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CHANGING COURSE

A comprehensive investor guide to
scenario-based methods for climate risk
assessment, in response to the TCFD

May 2019

Twenty institutional investors from eleven countries, convened by UNEP FI and supported by Carbon Delta, have worked throughout 2018–2019 to analyse, evaluate, and test, state-of-the-art methodologies to enable 1.5°C, 2°C, and 3°C scenario-based analysis of their portfolios in line with the recommendations of the FSB’s Task Force on Climate-related Financial Disclosures (TCFD). The outputs and conclusions of this Pilot are captured in the following report and aim to enhance the understanding and ease adoption of the TCFD recommendations by the wider investment industry.



UN Environment – Finance Initiative is a partnership between UN Environment and the global financial sector created in the wake of the 1992 Earth Summit with a mission to promote sustainable finance. More than 200 financial institutions, including banks, insurers, and investors, work with UN Environment to understand today’s environmental, social and governance challenges, why they matter to finance, and how to actively participate in addressing them.

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Carbon Delta is a climate change data analytics firm that quantifies investment risks for more than 30,000 companies along numerous climate change scenarios. With our Climate Value-at-Risk (CVaR) model we aim to empower financial institutions with the tools necessary to protect assets from the worst effects resulting from climate change and also help identify new, innovative low carbon investment opportunities.

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PERSPECTIVES FROM THE PILOT MEMBERSHIP

We have high expectations for climate-related financial disclosure from the entities we invest in. Participating in the UNEP FI TCFD pilot project and preparing our own disclosure has improved our understanding of the risks and opportunities we face as investors and enabled us to identify next steps to continue to further this understanding. It has also underscored the effort required by entities seeking to provide specific and complete climate-related disclosure to their stakeholders.

ROGER BEAUCHEMIN
CEO | Addenda Capital

As an institutional investor located in an emerging market it was an eye opener to see the level of expertise and deep analysis that is done by our peers worldwide in climate-related risks. This represents, both a challenge since we see the huge gaps that need to be addressed, and an opportunity, because we now know best practice and have identified how participation in the UNEP FI pilot has and can further help us better understand these topics. We at Afore Citibanamex are just in the process of incorporating ESG analysis to our investment processes, and the tools and learnings from this process will be a fundamental resource to our ongoing portfolio analysis and decision-making process.

LUIS SAYEG
CEO | Afore Citibanamex

The planet does not have time for excuses. Investors have a central role to play in moving the world to a low carbon future; this collaboration shows how we can all take better decisions, for our customers and for the environment. Aviva will keep calling for proper disclosure from the companies we invest in, while working with regulators and policymakers to make sure capital markets properly take account of these risks. The cost of doing nothing is far greater than any costs incurred by taking action.

MAURICE TULLOCH
CEO | Aviva plc

Climate change is posing a significant threat across many sectors and regions, and businesses must play a key role in ensuring transparency around climate-related risks and opportunities. To accelerate our climate action, we have adopted science-based emissions reduction targets validated by Science Based Target initiative (SBTi) and climate change scenario analysis based on the TCFD recommendations. These efforts aim to future-proof our businesses by identifying risks for mitigation and adaptation with a view to delivering lasting value for our business, investors, stakeholders and the environment at large. CDL is pleased to be part of the UNEP FI Pilot and will continue to uphold our long-established sustainability strategy and pursuing best practice around carbon disclosure.

SHERMAN KWEK
CEO | CDL Group

The Earth is 1°C warmer today compared to preindustrial levels, and we are already seeing the consequences. The pilot project has been an important learning exercise for international investors, establishing a systematic approach to measuring and mitigating climate change impacts at portfolio level. While further work remains to refine the methodology, it signals to companies that ignoring climate change is no longer an option. Addressing these risks and opportunities will be critical to fulfilling our fiduciary duty to our clients moving forward.

OLA MELGÅRD
CEO | DNB Asset Management

It is not an option to ignore climate risk as it may threaten financial stability and returns over a long period of time. Yet, what KLP has learned about the complexity of assessing climate risk in the pilot project, suggest that we also have a long way to go before climate risk to the financial sector is measured in a manner which is consistent with the TCFD. We therefore hope to continue our collaboration with peers, academics, service providers and other stakeholder, in order to improve the climate risk transparency in financial markets in the years to come.

HÅVARD GULBRANDSEN
CEO | KLP Kapitalforvaltning

As a responsible investor, our goal is to make informed investment decisions. The further integration of climate-related risk metrics into our investment process and reporting documents is a positive step. The Pilot group has been a useful forum to challenge methodology and findings and to learn from group discussions. This report will spread the knowledge to a larger public of like-minded investors and stakeholders.

LAURENT JACQUIER-LAFORGE
Managing Director and CIO Equities | La Française AM

All financial institutions need to understand the risks and opportunities that stem from climate change and the resultant transition to a low-carbon economy. Cognisant of the complexity of this challenge, we see great value in collaborating with our peers in the investment community to develop our collective understanding of the investment implications of future climate scenarios. We look forward to building on these initial efforts and will be using the findings as a crucial first step in stress-testing the resilience of our investments against one of society's greatest challenges.

JOHN FOLEY
CEO | M&G Prudential

One of the key lessons from the pilot was the power and necessity of collaboration to enable investors to respond to climate change. Otherwise, it would take many years for investors to individually experiment with scenario analysis, and for industry best practice to iteratively evolve from that. The recent IPCC report underlined that the planet doesn't have time for that either.

CHRISTOPHER CONKEY
CIO, President and CEO | Manulife Investment Management

Addressing climate change is high on the agenda and Nordea supports the TCFD recommendations and management of climate-related risks. We believe collaboration with other investors and stakeholders will continue to be key in order to further develop methodologies to manage the complex issue of financial implications of climate change. We will continue to promote disclosure according to the TCFD recommendations in our portfolio holdings.

NILS BOLMSTRAND
CEO | Nordea Asset Management

In order for Asset Owners and Asset Managers to produce meaningful climate change disclosures, they will need to collaborate with management of their portfolio holdings to do the same. This is a critical innovation of the TCFD Recommendations, and ultimately the one that will drive robust and comparable reporting on climate change risks and opportunities.

MEREDITH BLOCK
Senior Vice President | Rockefeller Asset Management

The question is no longer why sustainability should be integrated into decision making, but how to further excel it. The UNEP FI TCFD pilot enabled collaboration among peers, highlighting critical questions on how to improve our work. The in-depth discussions within the team have led to a better understanding on what needs to be done to enhance the knowledge on how to integrate climate-related risks and opportunities during decision making.

JAN ERIK SAUGESTAD
CEO | Storebrand Asset Management

Climate change is certainly a risk to portfolios, and clients are increasingly requesting information to better understand that risk. The pilot has allowed us to explore additional tools that aim to quantify the impact of climate risks to portfolios, providing us greater context for ensuring that risk and return parameters are balanced for any investment. Moving forward, we hope that the pilot serves to encourage continued discussion around the strengths and weaknesses of various climate-based scenario analysis methodologies.

BRUCE COOPER
CEO | TD Asset Management

FOREWORD

In 2015, I spoke of the ‘Tragedy of the Horizon’ – the catastrophic impacts of climate change will be felt beyond the traditional horizons of most banks, investors and financial policymakers, who do not have the direct incentives to fix them. Since then, important progress has been made from the Paris Accord to advances in managing the risks around climate change and optimising the returns in the transition to a low carbon economy. For the first time, a path to break this Tragedy is becoming possible.

Institutional investors, as guardians of long-term saving, have the horizons to appreciate climate risks and opportunities and many are developing the skills to manage them. But to appropriately price climate risk and to reward innovation, investors need the right information.

The work of the Task Force on Climate-Related Financial Disclosures (TCFD) is vital to improving the reporting and understanding of climate-related financial risks. Since the TCFD’s recommendations to the G20 Leaders Summit there has been a step change in the demand by investors for better climate reporting. TCFD supporters now manage almost USD 110 trillion on assets.

Momentum behind TCFD’s voluntary disclosure recommendation is creating a virtuous circle by encouraging learning by doing. As companies apply the recommendations and investors differentiate between firms using better information, adoption will continue to spread, disclosure will become more decision-useful, and its impact will grow.

Translating climate models into economic and financial impacts is difficult, even more so for investors who depend on the information provided by firms. Initiatives like UN Environment’s Finance Initiative are invaluable for sharing of good practice—such as in scenario analysis—so firms can make their approach more granular and sophisticated.

Much remains to be done. This report will help us maintain momentum as we continue along the virtuous circle where more companies disclose more information, investors make better informed decisions, and sustainable investment goes mainstream.



Mark Carney
Governor of the Bank of England

FOREWORD

The climate challenge over the next twelve years presents a unique opportunity for coordinated efforts by the private sector to lead a more concerted and systemic change in accounting for environmental externalities and greening business operations. Companies play a critical role in shaping the status of nature and in driving resilience focused action in countries, which affects the well-being of 3.2 billion people.

Successfully meeting the Paris Agreement and Sustainable Development targets is only possible by leveraging private sector finance and increasing investments in activities that can deliver the greatest number of benefits for livelihoods, climate, ecosystems and biodiversity. Better metrics and guidance standards are needed that extend to measuring public benefits as key indicators of corporate performance.

The TCFD framework is such a definitive guide for investors, as well as all other corporate and financial actors in moving towards a circularity oriented lens that can deliver more informed decision-making and support the growth of climate-friendly investments.

Mainstreaming such triple-bottom-line metrics is critical and UN Environment is working with key industry leaders to facilitate access to the framework and the guidance it provides on disclosures. As a part of this process, UN Environment will continue to mobilize partners, especially from financial markets, to deliver positive change by accelerating the alignment of financial systems with the Paris Agreement and climate change goals.



Satya Tripathi

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EXECUTIVE SUMMARY

CONTEXT

Climate change - of about 1°C of warming today relative to pre-industrial times - is already having disruptive effects on economies across the globe, through both its physical manifestations and the mitigation actions aimed at avoiding these. On the physical side, extreme weather events are increasing in frequency and intensity, resulting in severe repercussions for livelihoods, communities as well as, through impacts on operations, supply chains and customers, for companies. Without policy action, these effects will only intensify as the global mean temperature continues to increase (IPCC, 2018). On the transition side, policy and technology shifts have begun to affect the competitive positions of emissions-intensive companies relative to providers of low-carbon alternatives. The Paris Agreement—ratified by 185 Parties—aims to ensure that the increase in average temperatures above pre-industrial levels is kept to ‘well below’ 2°C by 2100 (UNFCCC, 2015). Continued physical climate change and rapid policy action to limit it present investors with potentially unprecedented and uncertain financial impacts that they will need to manage.

The recommendations of the Task Force on Climate-Related Financial Disclosures (TCFD) outline the need for corporate and financial institutions to conduct forward-looking scenario-based assessments of these climate-related risks and opportunities. The recommendation to use scenario-based analysis to assess the long-term effects of climate change aims to ensure that corporate and financial institutions incorporate these effects into strategic decisions. For investors, as both users and issuers of climate-related disclosures, engagement with forward-looking climate-related risk analysis is doubly relevant. In holding large portfolios, most institutional investors face exposure to risk across sectors, geographies and financial instruments, while at the same time financing the development of the real economy. The longer time horizons of their asset and liability management, as well as their exposure to equity and unsecured debt, further highlight the importance of considering climate change in strategic decisions. However, the scope of investors’ exposure to climate change can be particularly difficult to assess given the size and diversification of their portfolios.

