



**Strategic reviews are a common first step.** One example not featured as an illustrative case study was the UK Prudential Regulation Authority’s study, published in 2015, into the impacts of climate change on the insurance industry. The methodology employed consisted of structured questionnaires being distributed to regulated entities, follow-up interviews and industry-wide roundtables, all informed by a review of available literature and independent expertise.

**To estimate total exposure, either at the firm or industry level, proxies are being used.** In Case Study 4, for example, a bank wanted to understand its total exposure to ‘natural capital’ risks, i.e. negative externalities created by the companies it finances that could in the future be internalised by a range of interventions. The bank used an ‘environmentally extended input output (EEIO) model’ to assign a monetary value to the negative externalities of economic activity, in this case in India. These values were then aggregated at a sector level across 50 different industries and these values mapped across to the bank’s exposure through its financing activities. In Case Study 1, a banking association wanted to carry out the same exercise at the sector level, though arguably with greater urgency because the precedent in the country (Brazil) means financial institutions can be held liable for environmental damage caused by their clients. Using industry classification codes for a selection of industries with known environmental impacts, the country’s major banks were asked to provide details of their relevant financial exposures over a 12 month period and the totals aggregated. **The research estimated that 33 per cent of the country’s top ten banks’ corporate lending is to sectors exposed to high levels of environment-related legal risk.**

**Finally, in Case Study 8, a central bank also wanted to assess its country’s financial sector’s exposure, this time to transition sources of risk.** The methodology was similar to that in Case Study 1; financial institutions were asked to provide data about their exposure to a range of pre-identified sectors. A further step was introduced whereby

financial institutions were asked to submit details of the duration and seniority of their exposures so that exposure to a relatively abrupt transition could be understood. **The study noted that up to 12.4 per cent of Dutch pension funds' assets are in fossil fuel or carbon intensive industries.**

All of these approaches are designed to obtain high-level overviews of exposure within the current constraints of data limitations. Therefore, they are necessarily approximations that make a number of, sometimes quite significant, assumptions. Nevertheless, they can play an important role in informing decision-makers about the magnitude of risk that they need to consider.

**For risk assessment, different scenario-based tools are being evolved according to the context, including stress testing, realistic disaster scenarios and probabilistic modelling.**

**Where financial institutions are trying to assess the potential impact of risks on individual clients or investees and subsequently aggregate the results to a portfolio level, stress testing techniques are being adapted.** In Case Study 14, for example, a bank has developed a carbon stress testing methodology to model the impact of increased carbon regulation and market responses to low carbon transition incentives on specific industry sector client portfolios, ultimately to inform decisions about credit risk. Case Study 2 sees another bank develop a very similar methodology, albeit the motivator here being air quality regulation. By constructing scenarios for 'heavy', 'medium' and 'light' regulation, the bank was able to identify different levels of plausible stress with which to test the financial performance of high emitting client sectors. The results were then fed into the bank's internal credit rating model to derive fresh probabilities of default, which could subsequently be converted into non-performing loan ratios. Case Study 3, developed by a group of investors, takes a similar approach while also explicitly factoring in the ability of investee companies to react to tighter regulation and thus reduce the impact on their performance. **It concludes that the margins of poorly prepared energy intensive companies in different markets could be reduced by more than 10 per cent in a strong carbon price scenario.**

**To analyse impacts that may propagate through entire economies, realistic disaster scenarios have been deployed.** Case Study 13 is a prominent example of this approach, whereby an insurance market wanted to understand the impact of global food price shocks on both micro- and macro-economic performance. Working in collaboration with climate scientists and agricultural economists, the team first devised a plausible scenario for an extreme, deep El Niño phase that would drive extreme weather events (including both floods and droughts) simultaneously around the world, causing crop failure in a number of major food producing regions and major price spikes. **The analysis concluded that such a global food price shock could suppress European stock markets by 10 per cent, and US stocks by 5 per cent, over a sustained period.** Not only was the scenario development informed by a multi-disciplinary team of experts, but the probability of occurrence based on the best available data and science was estimated as significantly higher than the benchmark return period of 1:200 years applied for assessing insurers' ability to pay claims against extreme events. Further, the magnitude of the resultant shock for prices for each commodity in the scenario was based on de-trended FAO data from 1961 to 2013, using three de-trending methods to address shifts in crop area, yield and technology during the time period. In combination, this results in a scenario that not only has major plausible implications for social and political stability and micro- and macro-economic performance, but is also demonstrably not 'unrealistic'.

**Where data allows, probabilistic modelling can help to navigate uncertainty.** In Case Study 5, a global reinsurer worked with a ratings agency to integrate the impacts of

climate change into sovereign debt ratings. Uncertainty about the event characteristics of future climate-related natural catastrophes was a particular challenge to contend with. As is common in the catastrophe models used by the insurance industry, rather than just use one natural catastrophe scenario, the reinsurer used simulations of a variety of events that could unfold within a given period of time. This produced a spread of event damages that more accurately reflects the possible impacts of a variety of events that might occur. The research assessed that the damage-to-value ratio for a sovereign of a major climatic catastrophe could increase by an average of 25 per cent as a result of climate change. The negative ratings impact of the catastrophes due to climate change increases accordingly, on average by about 20 per cent compared to a scenario not including climate change.

**For risk mitigation, an important innovation is the use of systems modelling to identify ‘no-regrets’ actions institutions can prioritise in the context of complexity.**

When it comes to risk mitigation, most financial institutions are understandably focused on what is within their control, such as decisions to engage with their clients/investees so that they reduce their own risk exposure or ‘tilting’ the composition of their portfolios away from high risk exposures. All of these options are perfectly valid, but many are limited in their ability to respond in situations of marked complexity where it may not be clear that such actions will actually achieve the intended results. Case Study 9 sees an insurance company use a systems modelling approach to determine that human-induced changes to ecosystems are likely to be as important a driver of increased risk exposures as hazards that are made more intense or frequent by climate change. For instance, the impact of the introduction of alien species of vegetation on the risk of wildfire is equivalent to that of projected increased temperatures. What has emerged as a response is collaboration with local authorities to address the human-induced ecosystem change. By focusing on explaining the different risk drivers within a defined system (here, a region in South Africa), the insurer was able to identify no-regrets actions that are within its control that could have a meaningful impact on risk mitigation.

**Credit and market risks are receiving the most attention and analysis is revealing some material impacts.** Examples of some of the conclusions being reached by the risk analysis in the illustrative case studies are drawn out in the above section.

**Early-stage evidence exists of financial institutions acting on the findings of such risk analysis in their financial decision-making.** In Case Study 2, for instance, a major Chinese bank reports that the findings of its analysis of the impact of tighter air-quality standards on the financial performance of thermal power and cement companies have informed a recalibration of the bank’s risk appetite in those sectors. In Case Study 12, a UK bank is offering corporate real estate clients pricing incentives on loans when they can evidence their action to reduce their exposure to transition risk. Finally, in Case Study 9, a South African insurer is partnering with agencies that can materially reduce the hazard levels to which its customers are exposed in priority regions.

## 3.2 Sector trends

**The insurance industry has the deepest experience of innovation in analysing the physical sources of risk, having developed coherent metrics, methodologies and models to manage the financial impacts of natural catastrophes such as hurricanes, storms and floods.** This was prompted by the regulatory requirement to be resilient to a 1-in-200 year tail risk event. A mature network of modellers, both in-house and external, has developed as a result, supported and enabled by an ecosystem of data providers. In turn, a culture and comfort level for working with multi-disciplinary

teams, including from across academia, has developed. This is an important factor in understanding how a variety of shocks can propagate through to having impacts that are material to insurance companies. Lessons could be learned about how the sector's experience here has enabled low probability, high impact risks to be integrated into annual capital planning. One key question for the sector relates to the fact that it is less clear whether these tools and techniques are being applied to transition sources of risk.

**Investor innovation appears most focused on transition sources of risks, specifically as they impact heavy polluting and energy intensive sectors.** Innovation is focused at the investee and portfolio level, driven by concerns around market, credit (counterparty) and business (reputation) risk. Policy and regulatory change, rather than technology breakthroughs or sentiment shifts, appears to be of greatest concern, though it is notable that specialist investment funds have been launched specifically to benefit from disruptive technologies and business models, presumably based on qualitative and quantitative analysis of the opportunities on offer. One key question for the sector is whether techniques to analyse market risks associated with shifts in energy commodity prices (e.g. oil) are being adapted for broader application to transition sources of risk, for instance around prices being attached to carbon.

**In the banking industry, transition sources of risks affecting energy intensive sectors are also a focus, with some broader innovation too.** Driven by their potential exposures to all forms of financial risk, banks are certainly focused on transition sources of risk related to the decarbonisation of the economy. Discussions in political fora about the possibility of regulatory 'carbon stress tests' will no doubt be spurring this. In addition, though, it is notable that banks in various countries are focusing innovation on a broader set of risks, including those derived from physical sources like water stress and transition sources where regulatory or other efforts seek to internalise the negative externalities created by companies they finance. One key question for the sector is whether physical sources of risk are already incorporated in mainstream decision-making, for example for lending, or whether collaboration with the insurance industry might be fruitful.

### 3.3 Possible gaps in current practice

**While attention is widely being applied to transition risks, the possibility of abrupt shocks is rarely considered in practice.** Expert bodies such as the Advisory Scientific Committee of the European Systemic Risk Board (Gros et al, 2016) consider the possibility of a delayed and abrupt transition away from a high emission energy system to be a plausible scenario. Meanwhile, research has shown that the impact of short term, abrupt shifts in market sentiment induced by awareness of future climate risks could lead to material economic shocks (CISL, 2015). When looking at transition sources of risk, most innovation is focused on policy or regulatory change. While scenario analysis does allow for 'strong' policy interventions to be modelled, these are rarely assumed to be introduced in a sudden manner. A tension between the literature and current practice therefore appears to exist. This is despite recent experience whereby the Tohoku earthquake of 2011 led, albeit indirectly, to abrupt changes in the German government's policy towards nuclear energy.

**Limited work to assess interlinkages between sectors and subsequent aggregation appears to be happening.** Across the spectrum of financial risks that can be driven by environmental sources, the majority of work is concentrated on assessing direct impacts to financial institutions via the companies they insure, finance or own. Meanwhile, some regulatory authorities and academic experts are already considering the indirect channels through which network effects could see impacts propagate through the financial system

and affect financial institutions indirectly. Researchers at the Bank of England, for example, are considering the impact of uninsured losses from natural catastrophes on collateral values securing loans in the property and small business market (Batten et al, 2016), while a group of international academics has developed a methodological framework to assess the exposure of the financial system to climate policy risks including through indirect channels such as energy-intensive sectors, housing and finance (Battiston et al, 2016).

**Market risk from fluctuations in commodity prices is well addressed, however more work is needed to use such tools for assessing the impact of carbon pricing.** It is common practice for financial institutions to incorporate fluctuations in commodity prices like oil and coal into macroeconomic models that they use to assess their exposure to market risk. A case in point is Royal Bank of Canada, which ran a group-wide stress test based on oil staying at \$25 per barrel throughout 2016 in order to examine the ‘contagion effect’ on the rest of Canada (McLannahan, 2016). However, despite the fact that some research has concluded that a worst-case scenario for transition risk would have an impact on equities and bonds with a magnitude similar to that which investors already face with the fluctuation of energy prices (2°ii, 2016), relatively little evidence has been found that carbon pricing is being modelled in a similar way. Case Studies 7 and 10 are offer some insight into innovation in this area.

**Of all the financial risks, the biggest knowledge gap may be around legal risk.**

Despite featuring prominently in legal contexts or strategic reviews of markets such as Brazil, China and the UK, legal risk does not appear as the primary focus of any of the quantitative analysis submitted to this study, nor of any discrete scenario-building work. This may be because of the uncertainties involved or because legal risks tends to be derived from failures to manage physical or transition risks, or both. Equally, there is anecdotal evidence that some financial institutions are indeed tracking developments in this space, but are doing so privately. Nevertheless, experts and industry bodies alike argue that this is a significant risk (Barker, 2013; Geneva Association, 2011).

# 4.

# Challenges and options

## 4.1 Four challenges to mainstream integration

**The illustrative case studies highlighted in this stocktake show that innovation in risk analysis is emerging, but is far from integrated into mainstream decision-making.** The stocktake has drawn attention to pockets of innovation in risk analysis tools and techniques across financial sectors. Most examples are in the development stage, where new methodologies are being trialled – often for the first time – on subsets of relevant exposures financial institutions may have. Where the results of this innovation are being implemented in risk management practice, these are the exceptions rather than the rule. On the one hand, such innovation by major incumbent players in different financial sectors from around the world shows how significantly the need for new analytical tools and techniques is being felt at the heart of the financial system. On the other hand, given the importance of this agenda, the fragmented and early-stage nature of such innovation should be cause for motivation to identify, and address, challenges preventing quicker mainstream uptake.

**Challenges relating to each stage of the standard risk management cycle have been identified by market participants.** These challenges are raised consistently across the illustrative case studies, appear regularly in the expert literature and have been validated as priorities in engagements with private sector institutions convened for this study.

1. **Lack of capacity: developing credible analyses on how environmental sources can create financial risks is complex and requires expertise that is often not found in one institution.**

Assembling the insight required to convert threats, transmission mechanisms and impacts into useable scenarios can be a complex process. It may require financial institutions to form new partnerships with experts from a range of sectors, all with different capabilities and motivations.

In the vast majority of illustrative case studies profiled in this research, the financial institution in question had to work with at least one other type of stakeholder, whether consultants or academics to fill knowledge and skills gaps or clients/investees to acquire relevant data. This is unsurprising given that many of the environmental sources of risk in question have not been felt to be material until recently.

Within the financial industry, the insurance sector is perhaps the best accustomed of all financial sectors in building plausible but extreme scenarios for how environmental threats could evolve in close co-operation with experts from a range of disciplines. Case Study 13 demonstrates the complexity of the undertaking; in order to model the possible macro-economic and insurance impacts of a global food price shock triggered by an intense El Niño phase, collaboration between climate scientists, food system experts, political scientists, economists and insurance industry experts was needed. Even setting aside this more complex example, the number of case studies that have partnerships with an external body of expertise is strikingly high.

Many practitioners report that identifying the most likely and/or impactful transmission mechanisms between environmental sources and financial risks affecting their firms is a multi-disciplinary challenge that they struggle with. Collaborative approaches to connect disparate pockets of expertise are certainly required in the immediate term. Justifying investment in such approaches, with no guaranteed return and associated opportunity costs, is challenging to envisage at scale.

2. **Knowledge gaps: fragmented or absent policy signals are a major distraction from efforts to develop more holistic analysis of the risks that financial institutions are exposed to.**

One of the most consistently cited challenges by practitioners is a lack of clarity about the future policy responses to environmental threats. This is not a challenge unique to 'green finance' but it is a particularly important one. In a national context, financial institutions are often forced to contend with uncertainty about the speed and even direction of policy responses.

For global financial institutions, the mosaic of policies at the national level introduces significant complexity as the number of scenarios to consider quickly multiplies. Both of these trends are all the more challenging because the financial risks resulting from environmental sources are not always contained by national boundaries.

Meanwhile, because this challenge is significant enough on its own, more complex knowledge gaps are receiving relatively little attention from individual financial institutions. For instance, the majority of attention applied to analyse changing credit risk is focused at the client or investee level, with some work being done at the portfolio level. The question of how such risks may aggregate, therefore, is not well understood despite recognition from a wide range of regulatory authorities that this dimension needs attention.

Equally, despite qualitative strategic reviews such as those published by the Bank of England (Batten et al, 2016) identifying that the interlinkages between sectors may allow risks to propagate, our research has not identified any innovation focused on transmission channels between financial sectors. Correlations amongst and between financial sectors are therefore not deeply understood. Finally, while academic research (Gros et al, 2016; CISL, 2015) has identified the possibility of plausible, abrupt shocks arising from environmental sources, for instance through major shifts in investor sentiment, this type of risk does not appear to be the subject of significant private sector attention.

Apart from the fact that resources are likely to be already consumed by more direct sources of risk like public policy, there are also agency issues at play here (see below) whereby individual financial institutions may have insufficient incentives to focus on these type of questions (Schoenmaker, van Tilburg & Wiffels, 2014).

3. **Inadequate data: data is a critical input to risk analysis. The lack of comprehensive and consistent data dissuades financial institutions from investing in tool development.**

In order to incorporate environmental sources of risk into mainstream analysis, a variety of types of data is required, but significant challenges are associated with the comprehensiveness and consistency of data that is available to financial institutions.

The type of data most often cited as lacking by practitioners is that pertaining to the exposure of financial institutions' clients or investees to the risks in question. Within this category, different environmental sources of risk are likely to require different types of data. Analysing physical sources of risks typically requires data at the asset level, while understanding exposure to risks that are transition-related likely requires both asset and firm level data (2<sup>o</sup>ii, 2016). Further, industry classifications vary across different assets and institutions, making it problematic to measure exposure to carbon and related energy regulation in a consistent and comparable manner. It is at this level of data disclosure that some countries have introduced legislation (e.g. France through its Energy Transition Law, 2015). Other supra and international bodies like the European Commission<sup>1</sup> and Financial Stability Board (FSB, 2015) have initiated consultations to assess how they can support more standardised and decision-ready disclosure of this type of data.

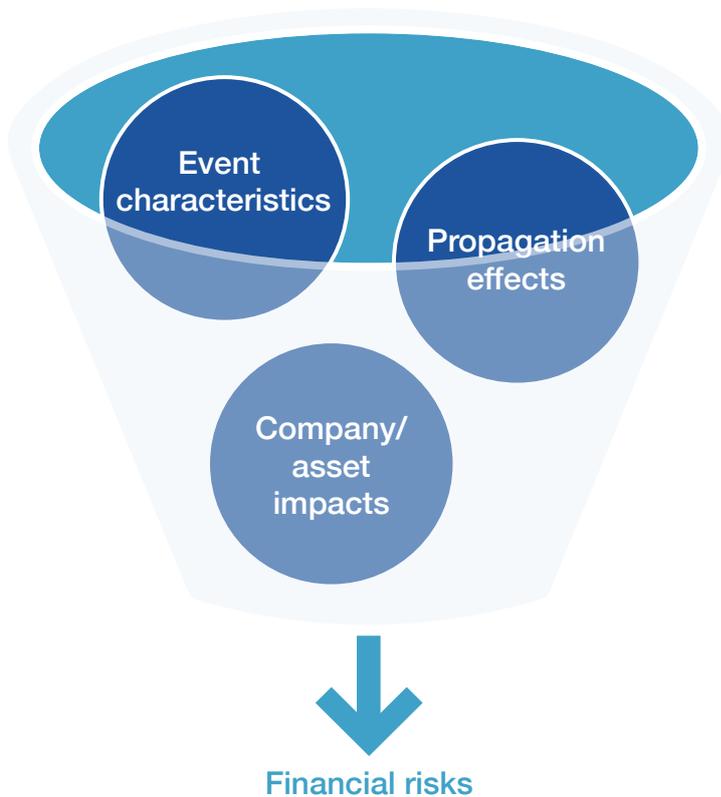
However, it is incorrect to conclude that this is the only type of data needed by financial institutions. As demonstrated in the simple schematic in Figure 6, at least two other types of data are needed by individual financial institutions. The first is information relating to the events that trigger the risk in the first place, and how they are changing. Examples include the kind of datasets compiled by the insurance industry relating to changing weather-related extreme events, though one of the major risk modelling firms servicing the insurance industry highlighted to this study how a lack of regional data relating to water stress and drought is proving to be a major inhibitor for its work in this important area. The second is data that gives financial institutions insights into how the impacts of different hazards or transition-related events propagate. For example, the consortium behind Case Study 6 which developed a methodology to integrate water stress into corporate bond analysis notes that it could not access data relating to how water infrastructure and ownership rights (e.g. arrangements to pump water into a given region from a different basin during a period of stress) influence how drought impacts different regions.

In parallel, but related, to the need for better data, many traditional risk assessment methodologies need to be adapted to analyse risk arising from environmental sources. This is not just a question of having the right data, but of having the tools and expertise that are required to interpret it; even if there was perfect data disclosure, issues associated with complexity, uncertainty and time horizons would still exist and pose challenges for effective decision-making. As demonstrated by the prevalence of financial institutions partnering with expert consultancies or academic institutions to develop methodologies, it cannot be assumed that internal capacity in mainstream financial institutions is currently sufficient. In private submissions to this study, different types of institution shared that they are trying to adapt scenario-based tools to analyse risks with environmental sources but are struggling, for instance, with which transmission mechanisms to prioritise or with how to present the output of such tools in a decision-ready manner given the uncertainties involved.

<sup>1</sup> [www.iasplus.com/en/news/2016/01/consultation-on-non-financial-reporting-guidelines](http://www.iasplus.com/en/news/2016/01/consultation-on-non-financial-reporting-guidelines)

Given inadequate data, it is difficult for financial institutions to devote major resources to tool development, but unless these capabilities are grown in parallel, solving the data issue will not suffice.

**Figure 6: Data needs for modelling the impact of environmental sources of financial risks**



4. **Lack of a level playing field: if risk is being under-priced, or if short termism means risks are not being sufficiently taken into account by financial institutions, a competitive market may force a 'race to the bottom'.**

Where enhanced risk analysis reveals risk has been mis-priced, a competitive market context can act as a disincentive for individual firms to act unilaterally. This would appear to be especially true when financial institutions are acting as intermediaries and have client relationship management pressures to navigate. The emergence of voluntary industry risk management initiatives such as the Equator Principles for the project finance industry perhaps speaks to this challenge. However, it is ultimately a far broader issue. Just as one anecdotal example, in the United States, the City of Norfolk (Virginia) invested in analysis to enhance its understanding of its own exposure to sea-level rise. When it published its findings, this triggered ratings agencies to downgrade its credit rating. While it is true that consequential work to manage this risk exposure may result in the 'reward' of its credit rating being uplifted again, in the near term this has been seen as a clear disincentive to action.

Similarly, short termism in financial decision-making is a challenge cutting across many issues but particularly relevant to risk analysis (Caldecott & McDaniels, 2014; Chenet, Thoma, & Janci, 2015; Mercer, 2015; WEF, 2014). Longer term risks are often being discounted out of financing decisions even though they may remain material to the financial system or wider economy. The Governor of the Bank of England, Mark Carney (2015) has consistently highlighted ‘the tragedy of horizon’ between the longer-term impacts of climate change and the time horizon of risk management decision-making in the financial sector. Case Study 5 featuring collaboration between a global reinsurer and a credit rating agency exemplifies this clearly. The analysis focused on climate-related natural catastrophes that are expected to recur on a 1-in-250 year return period and analysed the multiplier effect of climate change in the context of sovereign credit ratings. Despite the fact the results are shown to be material in various cases, the likelihood of such an event happening within the ratings horizon (5–10 years) is considered small. The result is that this risk factor is unlikely to be factored into the ratings that so many users depend on.

However, the stocktake has shone light on helpful experiences that already exist. For instance, the non-life insurance industry is typically oriented around one-year insurance contracts and yet regulatory requirements to ensure that insurance companies hold sufficient capital to be resilient to a natural catastrophe event with a 1 in 200 annual probability has brought the management of high-impact, low-likelihood risks into short term decision-making that affects both the safety and soundness of firms and financial stability. The insurance industry also has a heightened awareness of how extreme climate-related natural catastrophes are becoming more likely (the tails of the probability distribution curves are becoming ‘fatter’).

## 4.2 Four response options

In response to each of these four challenges, an option has been identified as a priority for next steps.

1. **To build capacity, national G20 regulators could convene multi-sector, multidisciplinary fora to develop environmental risk scenarios that represent priorities in their context.**

Countries have different exposures to environmental sources of financial risks according to their geographies, the structure of their economies and financial markets, their liability regimes and their public policy contexts, to name just a few factors. Ensuring adequate prioritisation of capacity building at the country level is therefore important. Outputs could include shared, baseline risk registers for financial institutions to work from and alignment between industry classification systems and risks relevant to the country. Sponsorship by regulatory bodies would be a powerful signal and may encourage greater clarity on the direction of future policy.

2. **To plug knowledge gaps, the G20 could support industry and academic research that helps to advance more holistic risk analysis on questions that are priorities across the G20.**

Research is needed to deepen collective understanding, ideally in a quantitative manner, of how the impacts of different risks can aggregate, how interlinkages

between sectors may allow risks to propagate and how abrupt shocks may impact different pools of capital. These are all questions that individual financial institutions find it difficult to prioritise and so their relative potential impact remains unknown.

3. **To improve data, the G20 could ensure work to improve data disclosure focuses on all types of data required for effective risk analysis.**

This would include firm- and asset-level disclosure as well as data related to how impacts may propagate through different systems. The FSB's Task Force on Climate-related Disclosures (TCFD) is one preeminent body focused in this area.

4. **To help level the playing field, the G20 could signal the importance of this issue by sponsoring an international forum in conjunction with the private sector and academic partners to facilitate knowledge sharing and develop common methodologies for environmental risk analysis in the finance sector.**

Scenario-based environmental risk analysis, when deployed appropriately to manage tail risks in particular, can help to address some aspects of uncertainty and time horizon issues. Experience is emerging around the world, in different sectors, focused on different environmental sources of risk. A concerted effort to share knowledge and experience across such boundaries could accelerate action.

# Appendices

## Appendix A

### Historical experiences of environmental sources of financial risk

History has shown that environmental threats can affect the efficiency and effectiveness of markets, the safety and soundness of financial institutions and even the performance of wider financial and economic systems. A range of historical experiences illustrating the direct and spillover effects of such events on financial institutions and economies is detailed below.

- The British economist William Jevons (1884) famously argued that financial crises were produced by sunspots, which could be shown to cause drought and poor harvests in key agricultural producing countries and then led to a downturn in international trade resulting in significant bank losses and related financial market stresses.
- Due to soil erosion caused by unsustainable farming methods, the United States suffered dust bowls in the agricultural belt states in the 1880s and 1890s and again in the 1930s. The ensuing economic downturns during these periods resulted in substantial losses on bank loans and related financial market distress, which spread contagion-like through the regional economy (Hornbeck, 2012).
- More recently, in the late 20th and early twenty-first century, increased hurricane activity in the Caribbean and south-eastern United States caused significant bank losses to businesses and individuals. Hurricane Andrew caused \$24 billion in damages to the south Florida economy in 1992, while Hurricanes Rita, Wilma and Katrina each caused widespread and extensive damage to Caribbean economies and to the south-eastern United States. Ranked as one of the costliest natural disasters in US history, Hurricane Katrina came ashore in south Florida in August 2005, causing in excess of \$200 billion in damages (Lambert, Noth and Schüwer, 2011). The damages led to high loan losses and provisioning for banks that were based in the affected areas. The bank losses led US regulators to review the adequacy of bank risk models addressing credit risk and hurricane damage.
- Geological events such as earthquakes and volcanoes can also result in banking and financial market distress. The Great Kanto Earthquake of 1923, which struck the south part of the Kanto district in Japan, is among the causes of the 1927 Showa financial crisis which culminated in the closure of numerous banks (Shimizu & Fujimura 2010). Similarly, the series of earthquakes that hit Turkey in 1999 required

international financial assistance to rebuild the economy and avoid the collapse of the banking system (Brinke 2013). Finally, the eruption of the Soufriere Hills volcano on the island of Montserrat in 1998 destroyed its capital, Plymouth, and forced 90 per cent of the inhabitants to leave the island. The financial system was severely disrupted, with the most important bank on the island, the Montserrat Building Society (MBS) collapsing due to a bank run (Clay et al 1999).