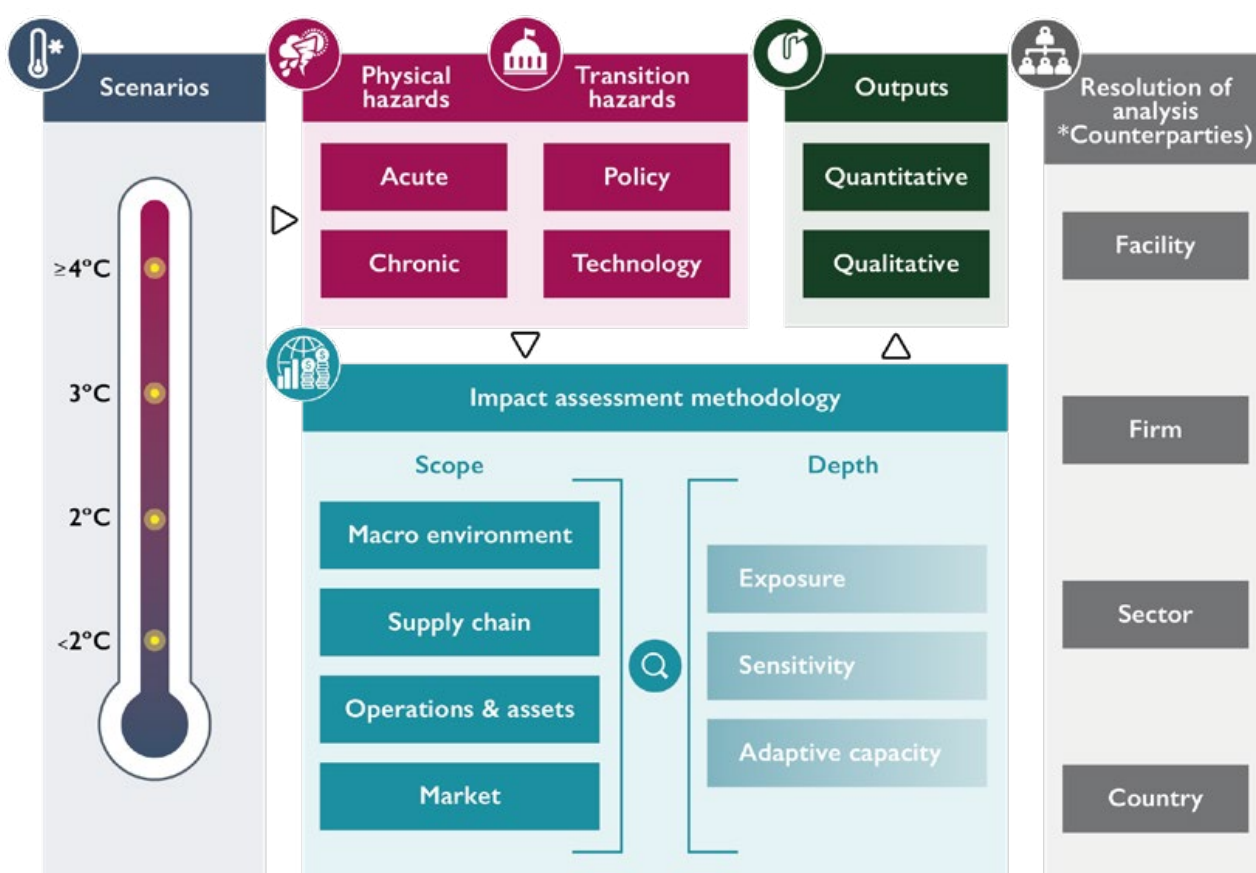
This report details the results of the UN Environment Programme Finance Initiative (UNEP FI) Investor Pilot on TCFD Adoption, a collaborative effort to explore, enhance and apply a methodology for assessing the impact of physical and transition risks and opportunities on the portfolios of institutional investors. The Investor Pilot Group comprises 20 institutional investors from across the globe. This report presents the methodology enhanced and used by the Investor Pilot Group in collaboration with the data analytics firm Carbon Delta. Outputs and evaluations of this methodology are intended as a first step towards understanding the potential for incorporating the TCFD recommendations on scenario-based risk assessment in investors’ financial disclosure. In addition, and in order to highlight the range of methodologies currently available to conduct these types of assessments, the report offers a ‘landscape review’ of other providers’ methodologies for climate-related scenario analysis.

The ultimate objective of the Investor Pilot including this report is two-fold: i) boost investor savviness and ii) support industry-wide harmonisation. The intention of the UNEP FI Investor Pilot is both to comprehensively guide individual investors on how to design and structure the application or use of scenario-analysis within their own institutions as well as to provide a basis from which the investment community can seek to achieve harmonisation and standardisation of investor disclosures so that over time these become comparable.

State of scenario analysis methodologies today

There are a large number of scenario analysis methodologies and providers that offer diverse and continually improving analyses. The overview conducted for this study found many available methodologies, and a vibrant market of service providers to support TCFD-compliant scenario analysis. Many providers share common core methodological elements, drawing on similar datasets, modelling components and methods for financial valuation. However, significant diversity exists, with providers offering different (and sometimes complementary) methodologies for assessing climate-related financial risks and opportunities across various asset classes, scenarios and output formats. As a result, there is already a large set of methodologies to choose from, depending on desired scope, depth and focus of analysis. The analytical framework for assessing methodologies for scenario analysis is outlined in Figure 1, and examines methodologies on the basis of scenarios used (or constructed), physical and transition hazards examined, impact assessment methodology developed, outputs produced and, finally, the resolution of analysis—or counterparties¹ of the risk examined.

Figure 1: Analytical elements of scenario-based impact assessments



Source: Vivid Economics

Building blocks of the Investor Pilot methodology

The UNEP FI Investor Pilot explored, enhanced and applied the Carbon Delta methodology, throughout the Pilot to road-test a ‘Climate Value at Risk’ (CVaR) for listed equities, corporate debt and real estate under several future scenarios. This measure brings together assessment of the physical and transition risks of climate change. On the physical side, the methodology examines the impacts of chronic changes in the climate and acute weather events on companies’ operations using business interruption as a

1. The term counterparty is used throughout this report to refer to entities that investors, through their portfolios, have exposure to and that are more directly affected by climate-related risk. These range from countries to companies and individual facilities/‘projects’. As such, different methodologies examine different counterparties, but may do so using similar methodologies.

proxy. On the transition side, it explores policy risk—the cost for companies from meeting countries’ emissions reductions targets; and green opportunities—the profits for low-carbon technology companies earn from providing the means by which to reduce emissions. These physical and transition impacts are then translated into financial values through financial modelling. The methodology further assesses portfolios against international climate targets to give a temperature alignment: the implied degree of warming of a portfolio.

Comparing Climate Value at Risk across 1.5°C, 2°C and 3°C Worlds

Applying the current methodology—and mindful of the current gaps and assumptions within it—to a ‘Market Portfolio’ that includes 30,000 equally weighted companies, and hence represents the investable market universe, yields noteworthy insights, including:

- **Investors face as much as 13.16% of risk from the required transition to a low-carbon economy:** The 1.5°C scenario, in line with the latest special report by the Intergovernmental Panel on Climate Change (IPCC), exposes companies to a significant level of transition risk, affecting as much as 13.16% of overall portfolio value. Considering that total assets under management (AUM) for the largest 500 investment managers in the world total USD 81.2 trillion, this would represent a value loss of USD 10.7 trillion.
- **It is at the sector level that climate-related risks, including risks from the transition to a low-carbon economy, become acutely apparent.** Utilities, transportation, agriculture as well as mining & petroleum refining sectors stand out as having high policy risk. Under a 1.5°C scenario, the utility sector is most strongly exposed to policy risk (-50.6% at risk), however, the sector contributes less than 10% overall to the portfolio’s climate-related risks. On the other hand, Manufacturing has a much lower risk of -16.5%, but gets the highest portfolio contribution of 46.7%. This highlights the significant variation in climate risk levels between sectors, while also highlighting how diversification can help to reduce these risks.
- **‘Green’ profits in a 2°C world are significant – approximately USD 2.1 trillion.** Addressing climate change and limiting global warming requires economic policies that support a low carbon energy transition. However, green revenues generated from the sale of low carbon technologies, which support the transition, will help companies offset costs from complying with greenhouse gas (GHG) reduction policies. Stronger climate policy therefore also translates into an increased potential for companies to generate ‘green’ profits. Under the 2°C scenario, the sum of all green profits generated by this 30,000-company universe equals approximately USD 2.1 trillion.
- **Low carbon technology opportunities help offset risk.** Aggregated technology opportunities across a portfolio will alleviate losses generated under the 3°C, 2°C and 1.5°C policy scenarios. The portfolio benefits by 3.21%, 6.94%, and 10.74% under these scenarios, respectively.
- **Companies face increased cost, and investors increased risk, if governments act late.** Finally, if governments delay action to enact climate policies that reduce GHG emissions, the 30,000 companies in the universe face a further cost of USD 1.2 trillion as compared to a scenario where climate policy is enacted smoothly and steadily with immediate effect. Furthermore, delayed action not only increases policy risk, but also results in much greater physical climate risk due the increased accumulation of GHG concentrations in our atmosphere.

Implementation case studies

Each member of the Investor Pilot Group was able to analyse at least one portfolio and trial different scenarios—the results of which some investors explore in case studies, organised around two key themes:

- **The first set of case studies represent deep-dives into investors' results from the portfolio analysis, focusing on the unique areas investors chose to explore.** These include the expansion of scenarios to more aggressive physical risk and delayed policy response scenarios (Aviva, Nordea), the non-linearity of risk across different temperature pathways (Manulife Investment Management), and the performance of actively managed portfolios relative to relevant indices (Rockefeller). Another case study from Caisse de dépôt et placement du Québec (CDPQ) examines the importance of considering value chains and non-substitutability of products in risk assessment.
- **The focus of the second set of case studies lies on the potential integration of results in internal processes and external engagement.** Case studies within this focus area examine the benefits of engaging with scenario analysis (Addenda), highlight the interactions between the Carbon Delta methodology and identification of metrics for future real estate assessment (Investa), explore evolving internal risk management processes surrounding climate-related risks (KLP), compare scenario-based results to climate risk signals provided by environmental, social and governance (ESG) data providers (TDAM), draw out the implications for development of internal scenario analysis tools and risk management practices (Norges Bank Investment Management (NBIM), La Française), and elaborate on how institutions intend to concretely utilise the results in engagement with investee companies (DNB).

Members of the Pilot Group highlighted several benefits of collaboratively engaging in the UNEP FI Investor Pilot:

- Considering physical and transition risk together can provide valuable insights into their interactions and result in a more comprehensive and consistent risk assessment for investors.
- The diversity of impacts across different scenarios of policy ambition and intensity of physical impacts emphasises the importance of considering a range of scenarios. This, in turn, makes standardised issuance of investor disclosures that are comparable more challenging.
- The CVaR measure—as one that is an 'extension' of a commonly used, core risk metric—can ease and facilitate internal discussion and harmonization of disclosure by quantifying risk that may previously only have been assessed through ratings and generating more internal interest.
- Some investors, in future engagement with investee companies on the need for disclosure of material climate-related data and risk management, intend to utilise the results of the assessment as supporting evidence of the need for action. However, investors also noted that scenario analysis should not form the sole basis for corporate or investor decision-making.

Future directions

Both the landscape review of methodologies available today as well as the methodology specific to the investor Pilot demonstrate the major innovation and methodological advancements recently made in this space as well as a number of key remaining gaps and areas of improvement:

- Across transition and physical risk analyses, methodologies currently do not cover the entire value chain of the counterparties they examine in depth; neither do they link microeconomic and macroeconomic impacts. Several methodologies restrict analysis to a counterparty's operations and physical assets rather than also considering the impacts of climate change on supply chains and markets, providing only a limited view of the scope of impact. Moreover, no methodologies integrate such microeconomic impacts with impacts on the macroeconomic environment, which could be significant, especially if the policy transition occurs in a delayed and more disruptive manner, or if climate change is unabated. Companies' entire value chains should be considered, from supply chain to market, as well as the broader macroeconomic environment. This would include distinguishing more clearly between Scope 1, 2 and 3 emissions² in order to holistically capture companies' carbon footprints.
- Few methodologies consider physical and transition risk in a fully integrated manner—as outputs of the same modelling exercise—or examine a range of temperature pathways. The type of risk assessed is often linked to a limited range of temperature scenarios. For example, physical risk methodologies often focus on a 4°C 'business-as-usual' scenario, while transition risk scenarios often focus on a 2°C scenario. In reality, both will have important trade-offs and should be considered together; however, the significant differences in how they are modelled present ongoing methodological challenges, resulting in a lack of availability of scenarios which incorporate the trade-offs. To sufficiently capture the interactions between physical and transition risk, analyses should, where possible and relevant, extend beyond the next 10–15 years.
- In general, there is scope for more bottom-up analysis that considers the unique characteristics of the counterparty strategy for managing climate-related risk. Few methodologies incorporate company-specific information on mitigative action taken, key performance indicators (KPIs) set or insurance purchased. Similarly, methodologies should quantify not just the exposure of counterparties to climate change risk, but also their sensitivity and adaptive capacity.
- Critical to further development is overcoming a number of data challenges, especially in relation to corporate reporting of factors affecting exposure at the asset level. Corporate disclosure practice to date not only fails to routinely provide risk assessments that are forward-looking. It also fails to provide information at the level of the physical assets—facilities, plants, infrastructures—owned by the company. Risk exposure, however, will manifest at 'asset level' more so than at the level of the companies as legal entities. The TCFD recommendations can form an important first step towards future data availability by asking both corporate and financial institutions to disclose this type of information.