### **The following case study draws extensively on the study Integrating water stress into corporate bond credit analysis, GIZ, NCD, VfU. (2015)**

Evidence of the potential impact of water stress on business can be found in regions such as California and Brazil, which have been gripped by severe droughts. In April 2015 after four consecutive drought years the Governor of the State of California directed that the State Water Resources Control Board impose restrictions to achieve a state-wide 25 per cent reduction in potable urban water usage. Farmers in California's Central Valley, the agricultural region that supplies half of the fruit, vegetables and nuts consumed in the United States, have paid 10 times more for water than they did before the drought. Farmers have been forced to leave land unused, businesses and residents have faced mandatory cutbacks and policymakers have considered seawater desalination. The drought also sparked social unrest with protesters calling for Nestlé, the largest water bottler in the US, to stop bottling operations in Los Angeles and Sacramento during the drought.

From the start of the drought hydropower production in California dropped 60 per cent, driving a shift to natural gas. Even at the onset of drought in 2012, several nuclear and thermal power plants in the US were forced to run at lower capacity due to lack of cooling water.

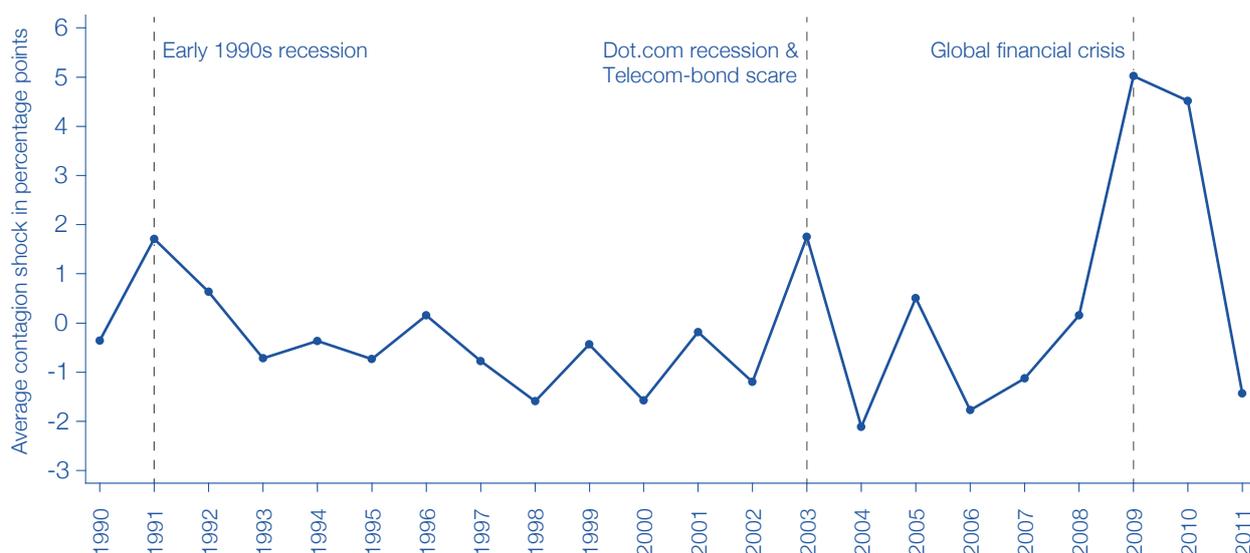
At a similar time in Brazil, industry and agriculture in the country's three most populous states – São Paulo, Rio de Janeiro and Minas Gerais – were exposed to the worst drought in over 80 years. Water rationing was imposed on the largest firms in the country's industrial heartland of São Paulo. Water reservoirs reached critically low levels. Given that two-thirds of Brazil's electricity comes from hydropower, the drought caused a shift to high-cost thermoelectric power, contributing to a 70 per cent rise in electricity prices. The effects of water and electricity rationing are thought to have cut GDP growth by 1–2 per cent in 2015.

Rating agencies responded by reviewing the corporate and sovereign ratings affected. As a result of the drought, S&P Global Ratings, Moody's and Fitch all placed the water utility Cia de Saneamento Basico do Estado de Sao Paolo (Sabesp) on Negative Outlook. Further drought in Brazil was mentioned as a factor when S&P Global Ratings cut its Brazil long term foreign currency rating to BBB – on 24 March 2014.

Based on this experience, the ratings agencies are investigating whether and how long term water scarcity trends may impact different economic sectors. Moody's mining sector report entitled 'Water Scarcity to Raise Capex and Operating Costs, Heighten Operational Risks' (2013) discussed the challenges of mining in areas where rainfall is consistently low and water stress is high. An S&P Global Ratings paper (2012) argues that: "power generators and energy-intensive firms could face more immediate financial risk from water use through business disruption and changes in abstraction licencing conditions".

- According to the International Finance Corporation report on climate risk (Stenek et al., 2009), the human and financial consequences of the summer 2003 European heatwave were substantial. The heatwave resulted in an estimated 35,000 deaths as well as a USD15bn loss to European agriculture sectors, 50 per cent cuts in France's energy exports and electricity price spikes of 1,300 per cent, which in turn resulted in USD300mn loss for one firm alone, EDF. It is noteworthy that without global warming, such a summer would have been classified as a 1-in-1,000 year event. Today its likelihood has doubled to a 1-in-500 year event. According to a variety of reports such summers will be normal 1-in-2 year events by 2040, and cooler than average by 2060 (De Bon et al., 2004; Stenek et al 2009; Stott, Stone and Allen, 2004).
- At the same time, increasing international financial integration is known to have enabled a steady increase in contagion during crisis events since the 1990s, as demonstrated by the graph below. The extent of financial integration is such that countries may suffer from shocks to other countries with which they have no direct economic or financial connection (OECD, 2012). Financial contagion can be understood as cross country spillover effects driven by real links (trade and/or foreign direct investment), financial links and herding behaviour (Schmukler, Zoido and Halac, 2003).

**Figure 7: Financial contagion via the bank balance-sheet channel reached unprecedented heights during the global financial crisis; Source: OECD (2012)**



## Appendix B

### Illustrative examples of environmental sources of financial risk

Illustrative examples of how each type of environmental source (Physical, Transition) can lead to different sorts of financial risks (Business, Legal, Credit and Market).

#### Physical sources of...

...**Business risk:** As part of modern contingency planning, financial institutions of all kinds around the world are accustomed to preparing for the impact of extreme weather events like flooding on their operations. With global financial centres like New York, London and Shanghai all potentially exposed to flooding from storm surges, this seems entirely appropriate. In the longer-term, climate and public health scientists warn of the impact of rising average temperature levels on labour productivity, with one risk analytics company warning that heat stress threatens to cut labour productivity in south-east Asia by 25 per cent within 30 years (Verisk Maplecroft, 2015).

...**Legal risk:** Whether through Professional Indemnity, Directors and Officers or other forms of third-party liability cover, insurers in particular are potentially exposed to claims against their insureds for their failure to adequately foresee or respond to physical extreme events. Depending on the jurisdiction, banks and investors may also be exposed to such risks by legislation that imposes joint and several liability on them through their financing relationships.

...**Credit risk:** One of the cornerstones of market initiatives like the Equator Principles for project finance or market practices like 'ESG integration' in the institutional investment industry is the recognition that physical risks can give rise to issuer or counterparty risk. The impact of drought on the probability of default of a water intensive company is just one example.

...**Market risk:** With a direct loss of US\$ 43bn (12 per cent of GDP), the floods that hit Thailand in the second half of 2011 were classed as by far the most expensive natural catastrophe in the country's history. Thailand's own economy shrank by 2.5 per cent in the fourth quarter of 2011 compared with the previous quarter, when growth still stood at +1.6 per cent. Flooding in Thailand's industrial areas affected Japanese corporations' production facilities, including numerous key electronic component manufacturers (Beilharz et al., 2013). By way of example, production of around 25 per cent of the world's computer hard-drive component requirements came to a standstill, leading to hard drive pricing jumps of 20–40 per cent (Ploy Ten & Chang-Ran, 2011). Six months after the floods prices remained above the pre-flood levels, leading some analysts to suggest that they became the new normal (Haraguchi and Lall, 2014).

#### Transition sources of...

...**Business risk:** One of the risks being analysed by banks and investors around the world is how the transition away from a high emission energy system could lead to material falls in demand for fossil fuels, potentially impacting pure play producers the

hardest and calling into question their business model. For financial institutions that are particularly overweight in such sectors, this might expose them to a requirement to change strategic priorities. Equally, there is a growing trend of asset owners wishing to decarbonise their portfolios; asset managers without credible service offerings to meet such rising demand will increasingly face strategic headwinds.

...**Legal risk:** In many developing economies, inadequate implementation of environmental regulations has driven financial regulators to mandate financial institutions to adhere to such regulations, which are enforced through, for example, lender liability regimes.

...**Credit risk:** Banks and investors are increasingly looking at the impact of carbon- and energy-regulation on the financial performance of their energy intensive clients and investee companies. Insurance companies may also experience such risks on the asset side of their balance sheets.

...**Market risk:** Unexpected breakthroughs in technology known to be central to the development of an affordable clean energy system at scale could have the potential to have abrupt impacts on investor sentiment and energy commodity markets. Such a scenario would affect all financial institutions, given the systemic impact of the energy system on the wider economy.

## Appendix C

### How environmental sources of risk are changing

**Many of the environmental threats, and efforts to address them, that trigger the risks faced by financial institutions in the 21st century exhibit new characteristics.**

The experiences submitted by financial institutions as part of this research point to at least three distinctions which evolutions in risk management tools and practices need to contend with.

**Scale.** Scientists are increasingly agreeing that humanity's combined impact on the Earth's atmosphere, oceans and biodiversity is now so significant that it has pushed the world into a new geological epoch: the "Anthropocene" (Waters et al., 2016). In other words, human activity is having such a significant impact on the planet that the indicators that enable scientists to delineate between major geological periods of history are now showing evidence of humanity's footprint. Traditionally, environmental sources of risk faced by financial institutions were more local in nature, for example relating to a firm's liability for pollution of a local watercourse or habitat. Now, the World Economic Forum's Global Risk Report 2016 (WEF, 2016) lists large-scale biodiversity loss and ecosystem collapse, water crises and a failure to adapt to the impacts of climate change amongst the most likely and most impactful risks the world faces, alongside more traditional boardroom concerns such as fiscal crises and asset bubbles. While the impacts of these risks may well be experienced locally, many of their drivers are operating on an inherently larger, even planetary scale.

**Likelihood.** It is becoming increasingly well-understood that historic experience can no longer be relied upon to predict emergent environmental risks; the asymmetry of events above and below the expected average and the likelihood of low probability, high impact events are increasing. In the risk management literature, these trends relate respectively to the 'skewness' and the 'fat tail' of probability distributions. Such trends are routinely studied in relation to environmental threats (for example, Holland and Bruyère, 2014, observe an upward trend in the global proportion of category 4–5 hurricanes, offset by a similar decrease in the proportion of category 1–2 hurricanes) but may also be true of efforts to address environmental threats, whether linked to the likelihood of different strengths of decarbonisation pathway (Zii, 2016) or the rise of liability claims. Even for the insurance industry, with its relatively long history of using sophisticated catastrophe models, the fact that past experience can no longer be a reliable guide to future risks is problematic; "catastrophe models are generally built to provide an estimate of today's risk rather than to anticipate climate trends or to extrapolate impact of these trends into the future" (PRA, 2015).

**Interconnectedness.** Financial institutions operate not just within a global financial system, but also within a global economic system and global ecological systems, all of which are capable of amplifying small triggers into large shocks. The globalisation of the world's economies is a key enabler. Businesses that only a few decades ago were operating regionally are now serving global markets and thus are reliant on the infrastructure and relationships connecting hundreds of cities and economies worldwide

(Coburn et al., 2014). In parallel, scientists have identified and quantified a set of nine 'planetary boundaries' (Rockström et al., 2009). They argue that these are the planet's 'system boundaries', within which humanity can continue to develop and thrive for generations to come. Transgressing one or more such boundary may be catastrophic as it will "trigger non-linear, abrupt environmental change within continental- to planetary-scale systems". Worryingly, they estimate that humanity has already crossed three out of nine planetary boundaries, pointing to the fact that human impact on the environment may already be driving dynamic and interconnected system responses, on top of those magnified by an increasingly globalised economy. Insurance companies are amongst those in the private sector that have been seeking to analyse the impact of such 'tipping points', especially those associated with climate change (Allianz, 2009). These 'tipping points' can also drive non-linear policy and technological responses, as well as disruptive business model innovation, further increasing the potential for abrupt rather than 'steady-state' changes.

## Appendix D

### Financial sector bodies directly invited to contribute to this study

Asia Securities Industry and Financial Markets Association (ASIFMA)

Association of Banks in Singapore (ABS)

Association of Supervisors of Banks of the Americas (ASBA)

Banking Environment Initiative (BEI)

ClimateWise (insurance leaders)

European Finance Services Roundtable (EFR)

European Fund and Asset Management Association (EFAMA)

European Insurance and Occupational Pensions Authority (EIOPA)

European Systemic Risk Board (ESRB)

Geneva Association

Global Federation of Insurance Associations (GFIA)

Hedge Fund Standards Board (HFSB)

Institute of International Finance (IIF)

International Cooperative and Mutual Insurance Federation (ICMIF)

Investment Association

Investment Leaders Group (ILG)

National Association of State Retirement Administrators (NASRA)

Pensions and Lifetime Savings Associations

Securities Industry and Financial Markets Association (SIFMA)

Sustainable Banking Network (SBN)

Sustainable Finance Lab (SFL)

World Economic Forum (WEF)

## Appendix E

### Illustrative case studies

#### 1. Brazil: Measuring the exposure of the Brazilian banking system to environmental risks

<b>Organisation:</b>	Brazilian Federation of Banks ('FEBRABAN')
<b>Geography:</b>	Brazil
<b>Financial sector:</b>	Banking
<b>Environmental source of risk:</b>	Physical, Transition and Liability
<b>Tools or approach used:</b>	Industry-wide data survey of risk exposure
<b>Motivation:</b>	Analysis of sectoral risk exposure

**Executive summary:** Against the background of a Central Bank resolution to raise the standard of environment and social risk management in the Brazilian banking industry, and in the context of the UNEP Inquiry into the Design of a Sustainable Financial System, FEBRABAN and the Fundação Getúlio Vargas Centre for Sustainability Studies (FGV) analysed the exposure of the ten largest Brazilian banks (or Brazil-based subsidiaries) to environmental and social risks (FEBRABAN, 2014). This created conditions for the banks to measure, assess and manage their portfolio, segmented by sector of activity, as well as compare the amounts of funds intermediated by them towards the green economy.

#### Approach:

1. In April 2014, the Brazilian Central Bank issued Resolution 4.327/14, which requires regulated entities to set up and implement environmental and social risk policies, along with an implementation action plan. The resolution covers credit, legal and reputational risks that may arise from environmental and social issues. From the banks' point of view, physical and transition sources are both relevant, but the legal risks which may result take on particular significance because there is some precedent in Brazil for financial institutions being held liable for environmental damages caused by their clients.
2. Against this backdrop, and in the context of the UNEP Inquiry into the Design of a Sustainable Financial System, FEBRABAN set out to measure the financial resources exposed to such risks by the Brazilian banking industry, working directly with FGV and ten major banks in the Brazilian market (namely Banco do Brasil, BICBANCO, BNDES, Bradesco, BTG, Caixa Econômica Federal, HSBC, Itaú Unibanco, Santander and Votorantim).
3. The methodology underpinning the collection of exposure data was co-created by FEBRABAN, a working group of banks and researchers at FGV. Existing Brazilian

legislation was used to identify which economic sectors are known to have major environmental impacts (National Council for the Environment Resolution 237/97) and are subject to special due diligence by banks. The green economy sectors were aligned with the UNEP definition.

4. These sectors were then assigned codes from the National Classification of Economic Activities, which is a system for codifying Brazil's industrial sectors used in one form or another by all banks. Sectors identified included various agricultural commodity industries, electricity generation, forestry production, waste treatment, extractive industries, beverage and food producers, tourism, transportation, textiles and metallurgy.
5. Participating banks were then asked to use these codes to provide their financial exposures to these sectors in terms of amounts of contracted loans, amounts disbursed and the balance of the portfolio. Working capital financing, provided they had tenors exceeding 12 months and specific purposes, were included.
6. These exposures were then aggregated at an industry level to understand the overall exposure of the banking sector to sectors with potential to cause environmental impacts, as well as the financing provided by banks to green economy sectors. Individual banks were shown their exposure relative to their peers.
7. The study estimated that the amount of financial resources disbursed in sectors with the potential to cause environmental impacts was around R\$408 billion in 2013 and R\$365 billion in 2014, accounting for around 33 per cent of the total corporate lending in 2013 and 2014. The amount of funds channelled to sectors of the green economy stood at R\$110 billion in 2013 and R\$107 billion in 2014, accounting for 8.8 per cent and 9.6 per cent respectively of total corporate lending in 2013 and 2014.
8. The largest exposures by amounts disbursed were to the manufacturing of food products; electricity, gas and other utilities; and agriculture, livestock farming and related services.

#### **Impact on decision-making:**

- The study required a range of business units in participating banks to work together for the first time, including compliance, accounting, risk management and product specialists. This will undoubtedly have led to wider awareness across such institutions of the relevance of such issues.
- Equally, the benchmarking process whereby individual banks were able to compare their exposures to the average of the industry may trigger competitive responses and lead to changes in the strategies governing such exposures.

#### **Potential next steps:**

- All involved recognised that this study represented the first attempt to quantify the exposure of the Brazilian banking industry to environmental risk and that the methodology and its execution would need continual refinement.
- FEBRABAN has established internal resources to drive this effort forward, working directly both with banks themselves and the Central Bank, so that an annual survey

can be carried out more routinely. More banks are being invited to participate.

- A more standardised data request, initiated by FEBRABAN, will likely be needed to overcome operational issues.
- Ultimately, this work will need to inform the risk management procedures that are needed by, or expected of, Brazilian banks to manage their exposure to environmental risks.

## 2. China: Stress testing the impact of environmental factors on a Chinese commercial bank's credit risk

<b>Organisation:</b>	Industrial and Commercial Bank of China (ICBC)
<b>Geography:</b>	China
<b>Financial sector:</b>	Banking
<b>Environmental source of risk:</b>	Transition
<b>Tools or approach used:</b>	Stress test
<b>Motivation:</b>	Impact of environmental factors on credit risk

**Executive summary:** ICBC has developed a stress test methodology to analyse the impact of possible environmental standard improvement on the credit ratings of thermal power and cement industry clients.

### Approach:

1. A research group within ICBC identified that there are three channels by which banks can be affected by potentially new and stricter environmental policies in China: via credit risk resulting in a decline in client solvency, via shared liability with clients for environmental damages they may cause and via damages to the bank's reputation affecting both the bank's investor and depositor base should it be shown to have poor environmental risk management practices.
2. Having acknowledged that the credit risk was likely to drive both the liability and the reputation risk, ICBC developed a methodology to assess the impact of environmental protection policy on the credit rating of counterparties in polluting industries. The bank built on existing stress testing techniques because of the uncertain, systemic and forward-looking nature of the environmental risks that its clients face.
3. Two industrial sectors (thermal power production and cement) were selected from a group of the major polluting industries whose combined emissions account for more than 50 per cent of China's total emissions. These sectors are also a priority for Chinese environmental protection policy.

4. Through expert analysis and consultation with industry practitioners, ICBC developed scenarios specific to both thermal power and cement production to model different strengths of environmental policy changes that are being considered by the Chinese authorities. These were broadly characterised as representing heavy, medium and light stress and particularly focus on air quality standards.
5. Using its own analytics, the bank then modelled the impact of the different stress scenarios on the financial performance of companies in the two sectors, focusing on metrics relevant to the income statement and underlying balance sheet such as revenue and cost of goods sold.
6. Then, using ICBC's existing credit rating model, they calculated the credit ratings of the stressed enterprises (adjusting the qualitative input by the same amount of change as the quantitative input change) and derived fresh probabilities of default. Finally, these probabilities were converted into potential non-performing loan ratios.
7. The results showed that under all scenarios, the thermal power production industry experiences significant cost pressures, but ultimately remains stable given the steady growth of the economy and the huge demand for electricity. However small- and medium-sized enterprises will be under most stress, confronted with "obvious financial pressures".
8. For the cement industry, the analysis finds that raised environmental standards will impose relatively obvious financial pressure on the cement industry, seeing it enter a low-growth stage by and large, with continued pressure to reduce capacity.

**Impact on decision-making:**

- The analysis could lead ICBC to conclude that it should continue its focus on banking AAA-rated customers and strategically target new business from similar quality customers as a priority.
- ICBC could also conclude that for customers with credit ratings of AA+ and below, it will need to enhance its scrutiny of the impact of environmental protection policy on these customers' financial performance.
- Finally, ICBC could use the analysis to renew its focus on seeking out opportunities to finance companies that are developing solutions to challenges such as air pollution in heavily affected industries.

**Key challenges identified:**

- The availability and accuracy of company-level data was a key challenge faced by ICBC in developing this methodology, so there is a need for more consistent and transparent data, driven by the authorities.

**Potential next steps:**

- ICBC plans to expand its stress testing analysis to cover other heavily polluting industries such as iron and steel, nonferrous metals, chemical and papermaking.
- It also plans to expand the factors it builds into its scenario analysis, such as carbon pricing and carbon trading, and is considering using such analysis to build an index of environmentally rated companies to encourage greater financing of companies with lower environmental impacts or environmental solutions.

### 3. Germany: Using scenario-analysis to assess the impact of different carbon and energy regulation in equity analysis

<b>Organisation:</b>	Allianz Global Investors and Allianz Climate Solutions
<b>Geography:</b>	Germany, with international application
<b>Financial sector:</b>	Investment
<b>Environmental source of risk:</b>	Transition
<b>Tools or approach used:</b>	Firm-level modelling of carbon- and energy-regulation under different scenarios
<b>Motivation:</b>	Evaluation of carbon risk in equity analysis and valuation

**Executive summary:** This institutional investor has developed, with partners, a methodology for modelling the impact of different carbon- and energy-regulation scenarios on the margins of individual carbon-intensive firms so as to support improved stock picking.

#### Approach:

1. Working in close cooperation with a specialist partner, the investor initially developed this scenario-based model and piloted it on the dairy and cement industries in Germany, the United States and China. These sectors were chosen because of their carbon intensity, weighting in the MSCI index and typical investor exposure. It has now worked with other institutional investors via CISL's Investment Leaders Group<sup>2</sup> to apply the same methodology to the oil refining, gas production and electric utility sectors in Spain, the United Kingdom and Canada.
2. Most climate risk analyses for investors are focused at the sector- rather than company-level, which does not support stock picking so ably. The model therefore quantifies regulatory risks at the company-level. It targets an individual company's direct emissions and energy use, instead of emissions along the value chain (scope 3 emissions).
3. Two regulatory scenarios for 2020 were defined to allow for an easy interpretation, communication and validation of results. One scenario, the 'Transition Scenario', comprises regulations or regulatory changes that have been discussed in the course of election campaigns, are within a legislative process or have already been confirmed as coming into effect by 2020. The other scenario, the '€45 Carbon Price Scenario', builds in a €45 price on carbon, based on the median Intergovernmental Panel on Climate Change (IPCC) carbon price assumption for achieving a 2°C world.
4. Carbon regulations as well as energy regulations are captured, because governments can use levers beyond the introduction of a carbon price to introduce a

2 [www.cisl.cam.ac.uk/investment](http://www.cisl.cam.ac.uk/investment)

climate-positive change in the real economy. The focus of the model is on individual countries due to a fundamental modelling assumption that regional differences in production technologies and markets are so profound that a global modelling of sector risks may produce highly misleading results.

5. Data for the modelling was sourced from public sector and industry reports as well as via direct company engagement. The modelling is dynamic in that it captures each company's potential for mitigating the regulatory risk. It thus provides a risk assessment arising from the chosen regulatory scenario before any company action and a risk assessment after each company had the opportunity to react.
6. The assumption behind the model is that existing equity analyses do not fully integrate multi-factor, interdependent stress-testing capacity for energy and carbon regulations and their company- (and thus also country-) specific impact before and after risk mitigation in a 2020 timeframe. Thus, the aim of the model is to provide additional insights for this specific area, and to allow for easy integration of the findings into the existing valuation models.
7. One of the outputs of the model is the impact on company margins arising from regulatory changes before and after company risk mitigation. This is useful as impact on company margin can be integrated into valuation assumptions and peer group analysis.
8. Not only do the results reveal material impacts on company margins but, more importantly, significant differences between individual firms in the same sectors or geographies are demonstrated. This is because the model takes into account factors such as their ability to adapt and respond to the carbon or energy regulation that is introduced. This underscores the importance of granular, bottom-up analytics for those trying to understand firm-level risks.

**Impact on decision-making:**

- The tool is currently still under development. Once the development is complete, it is envisaged that the tool would be used by fundamental analysts and fund managers for equity analysis and stock selection.

**Key challenges identified:**

- Current data disclosure by companies is inadequate compared to investor requirements.
- The scope of the analysis is currently limited to a few markets for country operations and is therefore not representative of full company exposure necessary for valuation purposes.

**Potential next steps:**

- Extend model to include entire company operating footprints.
- Extend analysis to a representative sector peer group to facilitate benchmarking and comparative analysis.

## 4. India: Measuring and managing an Indian bank's exposure to natural capital risks

<b>Organisation:</b>	YES BANK
<b>Geography:</b>	India
<b>Financial sector:</b>	Investment
<b>Environmental source of risk:</b>	Physical and Transition
<b>Tools or approach used:</b>	Trucost's environmentally extended input output model (EEIO) and the India Natural Capital Model, commissioned by GIZ and BMZ
<b>Motivation:</b>	Assess potential new and emerging credit risks

**Executive summary:** YES BANK, Chair of the Steering Committee of the Natural Capital Declaration (NCD), is cognisant of financial risks as a result of loans/investments with natural capital impacts. In the context of a study commissioned by the German Development Corporation (GIZ) on behalf of the German Ministry for Economic Cooperation and Development (BMZ), the bank engaged Trucost to understand these risks and potential opportunities. The recommendations suggest a need for more data on natural capital risk exposure and working with clients to address these risks, amongst others.

### Approach:

1. Trucost used its environmentally extended input output (EEIO) model to put a monetary value on environmental and social impacts in India so that they can be integrated into decision-making in a more effective way. Natural capital costs at the sector level were then mapped to YES BANK's sectoral distribution of loans and advances, covering 47 per cent of the bank's loans and advances as of March 2015.
2. The EEIO model integrates data concerning the use and emissions of over 700 environmental resources across more than 500 business activities, prices each environmental resource, and assesses, in financial terms, the economic and environmental performance of each sector.
3. Trucost used the EEIO model to quantify the natural capital costs of 50 economic sectors in India identified as being relevant to the financial sector through shareholdings and lending data of the Reserve Bank of India (RBI). These include sectors such as: coal-fired power generation, iron ore mining, textiles manufacturing, food processing and agricultural sectors such as cotton, wheat and rice farming. For each sector, the natural capital costs associated with six key environmental impacts were calculated: GHG emissions, land-use conversion, water consumption, waste, water pollution, and air pollution.