2. The GHG Protocol (<https://ghgprotocol.org/>) defines three 'scopes' of emissions: Scope 1 emissions are direct emissions from sources that an organisation controls or owns. Scope 2 emissions refer to emissions from purchased electricity, heat or steam. Scope 3 emissions comprise indirect emissions from an organisation's activities, including both upstream and downstream emissions.

In the interest of pursuing these improvements, there is a clear need for better disclosure of climate-related data from investee companies, particularly including a company's individual sensitivity and adaptive capacity. The more granular the data disclosed by investee companies, the more informative scenario-based analysis can be for investors. Analysis to date has relied on sectoral indicators of resilience, such as natural resource dependence and abatement potential. However, these could vary significantly across a sector, and more data on individual companies' sensitivities and adaptive capacity to physical and transition risk is needed. This includes data on individual facilities, such as production sites and real estate, which should cover location, as well as key climate-related characteristics, such as flood resilience, energy efficiency or facility-level emissions. To date, many scenario analysis providers either do not use this type of data or rely on proprietary location databases to conduct facility-specific assessment. If scenario analysis is to become more commonplace, particularly for smaller-scale investors, data on individual facilities needs to be collected and made available more comprehensively.

There remains an open question around the need for standardisation of scenarios, methodologies and outputs of scenario-based assessments. Financial regulators could provide a set of shocks or scenarios they would like investors to use in scenario-based analysis of their portfolios. Alternatively or in addition, thoughtfully-designed transparency requirements of modeling methodologies—rather than full standardisation—could further enable comparability, while reducing the risks of correlated model errors and preserving incentives to improve methodologies. In addition, Investor Pilot Group members agreed that additional guidance on disclosure of climate scenario analysis would help them interpret others' results, be it investee companies or other investors. Output standardisation could also help the interpretation of results by allowing investors to examine the same set of impact measures throughout.

Industry collaboration played an invaluable role in the Pilot project, as investors pursuing their individual interests culminated in a more holistic methodology. Continuous engagement in the pilot methodology advanced investor understanding of scenario-based analysis and allowed investors to collaboratively suggest methodological improvements. For example, over the course of the pilot project, investors highlighted the need for additional scenarios, which resulted in the inclusion of a more aggressive physical risk, as well as a delayed policy action scenario. Pilot Group members further pointed out that using the same methodology as other investors reassured them that results would be comparable and informative in the industry's TCFD reporting. Collaborative investor action—in coordination with regulatory advancements, existing disclosure standards, and other stakeholders—remains a key avenue to achieve fuller standardisation and comparability of investor disclosures in the future.

I. INTRODUCTION

I.1. EMERGING UNDERSTANDING OF LONG-TERM EXPOSURE

Climate change has become a defining challenge of the 21st century, and international consensus is growing that it will be, at best, costly for the economy and, at worst, disastrous for human society. In its special report of October 2018, the Intergovernmental Panel on Climate Change (IPCC) projects an increase from the present 1°C above pre-industrial levels to 1.5°C of average warming between 2030 and 2052 if warming continues at its current rate. Warming of 1.5°C will already pose unprecedented yet potentially manageable climatic challenges to ecosystems and societies. It is further increases from 1.5°C to 2°C—early in the second half of the century—that are expected to lead to fully disruptive impacts, including significant sea level rise, species extinction, increased impacts on human health from heat stress and vector-borne diseases, and higher risks of droughts and flooding (IPCC, 2018). Correspondingly, even if the Paris Agreement is implemented as envisioned and its objectives fully realised,³ the frequency and severity of extreme weather will continue to increase and the chronic, ‘slow-onset’ manifestations of physical climate change⁴ (such as sea-level rise or temperature increase) will continue to unfold. At the same time, corrective policy action itself—aimed both at decarbonising global economic activity and adapting societies to a changing climate—is likely to impose significant uncertainty and costs in key areas of the economy, with those costs likely to rise considerably as action is delayed. Increasingly, the expectation is that *both* physical and transition-related effects will significantly impact economic outcomes.

On the physical side, the increased frequency and intensity of extreme weather events and chronic changes in the climate are already having severe repercussions for companies, be it through their own operations or their supply chains. As warming continues these will only intensify. If companies’ operations are, for example, located in an area frequently affected by hurricanes, they may have their staff evacuated or facilities damaged during an extreme weather event, leading to business interruptions and repair costs. International supply chains will also expose companies to climate-related physical risks across a range of local environments, leading to business interruptions in one part of the world due to extreme weather events in another. A prominent example of the widespread disruption extreme weather events cause are the Thai floods of 2011.⁵ Local impacts were felt across several industries: from car manufacturers such as Honda, Toyota and Ford to Thailand’s rice export industry, one of the largest in the world. In total, the World Bank estimates the damages and economic losses associated with these floods, including on international supply chains, at USD 45 billion (The World Bank, 2012), with 70% of this loss coming from the manufacturing industry. Only approximately USD 12 billion of this loss was covered by the insurance industry (Lloyd’s of London, 2012).

On the transition side, emerging climate policy and low-carbon technologies have already begun to significantly affect companies’ financial performance. Policy action across the world is pushing for a reduction in Greenhouse Gas emissions-intensive activities, particularly in the power and transport sectors. The Paris Agreement requires each Party to prepare, maintain and communicate Nationally Determined Contributions (NDCs) to the

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3. The Agreement aims to keep global warming to 2100 well below 2°C above pre-industrial temperatures. Current Nationally Determined Contributions (NDCs) are only on track for a 3°C rise by 2100 (The Royal Society, 2018).
 4. While the term ‘weather’ describes short-term variation in the atmosphere, ‘climate’ refers to a location’s weather averaged over a period of time.
 5. It is difficult to attribute any individual weather event, including the 2011 floods in Thailand, to climate change (IPCC, 2012). However, the impact of anthropogenic climate change on the increased incidence of such events has been well documented. For example, a 2018 report combining 17 peer-reviewed analyses of extreme weather across six continents and two oceans during 2017 stated that ‘the U.S. Northern Plains and East Africa droughts of 2017, floods in South America, China and Bangladesh, and heat waves in China and the Mediterranean were all made more likely by human-caused climate change’ (American Meteorological Society, 2018).

target of limiting global warming to well below 2°C. These should comprise greenhouse gas emission reduction targets that consider each country's individual circumstances and capabilities. Policy action to fulfil these targets has already begun to affect companies, for instance, as Germany shifts away from nuclear and coal towards renewables, the value of utility companies has fallen significantly: RWE and E.ON recorded market capitalisation reductions of 59% and 65%, respectively, over the period from 2000 to 2015 (Chazan & McGee, 2016). At the same time, low-carbon technology companies recorded significant growth over recent years. In 2017, renewables comprised 61% of all net power generation capacity added globally, with solar alone making up 38% of total growth (UN Environment, 2018b).

Impacts on both the physical and transition sides of climate change will have to be factored into financial decision-making today if a 'tragedy of the horizon' is to be avoided. Mark Carney, Chair of the G20's Financial Stability Board and Governor of the Bank of England, has highlighted that time horizons typically applied by both regulatory and economic actors are too short to be able to fully consider climate impacts, which unfold over the long term (Bank of England, 2015). Fund managers and financial analysts generally have horizons that do not extend beyond the next five years and, as a result, corporate reporting rarely includes forward-looking disclosure beyond that time frame. While financial stability considerations of technocratic authorities like central banks do extend out closer to a decade, these horizons are still insufficient given that the costliest changes to the climate are likely to occur further into the future. Aligning decision-making horizons of financial and other economic actors with the long-term nature of climate change is critical to responding to the impacts of today's economic activities and the effect of climate change on long-term financial system stability.

Going further, the Paris Agreement calls for financial institutions to play an active role in limiting global warming to well below 2°C. Article 2.1(c) of the Paris Agreement aims to strengthen the world's response to climate change by '*making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development*' (UNFCCC, 2015). This calls on the finance sector to play an active role in the pursuit of international climate targets above and beyond focusing on long-term financial stability.

This Agreement [...] aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by [...] making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development."

Paris Agreement, Article 2.1(c) (UNFCCC, 2015)

As a first response from the finance sector to these challenges, the TCFD, chaired by UN special envoy on climate change Michael Bloomberg, published its recommendations for disclosure of climate-related risks and opportunities in June 2017. The industry-led initiative aims to increase transparency around the assessment and management of climate-related risks and opportunities. If unaware or misinformed of the risks and opportunities around climate change, investors and others are likely to collectively misprice assets and systematically misallocate capital, threatening financial stability and profit. The TCFD aims to address the 'tragedy of the horizon' by encouraging investors to conduct forward-looking, scenario-based assessments of the risks and opportunities surrounding climate change. Momentum around the recommendations has grown considerably since the initial publication, with the number of organisations supporting the initiative surpassing 500 in September 2018, including four national governments (Canada, France, Sweden and the UK).

This report details the results of the UNEP FI Investor Pilot on TCFD Adoption, a collaborative effort of 20 institutional investors to develop methodologies for forward-looking, scenario-based assessments of the climate-related risks and opportunities faced by their portfolios. The methodology produces an estimate of the financial value at risk from climate change or 'Climate Value at Risk' (CVaR) under several future scenarios, incorporating both physical and transition-related impacts of climate change, for listed equity, corporate debt and real estate assets. It was co-developed through an iterative process between the investors, the consulting firm Carbon Delta, and external experts convened by UNEP FI. Outputs and evaluations of these methodologies are intended as a first step towards understanding the potential for enabling investors to adopt the TCFD recommendations on scenario-based risk assessment in financial disclosure. These methodologies, which are tailored to the main asset classes in which institutional investors typically invest, follow the publication in 2018 of equivalent methodologies developed for the loan books of banks (the methodologies for physical risks and opportunities can be found [here](#); while those for transition-related risks and opportunities can be found [here](#)).

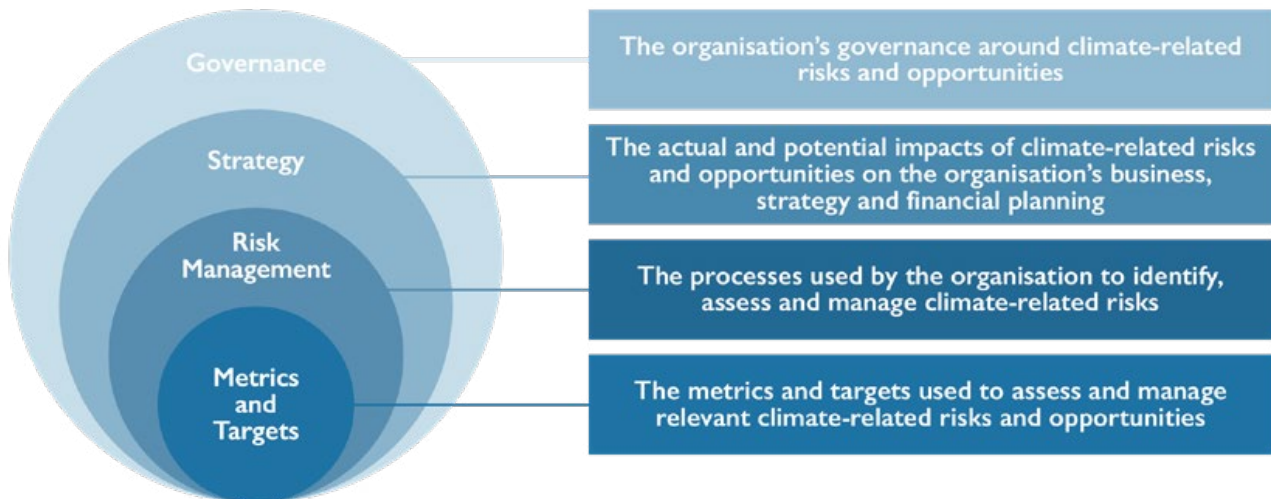
The remainder of this report is structured as follows:

1. Sections 1.2 and 1.3 highlight the objectives and innovative elements of the TCFD recommendations and outline the state of their implementation to date.
2. Section 2 summarises key existing methodologies for scenario construction and physical and transition risk assessments.
3. Section 3 details the methodology for scenario-based analysis co-developed under the Investor Pilot.
4. Section 4 presents the results of Carbon Delta's analysis of a global portfolio of 1,200 companies using the Investor Pilot methodology.
5. Section 5 provides investor case studies from the Investor Pilot Group, elaborating on the operationalising of the methodology and summarising the key lessons learnt across the broader membership.
6. Section 6 concludes the report by highlighting potential future directions of investor interaction with scenario analysis and the TCFD recommendations.