4. The exposure of banks to these natural capital costs was calculated by mapping the amounts of money loaned to those sectors and regions. This can be used to assess the potential magnitude of the natural capital risk in a bank's loan book. For ten of the sectors the study also calculated the different natural capital impacts across six regions of India as the same activity can have different impacts depending on the geographical location.
5. After quantifying the overall natural capital costs generated by a sector, a framework was developed to identify the drivers that can lead natural capital cost internalisation for a company. Natural capital costs represent the cost to society from a company's use or impact on unpriced natural capital. This social cost is often not paid by companies but can be internalised through mechanisms such as 'polluter pays' regulation, resource depletion, removal of subsidies, reputational damage and changing consumer preferences. The final step involved assessing the potential for a company's natural capital risk to be translated into a risk for an investor or financier.
6. The technique puts a monetary value on environmental and social impacts so that they can be integrated into decision-making. Financial institutions can use the environmental key performance indicators (EKPI) identified by the natural capital approach as a basis for integrating this cost dimension into their risk assessments, lending decisions and risk strategy.
7. To date, most approaches to incorporating environmental and social risk (such as sustainability indices) focus on assessing company policies and management with regards to environmental and social risks. The natural capital valuation approach supplements the ESG analysis with economic valuation of environmental inputs. This allows for consideration of environmental externalities in financial analysis of companies, and the potential impacts on financials and credit risk. The quantification of environmental risks in monetary terms enables their aggregation at portfolio level. A financial institution can therefore stress test its portfolio for specific environmental risks and adjust its asset allocation strategy according to environmental risks.

#### Key challenges identified:

- The India Natural Capital Model estimates that the unpriced natural capital costs apportioned to the loans and advances of YES Bank are INR 1,226 billion, compared to investments analysed of INR 357 billion. The bank's Natural Capital Exposure (NCE) ratio is 3.4, higher than the industry benchmark across commercial banking of 2.9. This means that per INR million of credit disbursed, YES BANK is financing over three times the natural capital costs generated by these sectors.
- Agriculture accounts for 15 per cent of YES Bank's loans and advances compared to 13 per cent of total industry commercial bank lending. This is in line with the development goals of the RBI which requires banks to make the agriculture sector a priority with advances equalling 18 per cent of adjusted net bank credit or an equivalent amount of off-balance sheet exposure (whichever is higher). Yet, the industries with the highest natural capital intensities in India were agricultural industries such as cotton farming (NCE ratio of 12.9) and wheat farming (10.5) due to the significant use of direct water for irrigation. The sector accounts for 78 per cent of natural capital costs within YES Bank's loan book compared to 71 per cent for the commercial banking industry as a whole.

**Impact on decision-making:**

- While one recommendation suggests a reduction of advances to agriculture and allied activities to 12.5 per cent of total loans, it may go against the RBI's development goals and hence working with bank customers to ensure natural capital risks are mitigated is seen as the best way forward.
- With this in mind, it was noted that YES BANK needs to apply best practice risk management strategies to loans in the agriculture sector. The bank is actively considering developing the capacity of farmers for climate resilience, encouraging climate-smart agricultural practices by promoting drip irrigation clients to farmers to reduce water stress.

## 5. International: Integrating the impacts of climate change into sovereign debt ratings

<b>Organisation:</b>	S&P Global Ratings and Swiss Re
<b>Geography:</b>	Expertise from across Europe, applied globally
<b>Financial sector:</b>	Insurance and credit rating agencies
<b>Environmental source of risk:</b>	Physical
<b>Tools or approach used:</b>	Probabilistic modelling, with sovereign credit risk analysis
<b>Motivation:</b>	Investigation of possible credit and market risk

**Executive summary:** Credit rating agency S&P Global Ratings worked with global reinsurer Swiss Re to assess the impacts of natural catastrophes today and aggravated by climate change, specifically tropical cyclones and floods, on the creditworthiness of sovereigns (S&P Global Ratings, 2015).

**Approach:**

1. S&P Global Ratings combined its economic modelling capabilities with Swiss Re's abilities to model natural catastrophes and climate change impacts. Specifically, Swiss Re was able to help S&P Global Ratings assess the contribution of climate change under a pronounced greenhouse gas emission scenario to estimates of economic loss from natural catastrophes for individual sovereigns.
2. As is now common throughout the insurance industry, Swiss Re uses probabilistic modelling to move beyond the limitations of modelling the impacts of just one natural catastrophe scenario. Probabilistic modelling uses simulations of a variety of events that could unfold within a given period of time to produce a spread of event damages that more accurately reflects the impacts of all the events that might occur.
3. In this case, the analysis was limited to assessing the direct impact of tropical cyclones and floods (as opposed to other natural catastrophes known to be exacerbated by climate change, such as drought) on property and infrastructure.

The knock-on effects on economic growth because of secondary effects on productive capacity or supply chains are modelled in the sovereign credit risk analysis.

4. The analysis compared the impact of natural disasters whose severity would be expected to occur once every 250 years under current climatic conditions with their impact under an extreme climate change scenario, whereby the damage potential of those natural catastrophes is materially increased.
5. Based on a sample of 38 sovereigns and 44 natural catastrophe events, the modelling shows climate change increases the expected 1-in-250 year damage-to-value ratio significantly, on average by about 25 per cent. The negative ratings impact of the catastrophes due to climate change increases accordingly, on average by about 20 per cent compared to a scenario not including climate change.
6. However, important differences exist among the sovereigns covered. In terms of geographical differences, the average potential direct damage for all the perils considered in this study is the highest for sovereigns in Latin America and the Caribbean, followed by Asia-Pacific. In terms of ratings, the hypothetical ratings for worst affected sovereigns could decline by almost two notches as a result of these climate change impacts.
7. Advanced sovereigns also see significantly raised potential direct damage from climate change, but are thought to be more able to adapt and respond, meaning the impact on creditworthiness through this channel is negligible.

**Priority challenges identified:**

- Limited data availability. The analysis had to omit drought and some other hazards related to climate change, despite the impact they can have on lives and economic activity, especially in low-income developing sovereigns with important agricultural sectors, because of lack of direct damage data to feed into the climate models. Many of the 130 sovereigns that S&P Global Ratings currently rates could therefore not be included.
- Time horizons. This analysis has focused on extreme events, expected to only happen once in a 250 year period. While the impact of such an eventuality has been shown in some cases to be material, the likelihood of such an event happening within the ratings horizon (5–10 years) is considered small. This assessment could be informed by close monitoring of indicators to signal whether certain climate change scenarios are in fact unfolding.

## 6. International: Integrating water stress into corporate bond analysis

<b>Organisation:</b>	Financial institutions from Colombia, Mexico, Switzerland and United States, led by GIZ (the German development agency), the Natural Capital Declaration and VfU
<b>Geography:</b>	Global
<b>Financial sector:</b>	Banking and Investment
<b>Environmental source of risk:</b>	Physical
<b>Tools or approach used:</b>	Stress test
<b>Motivation:</b>	Understanding credit and market risks from water stress

**Executive summary:** In an innovative project design seven financial institutions, GIZ, the German Association for Environmental Management and Sustainability in Financial Institutions and the Natural Capital Declaration (NCD), which is jointly managed by the UN Environment Programme Finance Initiative and Global Canopy Programme, have developed a new financial model to incorporate water stress into corporate bond analysis (GIZ, NCD, VfU. 2015). The model calculates shadow water prices, estimates their impact on recalculated financial ratios for individual companies and conducts scenario analysis of the impact of three potential water stress scenarios on 24 companies from the power, mining and beverages sectors.

### Approach:

1. Water-intensive companies may experience higher than anticipated costs or more volatile production in operations in areas facing high levels of water stress. Water stress can be understood as when the ratio of total domestic, industrial and agricultural water withdrawals in a catchment in a given year are high relative to the total available water.
2. In an innovative project design that included seven banks and investment managers (Bancolombia, Banorte, Calvert Investments, Pax World, Robeco, J Safra Sarasin and UBS), GIZ, the German Association for Environmental Management and Sustainability in Financial Institutions and the NCD have developed a new financial model to incorporate water stress into corporate bond analysis. Using newly available data from the World Resources Institute on water stress, the Corporate Bond Water Credit Analysis Tool enables banks and investors to systematically integrate water stress into standard financial analysis of companies, which can be used to inform engagement programmes, provide enhanced due diligence and support portfolio reviews.
3. The analysis used a total economic value framework, which attempts to capture both the public benefits that water provides with the private benefits enjoyed by water consumers. The framework estimated the value of water services, such as the value for agriculture, domestic supply, human health and environmental services. The sum of these values is then equivalent to the shadow water price.

4. There are two further independent variables that drive the calculation of the shadow water price: water stress and population size within a 50km radius. Areas that have high levels of water stress and are densely populated will have relatively high shadow water prices, reflecting expectations of increased costs to secure supplies and greater competition for resources. The resultant shadow price is an upper bound with which the model gauges the magnitude of direct potential exposure for the company as well as tests companies' financials against such a price. The market price may not reach the shadow price, however the costs of water constraint can be internalised via a variety of alternative mechanisms.
5. To illustrate the efficacy of the model, analysis was undertaken on 24 companies, eight each from the mining, power and beverages sectors. The Excel-based model is applied to investigate how these firms' credit ratios could be impacted by water stress, based on the potential costs associated with their water use under current and projected water supply conditions.
6. The model then assesses potential implications of three scenarios for the 24 analysed companies. The first scenario is on the exposure to current water stress: firms pay the 2010 shadow prices in 2014, 2015, 2016 and 2017. The second scenario is on the exposure to future water stress: firms pay the 2040 shadow prices in 2014, 2015, 2016 and 2017. And the third scenario is business as usual without water stress: Companies do not face the shadow price of water. In all three scenarios, the model assumes that the companies see their annual revenues grow by 3 per cent per year, and their annual cost of goods sold rise by 2 per cent per annum. It also assumes that water use grows at 2 per cent per annum and, where applied, water prices grow at 3 per cent per annum. Scenario analysis models the impact of shadow water prices on the financial ratio projections for the firms under scenarios 1 and 2 in comparison to scenario 3. The study then estimates the impact of the scenarios on the 2017 net debt/EBITDA ratio of the 24 companies.
7. The model then calculates company credit ratios before and after integrating the shadow price of the water used at their production locations. For some firms, the integration of the full value of water use that takes account of scarcity and population factors has the potential to have a significant impact on their credit ratios, which could lead to a rating downgrade and an adjustment in the value of their bonds.
8. When the model introduces water as a factor into the credit analysis of companies, the two parameters that determine estimates of how a firm's credit is impacted are the amount of water the firm uses, and the shadow prices that the firm faces for water depending on the locations in which it produces. These factors, coupled with the financial strength and business risk profile of each company determine the extent to which firms are impacted by water stress in the model.
9. The study analyses individual company water use and performance for each sector (mining, beverages and power) and chooses three companies that are most vulnerable to water risk: Barrick Gold, Sempra and Femsa. For these companies it then selected relevant US denominated bonds and charted the bonds in terms of modified duration versus yield. If water risk was translated into higher water-related expenditure or restricted access to water, these firms would be at risk of credit downgrades, and these bonds at risk of a sell-off. In a sell-off, the study would expect not only that the yields on these bonds would rise, but that their yield curves would steepen.

**Impact on decision-making:**

- The Corporate Bonds Water Credit Risk Tool presented in this study is of most immediate interest to credit analysts and portfolio managers working in the bond markets, both on the sell-side for banks or on the buy-side for asset managers or hedge funds. Credit analysts can use the tool to cover companies, which are not analysed in this study, or to extend the analysis to other water dependent sectors. The tool can also be used by other debt market professionals working in origination and syndication to analyse the potential impact of water scarcity on their issuer. Alternatively, rating agencies or companies themselves might use the tool to consider the potential impact of water stress on credit ratings.
- Environmental, Social and Governance (ESG) analysts and service providers can use the tool to identify firms “at risk” from water stress, firms with whom they could engage to encourage stronger disclosure and management practices around water.
- Bloomberg LP has included the shadow water prices that were developed through this project into a Water Risk Valuation Tool (WRVT) that it created in collaboration with the NCD and sponsoring partners Bloomberg Philanthropies to analyse water risk in mining equities.

**Key challenges identified:**

- Lack of availability of company data on site-specific water use.
- Complexity of modelling different response options (increasing water efficiency, building a desalination plant, relocating production) in a global tool.
- Complexity of taking into account impact of water infrastructure (e.g. water being pumped into the region from a different water basin/reservoir) in different geographies.

**Potential next steps:**

- Building on the success of their project to create a tool for the incorporation of water stress into corporate bond analysis, GIZ and the NCD are jointly leading a project with banks from Brazil (Caixa Econômica Federal, Itaú, Santander), Mexico (Caixa Econômica Federal, Itaú, Santander), China (Industrial and Commercial Bank of China (ICBC) Ltd), the US (Citigroup) and Europe (UBS) to develop a stress testing methodology for drought scenarios. They have contracted the risk modelling firm RMS in cooperation with the University of Cambridge and the University of Oxford. The aim of the project is to develop an analytical framework that enables banks to assess how drought impacts can affect the financial soundness of sectors they are lending to and hence their corporate lending portfolio.
- Specifically, the intention is to develop five probabilistic drought scenarios covering a 5 year period (2017–2021) for each of four focus countries (Brazil, China, Mexico and the United States). An exposure modelling tool will incorporate direct, indirect (for example through value chains) and macroeconomic effects of drought on 8–12 industries in each country. Finally a framework that applies the exposure model to stress banks’ corporate lending portfolios for sensitivities to drought will be developed. As a result, drought impacts will be linked to corporate credit quality indicators that can be added to banks’ internal stress test models.

## 7. Italy: Using stress testing and ratings models to align risk analysis with a 2°C climate scenario

<b>Organisation:</b>	UniCredit SpA
<b>Geography:</b>	Italy
<b>Financial sector:</b>	Banking
<b>Environmental source of risk:</b>	Transition
<b>Tools or approach used:</b>	Stress testing and rating models
<b>Motivation:</b>	Aligning risk analysis with the transition to a 2°C economy

**Executive summary:** UniCredit is developing advanced risk models to understand how a 2°C compliant world would affect its lending portfolio. As the likelihood of a broad shift towards climate friendly regulations is increasing, the bank addressed the issue of how creditworthiness of customers would be affected by such a shift.