I.2. CLIMATE-RELATED RISK AND OPPORTUNITY ASSESSMENT IN THE INVESTMENT INDUSTRY

The TCFD's core recommendations centre around four broad themes; **Governance, Strategy, Risk Management and Metrics and Targets**. The *Governance* theme encourages organizations to disclose the extent to which boards and management oversee climate-related risks and opportunities. The *Strategy* theme asks companies to assess the materiality of climate change to their business and to disclose their exposure to climate-related risks and opportunities, including through forward-looking scenario-based analysis. The *Risk Management* theme asks companies to report on how they integrate their process for identification, assessment and management of climate risks and opportunities into their existing risk management frameworks. The *Metrics and Targets* theme encourages financial reporting to include climate-related metrics and to set targets aligned with the material risks and opportunities identified through the process. This should include a company's induced Scope 1, 2 and 3 greenhouse gas emissions (GHG). The four themes are summarised in Figure 2.

Figure 2: The TCFD recommendations are structured around four broad themes



Source: Adapted from TCFD, 2017

The recommendation to use scenario-based analysis is particularly innovative and encourages forward-looking, long-term assessment of the financial implications of climate change. The timing and magnitude of the effects of climate change on companies' business models, strategies and financial performance is uncertain, and the most significant effects are likely to emerge over the medium-to-long term. To appropriately incorporate these potential effects in strategic decisions, and to overcome the 'tragedy of the horizon', organisations should consider the potential evolution of climate-related risks and opportunities over time under various conditions, as well as their potential implications. One way to conduct this type of assessment is scenario-based analysis of a range of plausible future states. In particular, the TCFD recommends the use of a 2°C or lower scenario to stress-test financial performance against a low-carbon transition in line with the Paris Agreement. The UNEP FI Banking, Investor and Insurance Pilots on TCFD Adoption aim to expand the list of scenarios explored to a more ambitious 1.5°C scenario and an NDC implementation, 3°C scenario.

Engagement with climate-related risks and opportunities is doubly relevant for institutional investors and other financial institutions since they act as both consumers and issuers of climate-related disclosures. Investors must assess and manage material risks to their portfolio. This necessitates a high degree of familiarity with the drivers of financial performance of individual investee companies. For this, investors rely on investees for information relevant to the assessment of risks and opportunities material to their business. At the same time, investors must issue their own financial disclosure incorporating this information. Many investors in the Pilot Group are already experiencing increasing demand from several stakeholders including regulators, beneficiaries, clients, and the public at large for climate-related disclosure, and cite this as a key motivation for working together on UNEP FI and other platforms dedicated to developing the required capacity and tools.

As holders of large portfolios, investors are exposed to risks across sectors, geographies and financial instruments, and their collective actions can have substantial implications for global financial stability and climate-relevant financial flows. Institutional investors, alongside commercial lenders and other financial institutions provide the capital that fuels the development of the real economy. For investors, climate change risks can be particularly important owing to the longer time horizon of their asset-liability management, their exposure to equity and unsecured debt, and their universal exposure across the economy. At the same time, the magnitude and concentration of investor exposure to climate change can be difficult to assess given the size and diversification of their portfolios.

As a result, the UNEP FI Investor Pilot on TCFD Adoption has aimed to advance industry capacity on scenario-based analysis and sees these assessments as having five key components:

- 1. Choosing (or designing) a range of scenarios.** Scenarios should explore several of the key categories of uncertainty related to climate change, such as—on the transition side of climate change—policy timing and stringency, geographical dispersion, relative technology costs, and—on the physical side of the challenge—the evolution of both the severity and frequency of extreme weather events as well as the unfolding of chronic developments such as sea-level rise.
- 2. Selecting a financial modelling methodology.** Climate risks can be incorporated into different financial modelling methodologies, and which set of methodologies to use must be determined. In particular, it is important to decide whether to use macro-economic methodologies (that go from macroeconomic impacts to asset class impacts) or bottom-up methodologies (that go from asset-level cash-flow impacts to asset class impacts), or whether to combine these.
- 3. Measuring risk at the sector, country, and potentially asset class level.** A first step to measuring the financial impacts of potential future pathways is to measure risk at the aggregate level, be it for sectors or countries.
- 4. Measuring risk at the company level (at the level of the issuers of securities).** Institutional investors can also go one level deeper to analyse the exposure of individual companies in their portfolio to climate-related risks and opportunities. This would include selecting a financial modelling methodology for quantify the company- or security-level impacts.
- 5. Aggregating risks to the portfolio level.** Finally, aggregating risks to the portfolio gives investors a comprehensive overview of their exposure to climate-related risks and opportunities which in turn enables them to issue disclosures at the portfolio and institutional levels. This implies that the methodology covers all components of their portfolio on which climate change is likely to have material impacts.

It should be noted that, while scenario analysis can be a useful tool to explore and disclose the potential impacts of an uncertain future, it does not provide precise forecasts and should not form the sole basis for corporate or investor decision-making. The purpose of scenario analysis is to explore several plausible and ‘best-available’ ‘what-if’ scenarios, rather than to precisely forecast the future. Due to the complex nature of forecasting the relationship between (i) the economy and GHG emissions, (ii) atmospheric GHG concentrations and the climate system, and (iii) the climate system and the economy, every scenario, as much as every scenario analysis methodology, relies on many assumptions. This means that any number derived from such methodologies should be used with caution and fully evaluated in the context of the scenario’s and model’s underlying assumptions. This includes various, necessary simplifying assumptions relating to, among other things, the availability of abatement technologies, market structures, regional granularity, and mechanisms for policy impacts, such as carbon pricing.

1.3. IMPLEMENTATION OF THE TCFD RECOMMENDATIONS TO DATE

Many national and local governments have taken steps to mandate ESG risk disclosure for corporations and investors; however, these do not usually require forward-looking disclosure as recommended by the TCFD. Investors benefit from corporate disclosure on risk due to their exposure to corporate performance but are also themselves required to report on risks in many jurisdictions. To date, regulation has focused on assessment of current, short-term risk exposure, rather than forward-looking assessments as recommended by the TCFD. In 2016 the PRI identifies around 300 policy instruments in the largest 50 economies in the world, focusing on ESG disclosure for and from investors (PRI, 2016). These are divided into pension fund regulations, stewardship codes which govern the interactions between investors and investee companies, and corporate disclosure guidelines, which help investors access data on ESG risks and opportunities. However, it also found that many investors are sceptical of the effectiveness of these measures due to weak policy design and monitoring as well as inconsistencies across geographies.

Some initiatives, regulators and organisations, such as the European Commission, are considering alignment with the TCFD recommendations. January 2019 saw the publication of the European Commission’s Technical Expert Group on Sustainable Finance report which included a set of guidelines aligning the Non-Financial Reporting Directive (NFRD) with the TCFD recommendations, and expanding on them, as Box 1 illustrates (Technical Expert Group on Sustainable Finance, 2019). The NFRD applies to large public-interest companies with more than 500 employees, which covers approximately 7,400 companies and groups across the EU, including, among others, listed companies, banks and insurance companies. Banks and insurance companies should include the impact of their investing and asset management activities. Not all the revisions proposed in the January 2019 report would be expected of all companies—some, such as scenario analysis, would be expected only of those with significant exposure. Updated guidelines from the European Commission are expected in June 2019. Although not a regulating body, but rather a large international investor network, the PRI has also announced that TCFD-based reporting, but not public disclosure, is to become mandatory for signatories starting in 2020 (PRI, 2019). The PRI provides a directory of climate scenario tools on its [website](#).

Box 1: Climate-related disclosure regulation in the EU: The Non-Financial Reporting Directive (NFRD)

Revisions to the Non-Binding Guidelines (NBG) of the NFRD to include more guidance on climate-related reporting are currently under development and set to be finalised in June 2019. The European Commission has set up a Technical Expert Group (TEG) on sustainable finance to assist it in developing four new components of regulation: (i) a taxonomy, or EU classification system, to define whether activities are environmentally sustainable; (ii) an EU Standard for green bonds; (iii) benchmarks for low-carbon strategies for investment; and (iv) guidance on how to improve corporate disclosure of climate-related information. The final workstream released its report for public consultation in January 2019, and will, after another round of consultation, form the foundation of future climate-related disclosure in the EU.

Proposed revisions to the NFRD have been explicitly based on the TCFD recommendations, but expand on them in several key ways:

- Explicit alignment with national and international policy commitments. The TEG recommends the disclosure of KPIs linked to national and international climate policy, explicitly referring to the Paris Agreement and EU long-term strategic policy. The January 2019 report also calls for ambitious corporate action toward these goals: ‘More private capital flows need to be oriented towards sustainable investments to close the yearly €180-billion gap of additional investments needed to meet the EU’s energy and climate 2030 targets.’ With this addition, the NFRD takes a much more explicit stance on the need for corporate assessment and disclosure of contributions to the fulfilment of climate commitments than that taken by the TCFD.
- Incorporation of climate-related issues into business model considerations. Particularly given the EU’s clear climate policy pathway and the rising prices of emissions permits under the EU Emissions Trading Scheme (ETS), the TEG sees a need for companies to describe how their broader business model will adapt to these changes. This also includes the potential interactions of the business model with the potential impacts on climate change of the company’s activities, and with the company’s potential contribution to public climate policy targets.

Accordingly, scenario analysis is the most important gap in climate-related reporting to date. Both corporate and financial organisations have provided limited information on their resilience to different climate scenarios in their financial reporting, according to the September 2018 TCFD Status Report (TCFD, 2018). Not only are the corresponding ‘recommended disclosures’ in the TCFD framework at the heart of its innovation (because they represent the clearest response to Mark Carney’s ‘tragedy of the horizon’), according to the TCFD they have to date scenario analysis outputs have been the least disclosed. Those that did report on the results of scenario-based analysis tended to be in the energy, materials and buildings, and insurance sectors. Many others stated that they intend to conduct scenario analysis in the near future.

A step towards encouraging more scenario-based analysis among financial institutions could be the incorporation of climate change into regular stress tests by financial market regulators. Following the Dutch government's announcement in 2018 of a 95% emissions reduction target by 2050 (compared to 1990), the Dutch central bank conducted an energy transition risk stress test for the country's financial system. This included four tail risk scenarios ('policy shock', 'technology shock', 'double shock' and 'confidence shock'⁶) and results suggested that a disruptive energy transition could lead to sizeable, but manageable, losses for financial institutions (De Nederlandsche Bank, 2018). In the same year, the European Insurance and Occupational Pensions Authority (EIOPA) included a natural catastrophe scenario in its stress-testing of the European insurance sector (EIOPA, 2018). Similarly, the Bank of England has indicated plans to include the potential impacts of climate change in its stress tests as soon as the end of 2019 (Binham & Crow, 2018). In the first instance, these analyses serve to highlight the relevance of climate change to financial stability. In the future, regulators could make it mandatory for financial institutions to stress-test their portfolios against a common set of scenarios.

In April 2019, the Central Banks and Supervisors Network for Green the Financial System (NGFS) released recommendations on how central banks, supervisors and policymakers can work towards ensuring the resilience of the financial system to climate-related risks (NGFS, 2019). The NGFS is a group of central banks and supervisors fostering the development of environment and climate risk management in the financial sector, and the mobilisation of mainstream finance to support a low carbon transition. Members have collectively pledged support for the TCFD recommendations and encouraged all companies issuing public debt or equity to disclose in line with the recommendations. The NGFS has also identified scenario analysis as an important tool to help central banks and supervisors assess the impacts of climate change on the macroeconomy, the financial system and financial firms. The NGFS is still in the process of considering how scenario analysis could be implemented into authorities' toolkits. The first comprehensive report expresses four recommendations for central banks and supervisors: (i) integrating climate-related risks into financial stability monitoring and micro-supervision, (ii) integrating sustainability factors into own-portfolio management, (iii) bridging data gaps, and (iv) building awareness and intellectual capacity and encouraging technical assistance and knowledge sharing. The report also issues two recommendations for policymakers: (v) achieving robust and internally consistent climate and environment-related disclosure, and (vi) supporting the development of a taxonomy of economic activities.

In summary, while some actors in the finance sector, especially in a few leading countries, have started to use scenario-based analysis for climate-related risk and opportunity assessment, it is far from commonplace. The next section will summarise existing methodologies for scenario-based portfolio analysis in line with the TCFD recommendations.

6. The four global scenarios explore technology and policy breakthroughs, and combinations thereof. The 'policy shock' scenario sees the effective global carbon price rising globally by USD 100/tCO₂ due to additional policy measures. The 'technology shock' scenario sees the share of renewable energy in the energy mix double due to a technological breakthrough. The 'double shock' scenario sees both developments (rising carbon prices and technology breakthrough) coincide. Finally, the 'confidence shock' scenario sees corporations and households postpone investments and consumption, due to uncertainty surrounding policy measures and technology developments.

2. OVERVIEW OF METHODOLOGIES⁷

This section provides a broad overview of some of the available methodologies for scenario design and use in the analysis of the physical and transition risks of climate change. The full list of scenario providers and assessment methodologies examined for the purpose of this report can be found in the Appendix. This list is not intended to be comprehensive or an endorsement of any one methodology; rather the intention is to highlight the main points of convergence as well as key differences and areas for development across a range of methodologies. Information about the methodologies is based on publicly available materials, except for the pilot project's methodology, which is detailed in Section 3.

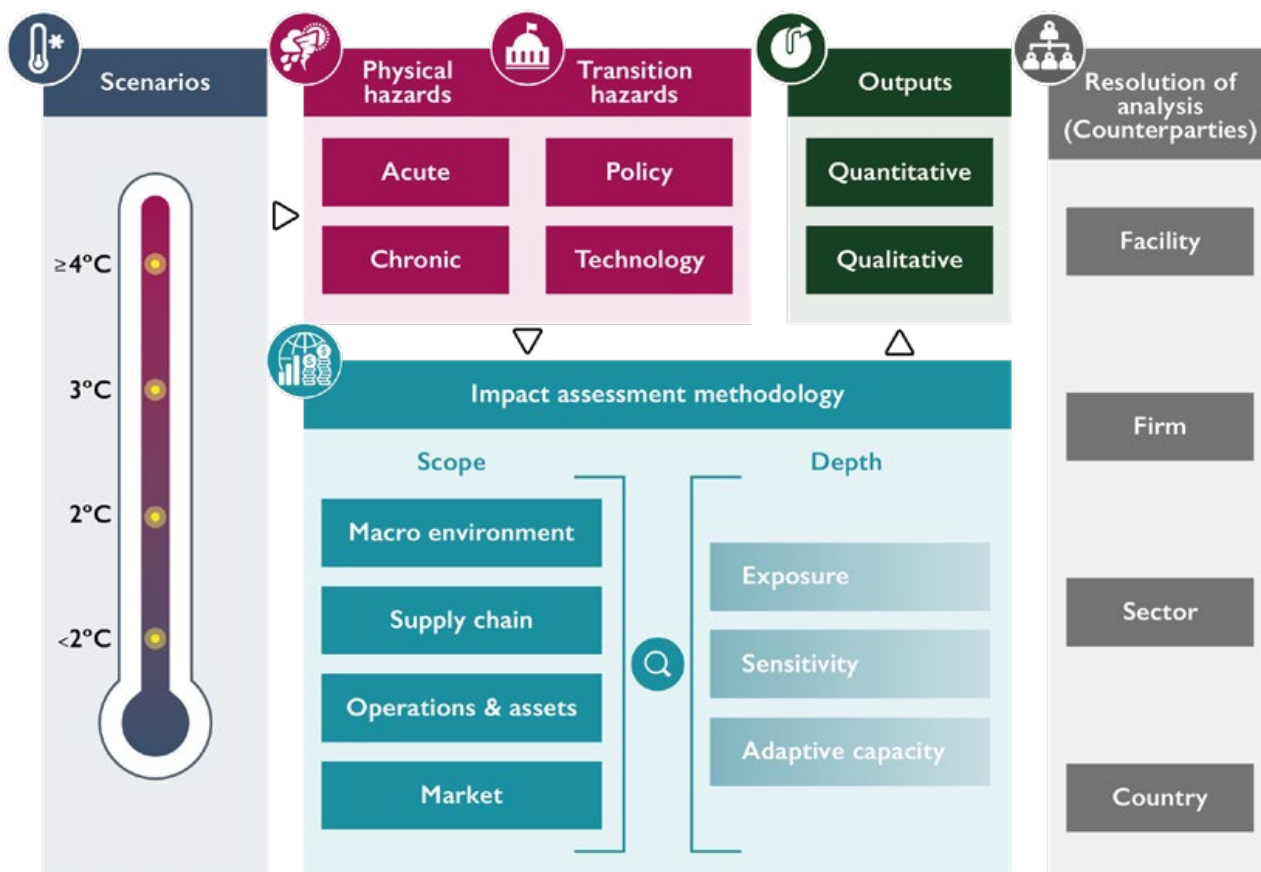
To effectively describe the methodologies for both transition and physical risk assessment, this report maps them separately against their treatment of the following analytical elements as illustrated in Figure 3:

- 1. Scenarios.** Transition and physical risk scenarios used by different methodologies may converge or diverge on many underlying assumptions, such as population growth and degree of international cooperation; however, for the purposes of this mapping, the focus lies on their temperature outcome. This is in line with the TCFD recommendations, which propose the explicit use of at least a 2°C scenario.
- 2. Hazards (or shocks).** Physical and transition risks can have several manifestations and methodologies do not always cover the full set of possible hazards. Physical risk from climate change can take the form of acute or chronic hazards, while transition risk can arise from policy and technology changes (or shocks).
- 3. Impact assessment methodologies.** At the core of each methodology lies its impact assessment methodology. This component is the most important aspect in comparing methodologies for scenario-based analysis. This report uses the same *scope-depth* framework to distinguish between methodologies in the physical and transition risk sections of this section:
 - i.** The *scope* of assessment can extend across a counterparty's⁸ macroeconomic environment and its value chain (specifically the supply chain, operations and assets, and market).
 - ii.** The *depth* of assessment across the macroeconomic environment and value chain depends on whether methodologies distinguish between a counterparty's exposure, sensitivity or vulnerability and adaptive capacity in relation to the risk.Sections 2.2 and 2.3 provide more detailed explanations of this framework for physical and transition risk assessments, respectively.
- 4. Outputs.** Outputs of scenario-based risk assessments can be either qualitative or quantitative, or a combination of the two. Qualitative outputs most often take the form of risk ratings, which evaluate risk for each counterparty on a finite scale. Some methodologies producing quantitative outputs attempt to quantify financial risk to the counterparty to produce a unique Value at Risk from climate change figure for each counterparty, while others examine average returns or borrower credit ratings.
- 5. Resolution of analysis.** Depending on their target audience, methodologies examine impacts on various counterparties, ranging from countries to individual corporate facilities.

7. Review of toolkits was based on publicly available documentation and interviews with providers. Efforts has been made to ensure the methodologies are represented as accurately as possible

8. The term counterparty is used throughout this report to refer to entities affected by the risk, ranging from countries to companies and individual facilities. As such, different methodologies examine different counterparties, but may do so using similar methodologies

Figure 3: Analytical elements of scenario-based impact assessments



Source: Vivid Economics

2.1. SCENARIO DESIGN

The first step in scenario design is constructing appropriate narratives for underlying assumptions around the climate, the economy, and societies. The overarching assumption of many scenarios is either a global temperature target, such as 2°C of warming above pre-industrial temperatures by 2100, or a GHG emissions pathway, which can be mapped to temperature and other climate changes. However, there will be several additional narrative assumptions, which may include carbon pricing developments over time, radiative forcing values or emissions pathways, energy demand and mix, drivers of demand such as lifestyle changes, resource availability, and relative technology costs. Which variables enter the model as assumptions, and which are determined within the model, will depend on the model at hand and its focus areas.

These assumptions can then be translated into consistent scenario outputs for analysis using various models, ranging from sector- and physical hazard-specific models to integrated assessment models (IAMs). Assumptions need to be translated into variables using models that are consistent across the system in question, be it a specific sector, the entire economy, or the climate system. To illustrate, assumptions about vehicle stock and composition (electric or non-electric) will affect demand for fossil fuels and modelling these two separately would lead to inconsistent outputs. Sector-specific models focus on consistency within a focus sector, hazard-specific models translate climate pathways into impacts on specific hazards, such as coastal flooding, and IAMs often consist of a combination of sector-specific models to link energy, economy and climate variables. Examples of these models include:

- Land-use models.** These models trace the impacts of climate change and mitigative action on land-use sectors. There are numerous examples of land-use models, such as the International Institute for Applied Systems Analysis's (IIASA) Global Biosphere Management Model (GLOBIOM) covering agriculture, forestry and bioenergy; the Potsdam Institute for Climate Impact Research's (PIK) Model of Agricultural

Production and its Impact on the Environment (MAGPIE) covering agriculture, bioenergy and water; and University of Bonn's Common Agricultural Policy Regionalised Impact (CAPRI) model covering agriculture. For further information on these and other land-use models used in climate-related assessments, see the JRC Science for Policy Report on global agriculture by 2050 (Meijl et al., 2017).

- **Energy system models.** The most well-known and widely used scenarios generated by energy system models are those provided by the International Energy Agency (IEA), which capture the entire energy-use chain of the economy but exclude non-energy sectors such as land-use and industrial process emissions. IRENA's Remap scenario develops a plan for doubling the share of renewables in the world's energy mix by 2030, while Greenpeace examines a fully decarbonised energy system by 2050 in its Advanced Energy [R]evolution scenario. Further examples of scenarios from energy sector-focused models include Shell's Mountains, Oceans and Sky scenarios, as well as the BP Energy Outlook.
- **Climate models.** These computer-based representations of the atmosphere are used to model the response of the climate to GHG emissions. Climate models, also known as circulation models, simulate the evolution of climatic variables including temperature, precipitation and sea-level rise at a spatial resolution of between 10 and 300km, typically up to 2100. Climate models vary in their assumptions and therefore produce varying estimates of the impact of GHG emissions on the climate. Typically, the outputs from multiple climate models are combined to produce a central estimate and an indication of uncertainty. 28 climate models are used in this way by the IPCC in its climate change Assessment Reports.
- **Hazard models.** Hazards such as drought, flood, hurricanes or sea-level rise are assessed with hazard-specific models. These make use of the outputs of climate models to model changes in risk between present day and future conditions. For example, models of future flood risk use estimates of the change in likelihood of extreme precipitation events derived from climate model outputs. These estimates are then combined with hydrological models to produce estimates of changes in flood risk under various climate scenarios. Similarly, the output of climate models can be processed to produce regional estimates of changes in drought, hurricane or risk from other acute hazards. Examples of hazard models include Climate Central's Surging Seas global model of sea-level rise and the World Resources Institute's models of water stress delivered in the Water Risk Atlas.
- **Macroeconomic models.** Computable general equilibrium (CGE) models are the most commonly used macroeconomic models. They allow impact assessment of changes in one part of the economy on the whole system. They include variables such as an economy's factors of production (capital and labour allocation), sectoral composition, international trade and various other macroeconomic variables. Examples of such models used in climate-related assessments include Wageningen Economic Research's MAGNET model, Ortec Finance's use of the Cambridge Econometrics E3ME model, and Vivid Economics' use of the Vivid Economy-Wide (ViEW) model.
- **Integrated assessment models (IAMs).** IAMs consider the socioeconomic factors driving GHG emissions, the biogeochemical cycles and atmospheric chemistry that determine how these emissions affect the climate and, through this, human welfare. They often embed many of the models referred to above, such as an energy systems model, and a land-use and a climate model. Examples of such models include the Potsdam Institute for Climate Research (PIK) Regional Model of Investments and Development (REMIND) model, the Global Change Assessment Model (GCAM) developed by the Joint Global Change Research Institute (JGCRI), the TIMES Integrated Assessment Model (TIAM) used by various research institutes, and PBL Netherlands Environment Assessment Agency's IMAGE modelling framework.