### Approach:

1. At the client level, UniCredit developed a prototype model to include a carbon component in its rating assessment, building on its credit rating model which already incorporates environmental factors. To do this, it used carbon abatement costs in Euros per Euro of economic value added (EVA) of a sector, devised by an external consultancy provider. This indicator is a measure for the relative financial burden a sector is facing as a result of climate change. At a counterparty level there are two ways in which the outcomes of the climate change risk assessment can be taken into account in the general risk management system: first, the results can be used to override the outcomes of the bank's internal financial rating process of a counterparty; second, the assessments of climate change risks faced by counterparties can be factored into the pricing of products.
2. At the portfolio level, UniCredit has conducted an inventory of externalities associated with its financing activities. In 2013, the bank launched a pilot project aimed at quantifying in monetary terms the impacts of pollutants generated by the construction and operation of coal fired power plants financed by the bank. These have been assessed for their impact on human health, ecosystems, climate change and reserves of natural resources. In 2014, the analysis was further extended to emissions intensive industries, such as those monitored under the EU Emissions Trading System (EU ETS). The project aims to develop a methodology to analyse external costs of investments not captured in traditional profitability assessments. No assumptions have yet been made about whether these costs are likely to be 'internalised' in the near future; the exercise simply sought to make such costs better understood.
3. UniCredit has also run a simplified carbon stress test for the same portion of its portfolio, based on different carbon price scenarios, to assess the impact on corporate revenues. The potential impact on clients' risk profile was assessed, as

measured by probability of default. Carbon prices were taken from the United States Environmental Protection Agency (EPA) and other US federal agencies to measure the social cost of carbon (SCC), which is an estimate of the economic damages associated with increases in CO<sub>2</sub> emissions.

#### **Impact on decision-making:**

- At present the models need further refinement. Within the Group Environmental and Social Council there is a constant review of environmental factors on a qualitative basis and the bank is currently working to identify ways to fully incorporate these elements into its current risk management framework.

#### **Key challenges identified:**

- No single stress driver is able to substantially affect risk management processes within short timeframes. While there is an increasing understanding of the materiality of environmental risk, and transition risk in particular, there are many elements to be considered simultaneously.
- The dependencies between a specific environmental event or a broad scenario and portfolio risk are not clear.
- Some of the environmental triggers are hidden in market price dynamics, thus making them largely invisible and difficult to include in analysis.
- Data sets are not uniform and comparable and thus they provide an insufficient market signal.
- Even if data were more accurate and comparable, it would still be difficult to segregate high risk activities for a single counterparty, unless an accurate and complete Life Cycle Analysis is done for each of the companies considered in the model. In current market conditions, that would be too an expensive exercise for both the bank and the counterparty.
- Finally, notably in the case of climate change but more broadly when analysing the impact of externalities, there is a strong need for policy clarity; the “political will” is still a key element to define a clear pathway to a 2°C world.

#### **Potential next steps**

- UniCredit is still watching closely other industry efforts to develop such methodologies. As a signatory to the Natural Capital Declaration, UniCredit will road test models developed. Meanwhile, the bank will continue to develop internal models and solutions, based on several quantitative methodologies and improved sets of data.
- UniCredit welcomes potential public-private joint efforts to develop meaningful and effective disclosure standards, and advanced risk management methodologies to address environment-related risks.

## 8. The Netherlands: The Dutch Central Bank's review of sectoral exposure to the transition away from a high emission energy system

<b>Organisation:</b>	Dutch Central Bank: De Nederlandsche Bank ('DNB')
<b>Geography:</b>	Netherlands
<b>Financial sector:</b>	Banking, Investment and Insurance
<b>Environmental source of risk:</b>	Transition
<b>Tools or approach used:</b>	Regulatory strategic review, supported by industry exposure data
<b>Motivation:</b>	Analysis of sector wide vulnerability to transition risks

**Executive summary:** DNB has conducted a fact-finding and analysis exercise on the exposure of the Dutch financial sector to the risks of the transition away from a high emission energy system.

### Approach:

1. A study group was organised within DNB to analyse the financial sector's exposure to the transition away from a high emission energy system. Members of the group included experts in both financial institution supervision and financial stability. The focus of the group was on carbon intensive sectors, including both fossil fuel producers and energy intensives.
2. The study group conducted qualitative interviews with a number of Dutch banks, pension funds and insurance companies to assess their views on energy transition risks and their approach to managing them. Sector leaders and a range of other experts were then invited to an expert seminar hosted by DNB to discuss the issues raised through the interview process.
3. The study group initiated a data request to map financial institutions' exposure to a number of emissions intensive industries across a range of asset classes and the profile of that exposure. Industries in scope included oil and gas, utilities, basic industry (chemicals, cement, metal, paper/ wood), transport, agriculture and residential property, and the data request included the duration and seniority of loans. Moreover, investments in a number of selected countries with high exposure to oil and gas were included. The data were aggregated to estimate the total assets exposed to transition risk under the scenario of an abrupt transition.
4. Results of the study<sup>3</sup> were published in 2016. It observed that the exposure of different financial industries to both fossil fuel and carbon intensive industries is not insubstantial (9.7 per cent of total assets for the banks surveyed, 4.5 per cent for the insurers and 12.4 per cent for the pension funds). Some early indications of material

<sup>3</sup> Schotten, G., Ewijk, S.E., Regelink, M.G.J., Dicou, D., Kakes, J.I. (2016). *Time for Transition – an exploratory study of the transition to carbon-neutral economy*. DNB.

exposure by banks and pension funds to real estate with mediocre to poor energy efficiency performance were also flagged as a risk should stricter energy efficiency requirements render such assets impossible to let or sell; 43 per cent of the real estate collateral for which the energy performance is known (a total of €171 billion) has an energy performance rated as D to G. At this stage, however, the study was unable to draw firm conclusions about precisely which vulnerabilities may arise during an abrupt transition.

#### Priority challenges identified:

- Limited data availability. As reporting is voluntary, data on the exposure of companies to carbon and related energy regulation is often incomplete.
- Issues with data consistency. Industry classifications vary across different assets and institutions, making it problematic to measure exposure to carbon and related energy regulation in a consistent and comparable manner.

#### Potential next steps:

- Timely and predictable government policy is essential to mitigate the risks of a late and sudden transition. Improving the transparency of climate-related risks through better data availability and measurability will allow monitoring of the risks, and potentially conducting stress tests.

## 9. South Africa: Understanding the impact of climate change on a locality in South Africa

<b>Organisation:</b>	Santam
<b>Geography:</b>	South Africa
<b>Financial sector:</b>	Insurance
<b>Environmental source of risk:</b>	Physical
<b>Tools or approach used:</b>	Scenario analysis and systems models
<b>Motivation:</b>	Assessing potential credit and market risks

**Executive summary:** A strategic research partnership between South Africa's largest non-life insurer, Santam, and academic and civil society experts analysed the complex interactions between changes in a particular region's landscape and natural hazard levels being driven by climate change to distil 'no regrets' actions that can be taken in the short term.<sup>4</sup>

4 [www.unepfi.org/fileadmin/documents/insurance\\_changing\\_risk\\_landscape.pdf](http://www.unepfi.org/fileadmin/documents/insurance_changing_risk_landscape.pdf)

**Approach:**

1. The study was motivated by a desire by Santam to understand practical risk reduction activities that could be undertaken in the face of increasingly volatile and seemingly unpredictable losses from climate-related natural hazards. The Eden District Municipality of South Africa, situated on the south-eastern coast of the Western Cape Province, between Cape Town and Port Elizabeth, was chosen for this study based on its varied topography, the considerable assets underwritten by Santam, as well as the volatile weather conditions that the area had experienced in the recent past.
2. Historical data and high resolution climate change simulation models determined that changes to local temperatures were likely to be the most significant changes to climatic conditions for the region.
3. These modelling outputs were then used to produce forecasts of future increases in the frequency or intensity of specific natural hazards such as wildfire, intense rainfall and sea storm, pointing to the role of climate change in increasing the levels of hazard to which the region could be expected to be exposed.
4. However, analysis of historical data relevant to these natural hazards then revealed that local human-induced changes to land cover and the buffering capacity of ecosystems was of equal or greater importance in driving increasing risks, when compared to climate change. For instance, the uncontrolled invasion of alien trees was found to be one of most important historical drivers of wildfires and the destruction of coastal foredunes and hardening of surfaces was found to be an important predictor of, and contributor to, coastal risk.
5. This finding therefore points to a conclusion that the proactive management and restoration of these ecological systems has the potential to offset substantial portions of the future increases in risk driven by climate change. This indicates a series of 'no regrets' risk reduction decisions that can be taken, perhaps offering a solution to the inherent uncertainty and complexity of modelling future climate change impacts.
6. The study also concluded that while models can predict broad changes in the risk landscape, the risks to individual assets are more often than not emergent properties of non-linear and dynamic systems and therefore very difficult to predict on a granular level. Instead, systems models that emphasise explanatory power (i.e. how the system behaves under different scenarios) may be more useful than conventional risk assessment models that focus almost exclusively on predictive power. Such systems models will not provide a single, neat risk probability, but will rather provide a suite of possible risk probabilities based on different plausible scenarios for the main risk drivers. At the least, this approach will deal more explicitly with uncertainty and avoid the false sense of security that may be provided by predictive models. More importantly, these systems models have the potential of focusing actors on the real drivers of risk.

**Impact on decision-making:**

- The study revealed a number of 'no regrets' interventions that could be taken in the short term to mitigate rising levels of risk driven by climate change. Following the study, Santam has partnered with five vulnerable municipal authorities to drive action in this way under the Business-Adopt-A-Municipality initiative.

**Key challenges identified:**

- Increased risks resulting from climate change and ecological degradation pose a shared risk to financial institutions, governments and society; financial institutions are dependent on governments and wider society for the development and implementation of prudential legislation, policies and management systems that are critical to the industry's identification, assessment and management of its risk exposure. There should therefore be a strong incentive for collaboration.

**Current and potential next steps:**

- Santam improves its risk assessment and surveying capabilities of material environmental risk on a continual basis as part of its strategic focus on improving the quality and size of its risk pool, in particular in the personal and commercial lines business unit.
- Santam is expanding its footprint across municipalities through the Partnership for Risk and Resilience Programme. The programme focuses on high risk municipalities and attempts to positively influence risk mitigation and risk reduction initiatives in these municipalities. A total of 54 municipalities have been identified across the country as high risk municipalities. To date the Ehlanzeni and Sarah Baartman districts have been targeted in addition to the initial 5 BAAM municipalities, with the Vaal district identified for action in 2016. Santam will continue with its partnership blueprint working with government municipal structures, inclusive of business, NGOs and community.
- There is a limit to the influence of a single insurer in the market and a broader sectoral approach should have a much more significant impact on the levels of climate risk specific communities are exposed to. The hope is that Santam's efforts will be supported by peers and other organisations in South Africa.
- Measuring the impact on the level of risk on the ground remains a challenge for these type of projects given the number of management and contextual variables present in the broader system, and considering the emergent nature of the projects. This challenge echoes the findings of the UNEP FI Principles for Sustainable Insurance Global Resilience Project two years ago that highlighted the need to standardise metrics describing the costs and benefits of disaster risk reduction activities.
- Building on the lessons learned in the Eden study and subsequent projects, another research initiative is being led by Santam's specialist business unit in partnership with ICLEI, ClimateWise and others, where on a city scale it hopes to understand better how project finance, insurance and infrastructure decisions can be made in a manner that reduces risk and improves resilience. A proof of concept is planned in Dar es Salaam during the second half of 2016.

## 10. Switzerland: Stress testing balance sheet and client vulnerability to climate change risks

<b>Organisation:</b>	UBS
<b>Geography:</b>	Switzerland, global application
<b>Financial sector:</b>	Banking
<b>Environmental source of risk:</b>	Physical and Transition
<b>Tools or approach used:</b>	Top-down balance sheet stress testing as well as bottom-up stressing of targeted sectors
<b>Motivation:</b>	Management of climate-related risks, on behalf of the bank and its clients, as part of a broader climate change strategy

**Executive summary:** In order to manage its own, and its clients', risk derived from both the physical and transition risks associated with climate change, UBS has performed both top-down balance sheet stress testing, as well as targeted, bottom-up analysis of specific sector exposures.

### Approach – top-down:

1. The top-down approach consisted of a scenario-based stress test to assess UBS's balance sheet vulnerability.
2. Leveraging its existing firm-wide top-down stress testing methodology, in 2014 the bank developed a climate change scenario and its related regulatory response to assess the impacts on financial assets, operational income and physical assets.
3. The scenario assumes severe weather events in late 2014 and early 2015 hit Miami, Zurich and China (Guangdong and Hong Kong) and result in governments around the world agreeing to implement carbon pricing mechanisms (tax and trading) at the UN Climate Conference held in Paris in November 2015.
4. The scenario anticipates that these mechanisms will prompt a shift away from coal and other fossil fuels to cleaner alternatives and adversely impact markets and GDP. The exercise sought to understand the implications of increased carbon regulation on sectors that have a relatively low level of protection from transition risks and provided a high-level depiction of the climate change vulnerability of the firm, focusing on financial assets, operational income and physical assets.
5. The methodology was developed in-house and relied on the existing firm-wide stress testing methodology. A multidisciplinary group of specialists designed the climate change scenarios (i.e. severe weather events in certain locations) and used data drawn from some of the most reliable publicly available sources.

**Impact on decision-making:**

- Financial impacts were moderate and in line with other stress scenarios used by the bank, particularly those that foresee an oil shock component. The biggest risk from the regulatory response (i.e. transition risk) was for exposures to large corporates that are most sensitive to shocks in market variables like equity indices. The impact on smaller unlisted companies, including the Swiss corporate portfolio, was limited. The biggest risk from severe weather events (i.e. physical risk) was damage to properties in Zurich due to the concentration of assets owned there. The operational income impact was quite minimal.

**Key challenges identified:**

- The firm-wide stress test framework is based on a macroeconomic model which estimates high-level, top-down changes in portfolio exposures and losses due to shocks in a variety of economic and market variables. As a consequence, financial losses tend to be more significant when portfolios are formed by large corporates that are sensitive to shocks in variables like equity indices.
- Impacts to macro variables appear to be quite muted. A plausible explanation for this is that any increased cost to overall GDP is offset by new investments and expenditures in resilience and adaptation measures to shift to a low carbon economy.
- However, the top-down approach masks the full impact of the climate change scenario to certain sectors with high exposure to climate change risks and it is debatable how existing relationships between the variables used as inputs in our models will shift as a result of climate change. To address these limitations a more targeted, bottom-up approach was executed as a second step.