IAMs are often used to produce climate scenarios which combine the analysis of physical and transition impacts. These scenarios aim to identify the optimal level of policy, acknowledging the interactions between policy and physical impacts. The most commonly used provider of these integrated models is the IPCC through the Representative Concentration Pathways (RCPs). The RCPs combine assumptions on future climate policy

pathways with climate modelling. For example, the RCP8.5 scenario describes a future where continuous use of fossil fuels results in rising CO₂ and methane emissions, with falling emissions growth rates post-2050. In parallel, the Shared Socioeconomic Pathways (SSPs) narratives provide consistent assumptions around demographics, urbanisation, economic growth and technology developments, setting the stage on which emission reductions may or may not be achieved (Hausfather, 2018). Carbon budgets and narratives from these models often form key inputs for other scenarios that focus on areas of the economy or the climate in more detail.⁹

2.2. METHODOLOGIES FOR PHYSICAL RISK IMPACT ASSESSMENT

This section provides an overview of methodologies for physical risk impact assessment to date. First, it details the framework for categorising physical risk impact methodologies according to their scope and depth. Second, it provides a high-level mapping of existing methodologies against their treatment of five methodological elements: scenarios, physical hazards, impact assessment, outputs and resolution of analysis. Finally, it draws out the findings from the mapping in terms of key commonalities and areas that have not been significantly explored.

Physical impacts of climate change can take the form of acute or chronic hazards. Acute hazards encompass extreme weather events that are often highly localised and produce immediate impacts, such as tropical and extratropical cyclones, wildfires and floods. Chronic hazards, by contrast, represent the slow, incremental impacts of long-term changes in the climate. These could include, for example, higher temperatures, rises in sea levels, the melting of glaciers, desertification or changes to precipitation patterns and water availability.

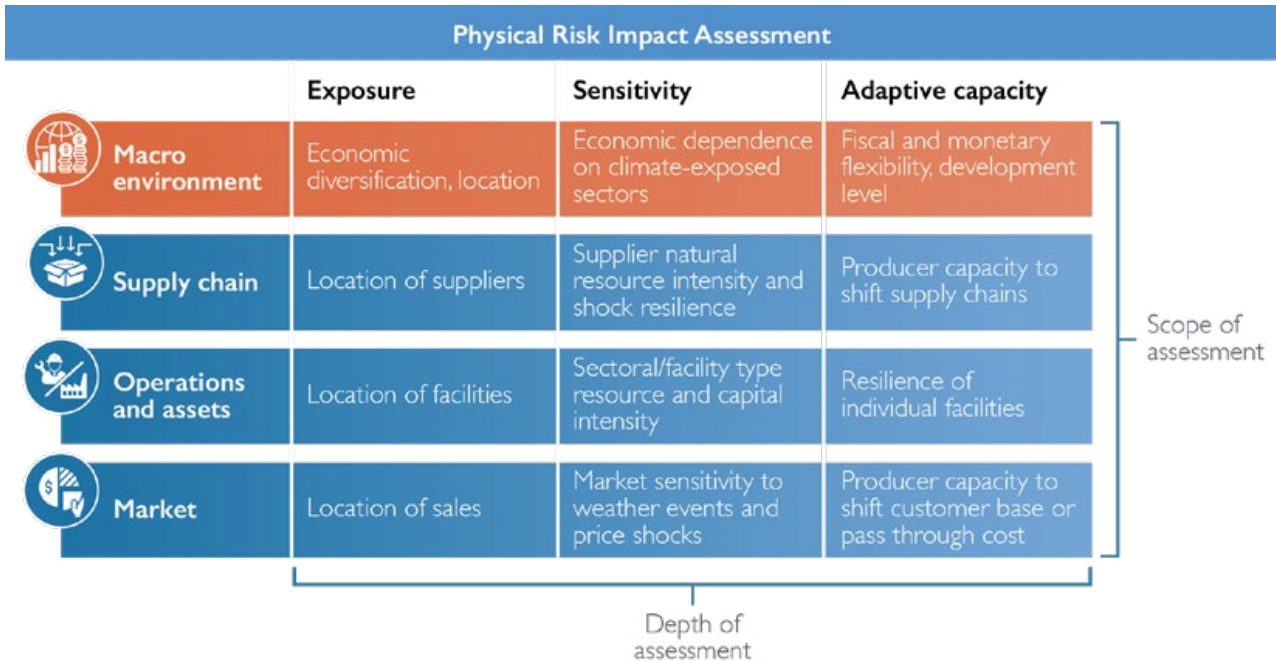
Figure 4 summarises the framework for distinguishing between different methodologies for assessing physical impact risks. Four impact channels describe the scope of assessment:

- **Macro environment.** Extreme weather events often destroy output and reduce productivity, while changes in average temperatures could weaken or strengthen productivity depending on the starting point. This means climate change will affect the aggregate output of goods and services (or GDP) of countries. In some instances, supply-side shocks due to climate change could also cause inflationary pressures, which, if unanticipated, may result in changes in real interest rates. At the same time, the differential impacts that climate change has on countries could affect regional trade balances and exchange rates. These variables contribute to the broader macroeconomic environment of a counterparty, and changes to them due to climate change will affect a counterparty's economic performance. Such macroeconomic impacts are not fully reflected in a bottom-up assessment looking directly at supply chain, operations and assets, and end-use markets (as described below).
- **Supply chain.** Acute or chronic physical impacts of climate change can have significant effects on the availability and pricing of inputs for a counterparty's production processes. This is independent of the location of the counterparty's own operations, given that complex supply chains span the globe. During the Thai floods of 2011, car manufacturer Toyota experienced business interruption at three of its plants in eastern Thailand—not because they were directly affected by the floods, but due to a shortage of parts from key suppliers in affected areas (The Associated Press, 2011).
- **Operations and assets.** The most direct impact channel would be the effects of a physical hazard on a firm's operations and assets. These could range from the long-term labour productivity impacts of permanently higher temperatures to business interruptions due to extreme weather events. There are many possible reasons for asset damage or business interruptions following extreme weather events: forced evacuations, damage to physical assets (production facilities, infrastructure or real estate), or migration of labour force could all cause disruptions.

9. For further elaboration on the interactions between models listed in this section, refer to the SENSES project (<http://senses-project.org/>). Headed by PIK and funded by the European Research Area for Climate Services, this aims to co-produce interactive visualisations, practical guidelines and manuals for climate change scenarios with several stakeholders by 2020.

- **Market.** Further down the value chain, if a counterparty's customers (or end-users) are affected by the physical impacts of climate change, this could affect the demand for its products. There may be immediate demand shocks from extreme weather events, such as when demand for construction materials surges after a hurricane, or gradual shifts from chronic changes to the climate, such as a reduction in ski tourism in regions experiencing gradually warmer temperatures.

Figure 4: Framework for categorisation of physical risk impact assessment methodologies



Source: Vivid Economics based on I4CE, 2018

The depth of assessment depends on a methodology's understanding of a counterparty's vulnerability to the risk, which consists of three components: exposure, sensitivity and adaptive capacity:

- **Exposure** of a counterparty to a physical risk is determined by its geographical location, which will determine the likelihood of it being affected by a climate hazard.
- **Sensitivity** to this hazard would then be determined by its dependence on factors most likely to be affected by the hazard, such as natural resources.
- **Adaptive capacity**, or ability to adjust to the hazard and mitigate its effects, refers explicitly to the capacity to adapt, be it through changing suppliers or customer base, or through adapting assets, as opposed to the adaptive capacity of the counterparty's suppliers or customers, which are instead part of its sensitivity.

The full mapping of physical risk assessment methodologies is provided in Figure 5. It sets out a broad overview of the coverage of current methodologies of four core methodological elements: scenarios, physical hazards, outputs and physical risk impact assessment. To provide the necessary context for each methodology, the map also includes the level of analysis of each methodology. Subsections 2.2.1 to 2.2.5 delve deeper into the results of this mapping.

Figure 5: Overview of physical risk assessment methodologies

		Physical risk impact assessment																							
		Scenarios				Risks		Macro			Supply chain			Operations			Market			Output		Counterparties			
		<2°C	2°C	3°C	≤4°C	Policy	Technology	Exposure	Sensitivity	Adaptive capacity	Exposure	Sensitivity	Adaptive capacity	Exposure	Sensitivity	Adaptive capacity	Exposure	Sensitivity	Adaptive capacity	Quantitative	Qualitative	Facility	Firm	Sector	Country
Provider	427				✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓			✓	✓	✓	✓	✓
	Acc 1		✓		✓	✓	✓				✓	✓		✓	✓		✓	✓		✓			✓	✓	
	Acc 2				✓	✓	✓							✓	✓		✓	✓			✓		✓	✓	
	C4		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓			✓		✓	✓	✓
	CD				✓	✓	✓							✓	✓					✓			✓	✓	✓
	CW		✓		✓	✓								✓	✓	✓				✓			✓	✓	✓
	Mer		✓	✓	✓	✓	✓	✓	✓			✓		✓	✓					✓					✓
	MIS			☺		✓		✓	✓	✓											✓				✓
	OF	✓	✓		✓	✓	✓	✓	✓	✓										✓				✓	✓

Note: 427 – Four Twenty Seven physical risk scores, Acc 1 – Acclimatise for UNEP FI Banking Pilot, Acc 2 – Acclimatise Aware for Projects, C4 – Carbone 4 Climate Risk Impact Screening (CRIS), CD – Carbon Delta Climate Value at Risk, CW – ClimateWise (with Vivid Economics) Managing the physical risks of climate change, Mer – Mercer TRIP framework, MIS – Moody’s Investors Service sovereign risk ratings, Ortec Finance – Climate-savvy scenarios set

Source: Vivid Economics



2.2.1. Scenarios

Methodologies for physical risk assessment most commonly include a scenario resulting in more than 4°C of warming relative to pre-industrial temperatures as well as at least one lower temperature scenario ideally compliant with the Paris Agreement. By representing several climate pathways, these methodologies allow users to directly explore the effects of a low-carbon transition in line with the Paris Agreement on the physical impacts of climate change relative to a world with unabated climate change. In the short-to-medium term, the physical effects under a decarbonisation pathway would be similar to one of unabated climate change. However, for medium- to long-term analyses (from 2040), including a below 2°C scenario, particularly in combination with one of 4°C of warming (or higher), could highlight the significant differences in expected physical effects of climate change as recently highlighted in (IPCC, 2018). For instance, one provider, Ortec Finance, conducts analysis for a 2100 horizon, including 4°C and well below 2°C scenarios, and combines physical and transition risk assessment. This allows the assessment of both the changing physical risks among significantly different policy pathways as well as their trade-offs with transition risk over the short-to-long term.

Other providers consider only a single temperature pathway or incorporate forward-looking data in other ways. Acclimatise (Aware for Projects) examines Global Climate Model (GCM) projections in line with the IPCC’s RCP 8.5, likely to result in more than 4°C of warming (IPCC, 2014b). This data is relied on for those hazards for which it is available, in addition to historical data on observed events in the location of a project. Moody’s Investors Service relies mainly on historical data on extreme weather events but

does take into account the likely longer-term effects of different climate projections from the World Bank and the International Monetary Fund, as well as vulnerability scores from the University of Notre Dame Global Adaptation Index (ND-GAIN), which rely on RCP 4.5 projections (Chen et al., 2015) for some indicators—a scenario that is likely to result in around 3°C of warming (IPCC, 2014b). Carbon Delta (UNEP FI Investor Pilot) focuses on a Business as Usual (BaU) scenario, offering an ‘average impact’ and a ‘tail risk’ variation which explores the 95th percentile of physical impacts.



2.2.2. Physical hazards

While the above methodologies cover acute hazards, analysis of chronic hazards is less common. Emphasis of methodologies to date has been on acute extreme weather events linked to asset impairment and business interruptions, rather than the effects of gradual changes in the climate on a broad range of business activities. This is likely to be linked to the different temporal nature of these hazards: acute climate shocks are likely to have short-lived effects on a business, for example, through temporary business interruption, while chronic changes in the climate lead to longer-term impacts and more fundamental changes in the nature of the business. These could include gradual changes in worker productivity or water availability over time, as well as the loss of viability of previously viable business models. It is therefore likely that different modelling capabilities are needed to estimate the two types of hazard.

Not only do these two manifestations of physical climate change vary considerably and hence require different modelling methodologies, the specific hazards covered within each vary significantly too. Most methodologies cover at least one hazard linked to changes in temperature or precipitation. For acute physical risks, the most commonly covered hazards are wildfires, coastal floods and tropical storms. Extreme temperatures, heat waves, extreme precipitation, droughts, landslides and river floods are also common. Among methodologies that cover chronic physical hazards, most include changes in average temperature. The Carbone 4 methodology covers a particularly wide set of risks, many of which are not included in any of the other methodologies. It is the only one that examines the acute risk of groundwater floods and the chronic risks of urban heat islands, coastal erosion, and biodiversity migration and loss.



2.2.3. Impact assessment methodologies

Most methodologies focus on the impacts of physical climate hazards on a counterparty’s operations and assets, which some then supplement with assessment of the broader value chain. For corporate counterparties, the disruption of their own operations and damage to their physical assets constitute the most direct channels of impact, as described above. As a result, this forms the unique focus for many methodologies. All methodologies except for Moody’s Investors Service and Ortec Finance (which focus on climate-informed macroeconomic risks at a country level) examine the impacts of physical hazards on operations and assets. The other two elements of the value chain (upstream and downstream) are less well studied: Four Twenty Seven, Acclimatise (UNEP FI Banking Pilot) and Carbone 4 provide the most comprehensive picture, by covering a firm’s exposure and sensitivity to all three impact channels within the value chain. However, for all methodologies, the granularity for ‘upstream’ supply chain and ‘downstream’ market impact assessment is at the country–sector level, meaning impacts depend on the countries of origin or sale and the relevant sector, rather than bottom-up analysis of suppliers and customers. Mercer (TRIP) includes analysis of the sensitivity of a counterparty’s supply chain by examining the impacts of changing access to resources, particularly water, on the energy and agricultural sectors.

Analysis of the macroeconomic environment has exclusively covered sovereign counterparties to date, and some providers include the results in company-level risk assessments. Four Twenty Seven, Carbone 4 and Moody’s Investors Service provide risk ratings for sovereigns which, by necessity, consider countries’ macroeconomic environments. Four Twenty Seven and Carbone 4 include the results of their sovereign risk assessments in their company-level analyses. Four Twenty Seven includes its country climate risk

indicators in the supply chain and market risk analyses of companies, which consider countries contributing to the supply chain and countries where products are sold. Mercer's TRIP framework conducts analysis for the US using sectoral damage functions and extends these results to other countries using sovereign exposure and sensitivity indicators. Integration of macroeconomic impacts into the assessment of corporate counterparties emerges as a clear area for potential future development. Ortec Finance relies on the Cambridge Econometrics E3ME macroeconomic model to assess the country, sector and technology-level impacts of climate change on variables such as GDP, inflation and interest rates. Ortec Finance then integrates this into a stochastic financial model in order to express these risks into financial risk metrics.

While exposure and sensitivity of counterparties are commonly assessed, few methodologies include measures of their adaptive capacity to mitigate physical climate risk. Across the four impact channels, methodologies consistently cover a counterparty's exposure and sensitivity, but there are few methodologies that include its adaptive capacity in their impact assessment. The ClimateWise (with Vivid Economics) methodology includes 'adaptation modelling', which incorporates property- and community-level adaptation measures into the analysis of physical impacts on UK real estate.¹⁰ This analysis highlights the potential reduction in losses associated with more resilient properties, be it through new-builds or retrofits. Moody's Investors Service measures a country's adaptive capacity through its economic and fiscal flexibility in setting up institutions needed to foster resilience to climate-related shocks. Economic diversification, political stability and fiscal responsibility are taken as determinants of a country's capacity to respond effectively to a shock and the associated costs. Four Twenty Seven and Carbone 4 use similar proxies to assess countries' capacity to respond to physical climate impacts in their sovereign risk ratings. Ortec Finance, through the Cambridge Econometrics macroeconomic model, captures countries' development levels and economic diversification, which can also act as proxies of capacity to respond to shocks.

These examples highlight the importance and additive nature of adaptive capacity analysis in physical risk impact assessments. However, they also highlight that this type of analysis is currently very difficult to undertake unless it is either *highly regionally focused* (as in ClimateWise (with Vivid Economics)) or *highly aggregated* (as in Moody's Investors Service and Carbone 4). This is due to a lack of available data on the resilience of individual physical assets at the global scale. **Increased disclosure as encouraged by the TCFD recommendations could play a vital role in making this data available and corresponding types of assessments possible in the future.**



2.2.4. Outputs

Some methodologies provide qualitative risk ratings, which vary considerably in the level of detail they provide. All methodologies provide these risk ratings on an individual hazard basis. Carbone 4 and Four Twenty Seven evaluate risk for all counterparties and provide ratings from least exposed (0) to most exposed (100) within the sample of companies they examine. At the less granular end of the spectrum, Acclimatise's Aware for Projects rates the risk of a project against each physical hazard as either 'High', 'Medium' or 'Low', and Moody's Investors Service rates sovereigns using four ratings, from 'Least susceptible' to 'Most susceptible'.

Other methodologies provide quantitative financial outputs: Acclimatise (UNEP FI Banking Pilot), Carbon Delta (UNEP FI Investor Pilot), ClimateWise (with Vivid Economics), Mercer and Ortec Finance. For the UNEP FI Banking Pilot, Acclimatise developed a methodology that allows banks to assess the impacts of physical climate risk on revenues and costs of goods sold, which are used to evaluate changes in probability of default of counterparties and sector portfolios in the agriculture and energy sectors. For real estate assets, changes in loan-to-value ratios are used to determine the value at risk from climate change under different future pathways. This methodology is therefore primarily aimed at banks, although it may potentially be adapted to investors' needs. Both Carbon

10. Hazard modelling on this project was conducted by Sayers and Partners LLP and ETH Zurich.

Delta (UNEP FI Investor Pilot) and ClimateWise (with Vivid Economics) produce a financial estimate of average annual losses for individual counterparties. Carbon Delta provides CVaR estimates for individual listed companies, disaggregated for debt, equity and real estate assets. The focus of the ClimateWise (with Vivid Economics) methodology is on the average annual losses for individual real estate assets, although the methodology is extendable to other assets. Ortec Finance calculates, at the asset class level, impacts on portfolio expected returns. Mercer's TRIP framework provides a different kind of quantitative output: it estimates the changes in financial returns for portfolios, asset classes and sectors due to climate-related risks and opportunities. Sectoral sensitivity heatmaps are constructed based on current-day evidence and forward-looking qualitative judgment using 0.25 increments on a relative scale from -1 to 1. These initial heatmaps form the basis of similar heatmaps for asset classes, which rely on the sectoral composition of, for example, developed market global equity, supplemented by further expert adjustment.



2.2.5. Resolution of analysis

For many methodologies, the most granular counterparty of analysis is a physical asset, for which datasets tend to be proprietary or reliant on investors' own databases.

Carbone 4, Carbon Delta (UNEP FI Investor Pilot), ClimateWise (with Vivid Economics) and Four Twenty Seven incorporate analysis of the impacts on individual real estate assets. Carbone 4 further includes infrastructure assets, which also forms the focus of Acclimatise's Aware for Projects. For corporate counterparties more broadly, physical assets, such as production facilities, are assessed only by Carbon Delta (UNEP FI Investor Pilot) and Four Twenty Seven. For this analysis, the two providers rely on proprietary corporate locational datasets. Data availability and processing capacity pose significant challenges for physical risk impact assessments: corporate facility databases are available for purchase for specific sectors, but can exhibit major gaps in coverage, particularly if the intention is to conduct a global impact assessment. Reliance on investors' own databases of physical assets can be a first step, but even investors do not always have full information on their real estate and infrastructure portfolios, let alone other types of physical assets owned by investee companies.

Others conduct impact assessment at the country and sector level, which requires less granular locational data on physical hazards. Moody's Investors Service focuses on the analysis of sovereigns and does not capture country exposure to individual climate hazards. Instead, it relies on the ND-GAIN Vulnerability country indices to assess exposure, sensitivity and adaptive capacity. Ortec Finance analysis produces country-level GDP impacts due to physical and transition risk, supplemented with some information on sectoral composition. The E3ME model producing these GDP impacts takes physical risk data per country per year as inputs. Mercer (TRIP) uses a model of damages at the sector and country level to construct a picture of the impacts of various physical hazards. The Acclimatise methodology for the UNEP FI Banking Pilot also uses sector-specific climate change impact models for chronic hazards in the agriculture and energy sectors. For acute events, the methodology relies on online hazard-specific data portals such as Princeton Climate Analytics Global Drought Risk Product.

2.3. METHODOLOGIES FOR TRANSITION RISK IMPACT ASSESSMENT

This section provides an overview of current transition risk impact assessment methodologies. It follows the same structure as the previous section: First, it introduces the framework for categorising transition risk impact methodologies according to their scope and depth. Second, it maps existing methodologies against their treatment of significant methodological elements. Finally, it draws out the key findings of this mapping.

This report focuses on two types of transition hazard (or shocks): policy and technology. Policy hazards describe the additional costs or revenues that could arise from changes in a counterparty's policy environment. Policy can impose a direct price on carbon, through a carbon tax or ETS, or it can impose an indirect carbon cost, for example through renewable obligations or coal production restrictions. Most methodologies summarise policies under a single carbon price, rather than going into detail on the policy suite used to achieve

this price. Technology hazards include the changes in relative technology prices, such as through the falling costs of renewable energy generation and energy storage technologies relative to traditional fossil fuel-based technologies. The two types of transition hazard are often closely linked, as policies directly target shifts in relative technology costs to accelerate the transition to low-carbon technologies.

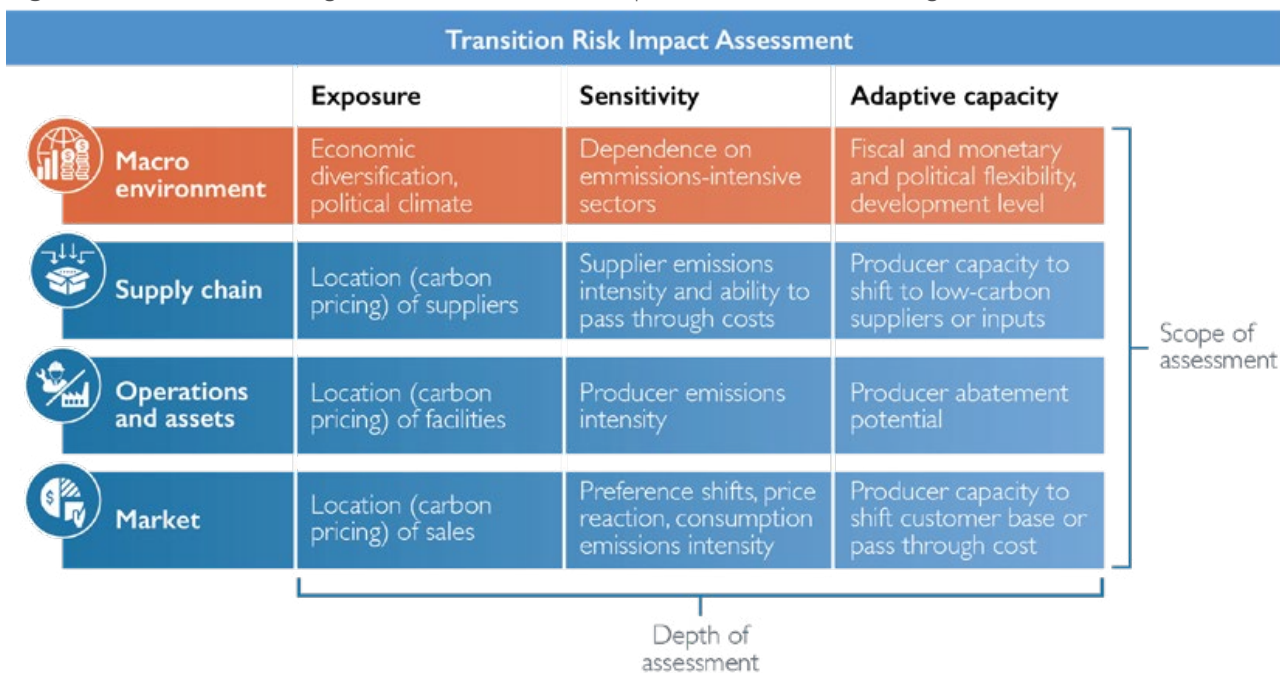
The TCFD further identifies legal and reputation risk as transition risk; however, these are not directly covered by any of the methodologies examined likely due to difficulties associated with quantifying these impacts. The TCFD identifies the following categories of transition risk: policy and legal, technology, market and reputation. This report examines methodologies' coverage of policy and technology risk, as well as market risk. Market risk, or the risk that companies' supply and demand patterns change during a low-carbon transition, is here treated within policy and technology risk, as these two are seen to be the drivers underlying market risk. Legal risk from climate-related litigation, and reputation risk from changing perceptions of companies' emissions performances, are not currently examined directly by any of the methodologies considered, as the information to estimate them is sparse. As a result, legal and reputation risks have not been included as transition hazards (or shocks) in this section.