**Approach – bottom-up:**

6. The bottom-up approach consisted of targeted, forward looking ‘what if?’ analysis.
7. Analysis was performed in 2015 to assess the potential impacts of climate change risks on the oil and gas and electric utilities take and hold credit portfolios of the investment bank. The loan portfolio secured by real estate was also assessed for vulnerability to physical risks.
8. Credit officers performed forward-looking analysis to assess impacts of a long term low fossil fuel price scenario resulting from policies promoting greater use of renewables, enhancing efficiency standards and limiting emissions. The impact on company probability of default was calculated and company-level results were aggregated at the portfolio level to assess changes to expected loss.
9. The vulnerability of loan portfolios secured by real estate in Switzerland (approx. CHF 155bn) and US (CHF 8bn) to physical risk was assessed by mapping the location of collateral in over 6,000 zip/postal code areas against Swiss Re’s CatNet tool, which aggregates a large dataset of observed natural hazards such as wildfire, river and pluvial flooding and tropical cyclones.

**Impact on decision-making:**

- Stress expected loss increases in the oil & gas portfolio are minimal when compared to the size of the credit portfolio. Negligible stress expected loss impact on the electric utilities. The low impacts are believed to be a result of a combination of high quality names (mostly well capitalized companies) in the portfolios and the maturity profile (3–5 years) of the loans.
- For the real estate portfolio, exposure concentrations were identified in hazard prone areas (wildfire, flood, and hail). Swiss Re's CatNet tool indicates considerable climate risk pre-mitigation (i.e. before insurance and adaptation measures are considered). However, there are no material impacts on the firm due to insurance coverage. Further, loan maturity profile is short when compared to the stronger expected physical impact of climate change.

**Key challenges identified:**

- For the oil & gas portfolio, the scenario was built around one factor and level of stress only (low oil and coal prices). In addition, the data required to understand and model transition risks across the value chain was found to be insufficiently detailed and reliable.
- For the real estate portfolio, high data quality and good level of granularity on real estate in developed markets is available from insurance companies. However, the role and response of insurance in the case of growth of mega events, especially as the likelihood and severity of events increase overtime, is uncertain.

**Potential next steps:**

- From both top-down and bottom-up approaches, stress tests suggest no immediate threat to UBS's balance sheet. The bank argues this results from its globally diversified credit risk exposure and risk concentration in the 'clean' Swiss economy; equities being first in line to absorb shocks, with credit portfolios relatively shielded due to short maturity profile and high quality names (well capitalized companies) in the portfolios; and the availability of insurance coverage that protects collateral from the mortgage portfolio.
- To improve its ability to assess climate change risks and integrate them into its existing risk appetite framework, the bank is supporting the work of the Task Force on Climate-Related Financial Disclosure from the Financial Stability Board and is currently working with the Natural Capital Declaration to better quantify climate-related risks.

## 11. United Arab Emirates: Integrating environmental risk into credit approval processes in the Gulf

<b>Organisation:</b>	National Bank of Abu Dhabi
<b>Geography:</b>	United Arab Emirates
<b>Financial sector:</b>	Banking
<b>Environmental source of risk:</b>	Transition
<b>Tools or approach used:</b>	Technology change scenario analysis and integration of environmental and social risk into credit approval process
<b>Motivation:</b>	Impact of unmanaged environmental and social risks on reputational and credit risk in context of growing market focus on such issues

**Executive summary:** In response to research commissioned by the bank into the strategic implications of the transition to clean energy solutions faced by financial institutions in the Gulf, the bank has initiated a wide-ranging process to integrate environmental and social risk assessments into the core of its credit approval process.

### Approach:

1. 2015 was the year in which the bank identified and formed its response to the issues of sustainability, the environment and, specifically, climate change as enduring forces that will shape the business world of the future. Consequently, the bank has a public target to finance, invest and facilitate USD 10 billion of sustainable business within the next ten years.
2. To inform its strategy, the bank engaged with the University of Cambridge and PwC to explore how the Gulf's financial sector can help shape a more sustainable future in the context of new energy solutions. The outcome was published in the 'Financing the Future of Energy' report. This major piece of research highlighted recent developments in the renewable energy sector and how they present an opportunity to the banking and financing industry.
3. The study drew on a model developed by the University of Cambridge called 'Future Technology Transformations in Power' to understand how technology innovations in the power sector diffuse across economies. Scenarios for different combinations of fiscal and industrial policies related to energy technologies were constructed and then modelled against understandings of how new technologies interact with existing technologies in the power sector, given the unique context in which such technologies do – or do not – become adopted by mainstream actors.
4. Overall, the research highlighted important new drivers of strategic risk and opportunities for the bank and triggered a cohesive, three pillar institutional response. A core element of this response is enhanced environmental and social risk evaluation.

5. The bank consequently became the first bank in the United Arab Emirates to adopt the Equator Principles. Building on this commitment, the bank's credit policy has been re-written and the credit application process redesigned such that front-line credit coverage teams will be required to include an evaluation of environmental risks in all credit application processes. Where these are deemed to be of sufficiently high potential risk, the credit files are passed to a central team of specialist analysts.
6. Where transactions are not covered by existing international best practice frameworks, such as carbon based commodity-backed financings, the same central team of specialist analysts will also evaluate the environmental or social risks to which the bank may be exposed, reporting directly to the bank's risk management division with its recommendations of how to proceed.
7. In relation to technology specifically, the importance of the enabling environment (e.g. energy and fiscal policy) for new technologies was reinforced by the scenario analysis carried out. NBAD's commercial efforts are therefore focused on the clean and renewable energy technologies that are currently considered bankable, while a watching brief is maintained on other, potentially disruptive technology breakthroughs.

**Key challenges identified:**

- The bank is focused at present on finalising the corporate architecture with which it will manage environmental and social risks. However, an early challenge has been identified in that the absence of obligatory environmental and social risk evaluation in the wider market or regulatory context means that general awareness about the relevance and potential materiality of these risks is low.

**Potential next steps:**

- As part of its rapidly evolving strategy, the bank is considering developing a range of position statements for particularly high risk economic sectors to offer front office staff clearer guidance on risks beyond the bank's risk appetite and/or minimum thresholds.

## 12. United Kingdom: A scorecard approach to integrating environmental performance into pricing decisions for real estate

<b>Organisation:</b>	Lloyds Banking Group
<b>Geography:</b>	United Kingdom
<b>Financial sector:</b>	Banking
<b>Environmental source of risk:</b>	Transition risks, specifically exposure to sustainability and regulatory risks, across Corporate Real Estate (CRE) lending activities
<b>Tools or approach used:</b>	A scorecard approach to integrating environmental performance into pricing decisions for real estate
<b>Motivation:</b>	Part of bank-wide initiative to integrate sustainability across its client and product mix and mitigate its risk exposure

**Executive summary:** In March 2016, the CRE Lending team at Lloyds Bank launched a new £1bn commitment for commercial real estate green lending to support its clients' sustainability investments, aimed at reducing CO2 emissions from their real estate assets. This initiative is focussed on loans greater than £10m secured against UK real estate or made to UK-based property companies. The product consists of a standard CRE loan but the bank provides margin improvements of up to 20bps in return for the borrower committing to certain green covenants.

By offering a margin discount on green loans, Lloyds Bank aims to support its clients' sustainability programmes, incentivise improved energy efficiency, improve data flow and understanding of risks in its loan portfolio, and catalyse a market for green loans to support growing investor demand for green and sustainable fixed income products such as green bonds.

### Approach:

1. Lloyds Bank is offering discounted pricing on real estate loans where the borrowers can demonstrate strong sustainability credentials and sign up to green covenants around improving the underlying energy intensity of the loan collateral. Its motivation is to improve its tolerances to credit, compliance, reputational and strategic risks.
  - i. **Credit Risks:** Lloyds Bank sees a growing body of evidence supporting the link between energy efficient or sustainable real estate and lower volatility of value or income/cashflow. Environmental issues have been known to adversely impact both these factors. Lloyds Bank believes that good quality data and analysis of sustainability risks at both the property-level and borrower-level can serve as a competitive edge in underwriting and risk management.
  - ii. **Compliance Risks:** Lloyds Bank is alert to environmental regulatory and market changes that also impact on the value and attractiveness of its underlying CRE loan portfolio. For example, Minimum Energy Efficiency Standards (MEES)

regulation may make leases and buildings redundant. Understanding exposure to regulatory and compliance risk is therefore critical.

- iii. **Reputational Risks:** Lloyds Bank's own Environmental, Social and Governance (ESG) agenda is an important part of the Group's 'Helping Britain Prosper' strategy and the bank is keen to ensure it mirrors the requirements and expectation of all its key stakeholders, including clients, shareholders, bondholders, staff and regulators. Real estate contributes a significant amount to the UK's overall carbon footprint and given the size and scale of the bank's activities in this area, incentivising and supporting green improvements for its real estate clients is a priority area of focus. To be showing no leadership on this agenda would represent an unacceptable reputational risk.
  - iv. **Strategic Risks:** Lloyds Bank needs access to capital and is challenged as an institution to demonstrate to its equity and bond holders that it understands the risks across the UK of transitioning to a lower carbon economy. It also sees significant investor interest in green and sustainable assets across the capital markets spectrum. Therefore, a key driver in the Green CRE Loan is in wanting to take the lead in innovating products in order to help spur growth in this essential market.
2. Each potential financing opportunity is run through a bespoke scorecard that assesses the sustainability performance of the underlying loan collateral as well as the forward-looking sustainability strategies of the borrower.
  3. For the former, the bank assesses, for example, exposure to F and G rated Energy Performance Certificates, energy intensity of the loan security portfolio and whether any buildings are certified as efficient (BREEAM or LEED).
  4. For the latter, the bank assesses, inter alia, what data the borrower collects and measures, what it communicates to stakeholders, what strategies it has in place to improve performance, and what targets it sets itself.
  5. Strong scores are granted to loans secured by high BREEAM / LEED rated or low energy intensity buildings, as well as loans secured by 'brownier' assets but where the borrower has specific strategies to improve the sustainability performance of the underlying collateral.
  6. If a borrower hits a sufficiently high score, it is eligible for a loan and Lloyds Bank looks to agree the green covenants that the borrower will need to commit to, in return for the margin discount. Typically these are set in line with the borrower's own sustainability strategies and will include the requirement that the borrower both reports on and delivers energy intensity performance, either through improving brown buildings or maintaining the performance of green buildings.
  7. There are annual reporting obligations on the borrower and performance is monitored and tracked by the bank, with the margin improvements reversed if performance or the green covenants are not complied with.

#### Impact on decision-making:

- The bank's decision as to whether to offer the green loan (rather than a BAU loan) is based on the outputs from the bespoke scorecard, which are a function of both real estate and borrower due diligence.

- The borrower due diligence is wider than what would otherwise be undertaken for BAU loans.
- In drafting and agreeing the green covenants, Lloyds Bank is mindful of needing the underlying assets to be sufficiently 'green' to attract Green Bond investors, if and when the bank decides to issue specific CRE Green Bonds.
- In due course, the data provided both through the initial scorecard/origination diligence as well as the subsequent ongoing monitoring resulting from the information covenants, supports the bank in building a data set which can be used to stress test the assumption that the default rate on green loans is lower than on BAU loans.

#### Key challenges identified:

- Defining what is green in the context of a heterogeneous sector, with different types of assets and borrowers of differing skills and approaches and business models, has been challenging. For example, although there are benchmarks for energy intensity, these are still relatively data-poor with relatively little differentiation across assets by age, type and sector.
- Developing a scorecard to consistently measure these different scenarios has also not been straightforward. The challenge has been to ensure a consistent scoring methodology across all opportunities and to develop a scorecard that has the right weightings in the questions posed.
- Finally, it has been a challenge to agree a set of covenants that represent appropriate reciprocity for the 20bps discount and developing a standardised suite that can be used as applicable across all lending scenarios without having to "reinvent the wheel" for each new opportunity.

## 13. United Kingdom: A realistic disaster scenario of the micro- and macro-economic effects of a global food system shock

<b>Organisation:</b>	Lloyd's
<b>Geography:</b>	UK, global application
<b>Financial sector:</b>	Insurance
<b>Environmental source of risk:</b>	Physical
<b>Tools or approach used:</b>	Realistic Disaster Scenario analysis
<b>Motivation:</b>	Examination of emerging market and credit risk

**Executive summary:** Lloyd's commissioned the development of a scenario of an acute and extreme shock to global food production in order to explore the implications for insurance and macro-economic risk in a manner that has not been done as systematically before (Lloyd's, 2015).

**Approach:**

1. Traditionally, insurance industry discussions have centred on long term pressures to the global food system. However, a sudden disruption could exacerbate these pressures and have dramatic consequences worldwide; in this case, the scenario developed by Lloyd's sees extreme flooding and drought events around the world, driven by a strong warm phase of the El Niño Southern Oscillation, trigger collapses in crop production in a number of regions, resulting in an acute disruption to the world food supply. The interconnectedness of modern food networks allows for this sudden disruption to quickly spread.
2. In keeping with its well-established Realistic Disaster Scenario process, the Lloyd's food shock scenario was developed by experts in the field of food security and economics and peer reviewed by a group of leading academics. Two workshops with insurance industry practitioners were conducted to assess the impacts of the scenario.
3. The shock results in wheat, maize and soybean prices quadrupling to levels seen in 2000, with the price of rice increasing 500 per cent. Food riots break out in urban areas across the Middle East, North Africa and Latin America. The Euro weakens, European stock markets lose 10 per cent of their value for a sustained period, and the US stock markets lose 5 per cent of their value.
4. The scenario includes governmental and international responses to the crisis including measures to combat civil unrest triggered by the rises in food prices. The report also offers four potential alternative responses.
5. Implications for a portfolio of insurance classes of business are discussed, identifying that significant claims across multiple classes of insurance, including (but not limited to) terrorism and political violence, political risk, business interruption, marine and aviation, agriculture, environmental liability, and product liability and recall could all follow. These losses could be compounded by the potential for a food system shock to last for many years. More broadly, the insurance industry may also be affected by impacts on its investment income.
6. The scenario describes a plausible, yet drastic shock to agricultural productivity affecting several regions and commodities. The likelihood of a similar scenario materialising was considered through the peer review process to be greater than the benchmark return period of 1 in 200 years, which means that it warrants serious consideration. The shock for each commodity studied was calibrated based on de-trended Food and Agriculture Organisation data from 1961–2013.

**Impact on decision-making:**

- It is clear that capacity building is required in financial services to enable full consideration of such risks.
- This study has demonstrated that many insurance classes could be affected simultaneously (on the liability side of balance sheet) along with impacts to the asset side of the balance sheet leading to a geared effect.

**Key challenges identified:**

- There are uncertainties in the scenario, arising in part from the difficulty of obtaining accurate data on some key metrics such as global food stocks.
- Furthermore, the ongoing globalisation of food trade networks is exposing the world food system to impacts that have not been seen in the past, and it is unclear how food system shocks cascade through a modern, interconnected economy. The historical information used as a guide for events within the scenario can provide only a partial example of what the reality might be for a present-day food shock.
- Finally, there is uncertainty surrounding the future impacts of climate change, particularly how it might affect the frequency and severity of weather extremes.

**Potential next steps:**

- Encourage development of coupled natural peril, economic and social (systems) models of risk; build in agent based perspective to allow for study of emergent features and system shocks;
- Encourage further academic study of decision-making under extreme uncertainty – stimulate stronger frameworks for incorporation of scenarios into risk frameworks with a focus on eliciting level of beliefs regarding scenario class probabilities.

## 14. United States: Stress testing a US bank's energy clients against regulation and incentives driving the transition away from a high emission energy system

<b>Organisation:</b>	Withheld
<b>Geography:</b>	United States, global application
<b>Financial sector:</b>	Banking
<b>Environmental source of risk:</b>	Transition
<b>Tools or approach used:</b>	Stress testing of specific industry sector client portfolios to determine relative lending client exposure to (i) increased carbon regulation and (ii) market responses to low-carbon transition incentives.
<b>Motivation:</b>	Investigation of potential new credit risk factors, responding to increasing disclosure expectations

**Executive summary:** The bank is focused on the development of a carbon stress testing methodology that models the impact of increased carbon regulation and market responses to low carbon transition incentives on specific industry sector client portfolios. This work is being undertaken to inform decisions about credit risk.

**Approach:**

1. The bank has an existing focus on climate change and carbon regulation since its historical client base includes a significant proportion of energy and natural resources-focused clients. The bank therefore considers itself to be indirectly exposed to the consequences of increasing societal concerns regarding climate change. As scientific evidence and public perception coalesce, additional regulatory or other mechanisms which penalise carbon-intensive industry sectors are anticipated.
2. Therefore the bank has focused its efforts on the development of a carbon ‘stress-testing’ methodology, ultimately to be applied in the context of credit risk decision-making. Developed in-house, the methodology is designed to assist internal credit risk management groups to understand the likely implications of increased carbon regulation on the clients they cover. It also helps management to understand which data sources are available, at both asset and corporate level, to identify which clients within a given portfolio may be impacted more versus their peers (for instance by virtue of their operating locations, position in the value chain or technology base).
3. The data sources used include private sources (e.g. transaction due diligence responses, company data at the corporate level), commercially-available sources (e.g. WoodMac and Platt’s data, which both provide both asset level data) and others sources in the public domain (e.g. communications from governments and government agencies, publically-available research work).

**Impact on decision-making:**

- Carbon stress-related risk is currently a live credit point in credit risk decision-making in specific sectors, principally pure-play coal, and power generation, and in the context of asset-specific financing opportunities. Credit decisions in virtually all cases involve many decision-factors, and a carbon stress-related credit point will feature more or less prominently (or not at all), depending on specific circumstances.
- In the context of capital markets transactions (e.g. debt and equity underwriting), the bank’s focus has been on ensuring carbon-related risks are included in due diligence, and properly disclosed to investors in offering documentation as appropriate.

**Key challenges identified:**

- The main challenge in methodology development has been a lack of data available to support an objective assessment of relative levels of ‘carbon stress’. Data gaps are both absolute, and in addition relate to problems of data quality and comparability.
- Political uncertainty is also a significant factor; the carbon stress testing methodology that the bank has developed incorporates an assessment of how ambitious individual country carbon emissions regulation measures are likely to be. Such assessment is dependent on both continuing political will and in-country resources available to meaningfully progress an announced decarbonisation program.

- Another element of the stress testing methodology considers a particular company's customer base to identify customers who may reduce demand for energy products in a newly carbon-constrained regulatory environment. Depending on the jurisdiction, companies may not necessarily be obliged to disclose who their customers are, or what proportion of company revenues they account for. This limits the ability to assess customer or off-taker sensitivity to carbon regulation.
- Limited visibility of risk management products (e.g. derivatives), contractual terms and other instruments which attenuate price signals adds to the challenge of accurately assessing impact of regulation and commodity price on client business economics and management decision-making.
- Management usually have good visibility of both customer perspectives and government policy direction. Incentives to disclose such details (e.g. in a Management Discussion & Analysis setting), would assist data users in understanding the company's position and business model resilience relative to sector peers.

# References

2°ii. (2016). *Reviewing the Evidence: 10 Questions for the FSB Climate Disclosure Task Force*. Retrieved from [http://2degrees-investing.org/IMG/pdf/2ii\\_fsb\\_taskforce\\_final\\_150216.pdf](http://2degrees-investing.org/IMG/pdf/2ii_fsb_taskforce_final_150216.pdf).

Allianz and WWF. (2009). *Climate Change: Are we past the point of no return?*

Andreeva, N. (2011). *Stress testing in the financial sector*. Cambridge University, Cambridge, UK.

Barker, S. (2013). *Directors' duties in the anthropocene: Liability for corporate harm due to inaction on climate change*, Vol. December.

Basel Committee on Banking Supervision. (1996). *Amendment to the capital accord to incorporate market risks*, January 1996 ed.: 1–54: Basel Committee on Banking Supervision.

Batten, S., Sowerbutts, R. and Tanaka, M. (2016). *Let's talk about the weather: the impact of climate change on central banks*. Unpublished manuscript. Bank of England.

Battiston, S., Mandel, A., Monasterolo, I., Schuetze, F., Visentin, G. (2016). *A climate stress test of the EU financial system*. Retrieved from: SSRN: <http://ssrn.com/abstract=2726076>.

Beilharz, H-J., Rauch, B., Wallner, C. (2013). *Economic consequences of natural catastrophes: Emerging and developing economies particularly affected – Insurance cover is essential*. Munich Re Economic Research.

Bennett, C. (2004). *Dictionary of insurance*. Harlow: Pearson Education Ltd.

BIS. (2005). *Stress testing at major financial institutions: survey results and practice*, Committee on the global financial system: 1–36. Basel: Bank for international settlements.

Brinke, K. (2013). *The Turkish 2000–01 Banking Crisis: Rabobank-Economic Research Department*.

Caldecott, B., & McDaniels, J. (2014). *Financial Dynamics of the Environment: Risks, Impacts, and Barriers to Resilience*, Vol. July: Smith School of Enterprise and the Environment, University of Oxford.

Carney, M. (2015). *Breaking the tragedy of the horizon – climate change and financial stability*.

Chenet, H., Thoma, J., & Janci, D. (2015). *Financial risk and the transition to a low carbon economy: a carbon stress testing framework*, Vol. July: 2i investing initiative.

Christoffersen, P. F. (2003). *Elements of financial risk management* London: Academic Press.

- CISL. (2015). *Unhedgeable risk: How climate change sentiment impacts investment*.
- CISL, & UNEP FI. (2014). *Stability and Sustainability in Banking Reform: Are Environmental Risks Missing in Basel III?*
- Clay, E., Barrow, C., Benson, C., Dempster, J., Kokelaar, P., Pillai, N., & Seaman, J. (1999). *An Evaluation of HMG's Response to the Montserrat Volcanic Emergency, Evaluation Report*, Vol. December: Department for International Development.
- Coburn, A. W., Bowman, G., Ruffle, S. J., Foulser-Piggott, R., Ralph, D., & Tuveson, M. (2014). *A taxonomy of threats for complex risk management, Cambridge Risk Framework*. Cambridge Centre for Risk Studies, University of Cambridge.
- De Bono, A., Peduzzi, P., Kluser, S., & Giuliani, G. (2004). Impacts of Summer 2003 Heat Wave in Europe, *Environment Alert Bulletin*: UNEP.
- De Galhau, F. V. (2015). *Climate change: the financial sector and pathways to 2°C*.
- Douglas, R. (2014). *Integrating Natural Disaster Risks & Resilience into the Financial System*. Willis Research Network.
- Economist Intelligence Unit. (2015). *The cost of inaction: recognising the value at risk from climate change*.
- FEBRABAN. (2014). *The Brazilian Financial System and the Green Economy – alignment with sustainable development*.
- Financial Stability Board. (2015). *FSB to establish Task Force on Climate-related Financial Disclosures*.
- Geneva Association. (2011). *Liability issues related to climate risk*.
- GIZ, NCD, VfU. (2015). *Integrating water stress into corporate bond credit analysis*.
- Gros, D., Schoenmaker, D., Langfield, S., & Matikainen, S. (2016). Too late, too sudden: Transition to a low-carbon economy and systemic risk, *Reports of the Advisory Scientific Committee*, Vol. 6: European Systemic Risk Board.
- Haraguchi, M., & Lall, U. (2015). Flood risks and impacts: A case study of Thailand's floods in 2011 and research questions for supply chain decision-making. *International Journal of Disaster Risk Reduction*, 14(3): 256–272.
- Holland, G. & Bruyere, C. L. (2014). *Recent intense hurricane response to global climate change*. *Clim. Dyn.*, doi 10.1007/s00382-013-1713-0.

Hornbeck, R. (2012). The Enduring Impact of the American Dust Bowl : Short and Long Run Adjustments to Environmental Catastrophe. *American Economic Review* 102 (4), 1477–1507.

King, D., Schrag, D., Dadi, Z., Ye, Q., & Ghosh, A. (2015). *Climate change: a risk assessment*.

Lambert, C., Noth, F., & Schuewer, U. (2011). *How do banks react to increased credit risks? Evidence from Hurricane Katrina*.

Lloyd's. (2015). *Food System Shock – the insurance impacts of acute disruption to global food supply. Emerging Risk Report, Innovation Series*.

McLannahan, B. (2016). Royal Bank of Canada suffers fresh hit from oil collapse, *The Financial Times*.

Mercer. (2015). *Investing in a time of climate change: Mercer*.

Moodys. (2013). *Water scarcity could increase rating pressure on global mining companies*.

Moorhead, R., & Vaughan, S. (2016). *Legal Risk: Definition, Management And Ethics: UCL Centre for Ethics and Law*.

Commission on the Economy and Climate. (2014). *Better Growth, Better Climate: The New Climate Economy*.

OECD. (2012). Financial contagion in the era of globalised banking? *OECD Economics Department Policy Notes*, No. 14, June.

Ploy Ten, K., & Chang-Ran, K. (2011). *Thai floods batter global electronics, auto supply chains*, Reuters.

Prudential Regulation Authority (PRA). (2015). *The impact of climate change on the UK insurance sector: a climate change adaptation report by the Prudential Regulation Authority*, September 2015 ed. Prudential Regulation Authority.

Rockström, J., Steffen, W., Noone, K., Persson, Å., III, F. S. C., Lambin, E., Lenton, T. M., et al. (2009). Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society*, 14(2).

Schmukler, S., Zoido, P., & Halac, M. (2003). *Financial Globalization, Crises, and Contagion*.

Schoemaker, P. (1991). When and how to use scenario planning: a heuristic approach with illustration. *Journal of Forecasting*, 10: 549–564.

Schoemaker, D., van Tilburg, R., & Wiffels, H. (2014). *If saving the world is not profitable: The missing ecological dimension of macroprudential supervision*.

Shimizu, Y., & Fujimura, S. (2010). Accounting in Disaster and Accounting for Disaster: the Crisis of the Great Kantō Earthquake, Japan, 1923. *Accounting History Review*, 20(3).

Sorge, M., & Virolainen, K. (2006). A comparative analysis of macro stress-testing methodologies with application to Finland. *Journal of Financial Stability*, 2: 113–151.

S&P Global Ratings. (2012). *How Water Shortages in Eastern England Could Increase Costs for UK based Utilities*.

S&P Global Ratings. (2015). *The Heat Is On: How Climate Change Can Impact Sovereign Ratings*. November 25. S&P Global Ratings Ratings Services, McGraw Hill Financial.

Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., & Ludwig, C. (2015). The trajectory of the Anthropocene: the great acceleration. *The Anthropocene Review*, 2(1), 81–98.

Stenek, V., Amado, J. C., & Connell, R. (2009). *Climate Risk and Financial Institutions: Challenges and Opportunities: International Finance Corporation*.

Stott, P. A., Stone, D. A., & Allen, M. R. (2004). Human contribution to the European heatwave of 2003. *Nature*, 432(7017): 610–614.

Trucost. (2013). *Natural capital at risk: the top 100 externalities of business*.

UNEP. (2015). *The Financial System We Need – aligning the financial system with sustainable development*.

Verisk Maplecroft. (2015). *The Heat Stress (Future Climate) Index*.

Waters, C. N., Zalasiewicz, J., Summerhayes, C., Barnosky, A. D., Poirier, C., Galuszka, A., et al. (2016). The Anthropocene is functionally and stratigraphically distinct from the Holocene. *Science*, 351(6269).

WEF. (2014). *Integrating Natural Disaster Risk into the Financial System Private Workshop Summary*. Geneva, Switzerland: World Economic Forum.

WEF. (2016). *The Global Risks Report 2016, 11 ed.*

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