Figure 6 summarises the framework for distinguishing between different methodologies for transition risk impact assessment. Four impact channels describe the scope of assessment:

- **Macro environment.** As economies pursue the goals of the Paris Agreement, transformative policy and technology changes will affect the output of different goods and services. This is likely to change the sectoral composition and competitive positions of economies on the international market through exchange rates and trade balances. At the same time, technological breakthroughs or sudden carbon price increases may inflict unexpected price shocks and create inflationary pressure. If some regions advance technology or introduce carbon pricing before others, this could also lead to changes in trade positions or exchange rates. Such macroeconomic impacts are not fully reflected in a bottom-up assessment looking directly at supply chain, operations and assets, and end-use markets (as described below).
- **Supply chain.** Policy shifts affecting a counterparty's suppliers could affect its cost of production if high-carbon suppliers pass through carbon prices to the counterparty. As an example, after the introduction of the EU ETS in 2005, some electricity generators passed through more than 100% of the cost increase to consumers.¹¹ This could double the burden of a carbon pricing scheme on high-carbon counterparties, which will also have to pay the costs of their own emissions, and might force them to consider alternative, lower-carbon suppliers. Counterparties may do so in any case if relative technology costs are changing, and low-carbon, cheaper alternatives emerge regardless of carbon pricing. This impact channel covers both Scope 2 and Scope 3 emissions.
- **Operations and assets.** The most direct channel of impact describes the effects of policy and technology shifts on a company's own operations and Scope 1 emissions. This would include the cost impacts of policy changes encouraging a low-carbon transition and shifts in relative technology prices.
- **Market.** For many counterparties whose products are emissions-intensive to consume, policy and technology shifts will be felt almost exclusively through markets (examples include all industries related to the extraction of fossil fuels, including oil & gas and coal mining). For example, fossil fuel producers do not tend to be particularly (Scope 1) emissions-intensive, so if a carbon price is introduced, the direct cost impact is likely to be quite small. However, fossil fuels produce significant (Scope 3) emissions in consumption, meaning that the producer's customers will face a potentially very large cost impact and, as a result, reduce demand for the producer's products. Market effects could also be substantial in other sectors, as consumer preferences may shift during a low-carbon transition, for example, to greater substitution of paper for plastic products.

11. The majority of estimates of cost passthrough rates were between 38% and 83%. (Sijm, Hers, Lise, & Wetzelaer, 2008).

Figure 6: Framework for categorisation of transition risk impact assessment methodologies



Source: Vivid Economics based on I4CE, 2018

The depth of assessment depends on a methodology’s understanding of a counterparty’s vulnerability to the risk, which consists of three components:

- **Exposure** of a counterparty is determined by its geographical location, which will determine the climate policy it has to comply with.
- **Sensitivity** to this hazard will then depend on counterparty emissions intensity, which determines the increase in costs it will experience per unit of output it produces. Further down the value chain, customers’ sensitivity to carbon pricing of their consumption will depend on their relative preferences and response to price shocks.
- **Adaptive capacity** is described by a counterparty’s ability to shift away from high-carbon suppliers and customers, pass through costs, or abate their emissions directly—for example, through energy efficiency measures. Adaptive capacity is dependent on the substitutability of a counterparty’s inputs and products for low-carbon alternatives. If current inputs are easily substitutable for lower-carbon alternatives, the counterparty has more capacity to adapt to transition risk. At the same time, if the products the counterparty produces are not easily substitutable for low-carbon alternatives, such as cement, it may find it easier to pass through costs to consumers.

The full mapping of transition risk assessment methodologies is provided in Figure 7. As for physical risk, this mapping provides a broad overview of the coverage of current methodologies of four core methodological elements: scenarios, transition hazards, outputs and transition risk impact assessment. To provide the necessary context for each methodology, the map also includes the level of analysis of each methodology. Subsections 2.3.1 to 2.3.5 highlight the key findings of this mapping.

Figure 7: Overview of transition risk assessment methodologies

		Transition risk impact assessment																							
		Scenarios				Risks		Macro			Supply chain			Operations			Market			Output		Counterparties			
		<2C	2C	3C	>4C	Policy	Technology	Exposure	Sensitivity	Adaptive capacity	Exposure	Sensitivity	Adaptive capacity	Exposure	Sensitivity	Adaptive capacity	Exposure	Sensitivity	Adaptive capacity	Quantitative	Qualitative	Facility	Firm	Sector	Country
Provider	2dii		✓			✓	✓							✓	✓				✓		✓	✓			
	C4		✓	✓		✓	✓					✓			✓		✓			✓		✓	✓		
	CD	✓	✓	✓		✓	✓							✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	
	CT	✓	✓			✓	✓							✓			✓	✓			✓	✓	✓		
	Mer		✓	✓	✓	✓	✓							✓	✓		✓		✓				✓		
	MIS			✓		✓	✓	✓	✓	✓									✓					✓	
	OF	✓	✓		✓	✓	✓	✓	✓	✓									✓				✓	✓	
	OW		✓			✓	✓				✓	✓		✓	✓		✓	✓	✓				✓	✓	
	Sch					✓					✓	✓		✓	✓		✓	✓	✓			✓	✓		
	TPI		✓	✓		✓	✓								✓					✓		✓	✓		
	Tru		✓	✓		✓	✓							✓	✓			✓	✓			✓			
	VE 1		✓			✓	✓	✓	✓	✓									✓				✓	✓	
	VE 2		✓		✓	✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		

Note: 2dii – 2 degrees Investing Initiative PACTA tool, C4 – Carbone 4 Carbon Impact Analytics, CD – Carbon Delta Climate Value at Risk, CT – Carbon Tracker 2 degrees of separation, Mer – Mercer TRIP framework, MIS – Moody’s Investors Service sovereign risk ratings, Ortec Finance – Climate-savvy scenarios set, OW – Oliver Wyman for UNEP FI Banking Pilot, Schrodgers – Carbon Value at Risk, Tru – Trucost Carbon Earnings at Risk, TPI – Transition Pathways Initiative TPI Tool, Ortec Finance – Climate-Savvy Scenarios, VE – Vivid Economics 1 – ViEW, 2 – Net-Zero Toolkit

Source: Vivid Economics



2.3.1. Scenarios

Most methodologies include a 2°C scenario, often in combination with at least one other scenario, and IEA scenarios form the basis of analysis for most methodologies. All methodologies examined for the purposes of this report, except for Schroders (this methodology utilises a USD 100/tCO₂ carbon price rather than a temperature alignment scenario), include a 2°C-compliant scenario. The majority supplement this with at least one additional scenario. The 2dii, Carbone 4, Carbon Tracker, Mercer, Moody’s Investors Service and TPI methodologies all use IEA scenarios either directly, or as a starting point for more customised scenarios. As a result, the most commonly cited 2°C scenarios are the IEA’s World Energy Outlook 450 and Energy Technology Perspectives 2D scenarios. Carbon Delta (UNEP FI Investor Pilot) uses scenarios from a variety of providers, including those produced by PIK’s REMIND model, GCAM, developed by the JGCRI and PBL Netherlands, and Environment Assessment Agency’s IMAGE modelling framework. Oliver Wyman (UNEP FI Banking Pilot) also relied on PIK’s REMIND model as well as IIASA’s MESSAGE model. Vivid Economics designs bespoke transition scenarios, exploring

various technology cost and policy timing assumptions. For the Net-Zero Toolkit, these are constructed in collaboration with Imperial College London, using TIAM.



2.3.2. Transition hazards (or shocks)

By using comprehensive transition scenarios generated using energy system models, most methodologies cover both policy and technology risks. The integrated assessment models used to produce prominent scenarios by providers like the IEA or PIK tend to include modelling of the energy system and rely on assumptions about policy changes as well as relative technology cost trajectories of key low-carbon technologies compared with traditional fossil fuel-based technology. As a result, methodologies that use these scenarios or others generated by IAMs automatically consider both types of risk. One methodology focuses exclusively on policy risk: Schrodgers imposes transition risk through a price of USD 100 per tonne on all global carbon emissions.



2.3.3. Impact assessment methodologies

Most methodologies focus on the impacts of transition risk on a counterparty's operations and assets. All but three methodologies—which focus on the macroeconomic environment—examine the direct effects of transition risk on counterparty operations and assets (Scope 1 emissions). This most common includes either an assessment of the costs from carbon pricing a counterparty will face under different scenarios or evaluation of the alignment of a counterparty with different temperature targets using carbon footprints. Half of the providers supplement this with analysis of the market and, to a lesser extent, the supply chain. Analysis of the market is relatively common, as around half of the examined methodologies consider shifts in customer behaviour in response to policy or technology shifts. Opportunities for counterparties due to growth in green technologies are examined by Carbon Delta (UNEP FI Investor Pilot), Mercer, Oliver Wyman (UNEP FI Banking Pilot) and Vivid Economics (Net-Zero Toolkit). Mercer assesses opportunities at the same time as risks, using the same sectoral sensitivity heatmap methodology described in Section 2.2.3. Oliver Wyman (UNEP FI Banking Pilot) assess the opportunities for banks from a low-carbon transition, examining sectoral investment attractiveness and interactions with bank strengths. Carbon Delta (UNEP FI Investor Pilot) and Vivid Economics (Net-Zero Toolkit) quantify company-level opportunities using patent data. This data is used to identify relatively innovative companies in growing low-carbon sectors and to estimate performance. Supply chain analysis is the least represented along the value chain and typically relies on input–output tables to assess the likelihood of production cost increases from suppliers.

Three methodologies examine the macroeconomic impacts of climate change transition risk: Ortec Finance, Moody's Investors Service and Vivid Economics. Ortec Finance first translates scientific climate models like those informing the IPCC reports into annual impacts on national GDP for 59 countries and regions using the Cambridge Econometrics model E3ME. This model includes complete representation of the interactions of the economy, the climate and land and energy systems. Ortec Finance uses these GDP impacts to estimate shocks over time to more than 600 financial and economic variables like interest rates and inflation, based on historical relationships. Vivid Economics also utilises a CGE model: the Vivid Economy-Wide (ViEW) model, which includes detailed representations of energy, food production, international trade, investment, manufacturing, mining and services. Moody's Investors Service examines the impacts of lower oil & gas demand under various decarbonisation pathways on oil & gas exporting countries' credit risk. Moody's assumes that impacts from these changes in prices and demand will be transmitted to sovereign counterparties through the oil & gas dependence of economic strength, fiscal strength and external vulnerability.

While many methodologies cover counterparties' exposure and sensitivity to transition risk along the value chain, assessment of adaptive capacity is less common, although is used more for transition risk than for physical. Along the value chain, most methodologies examine the adaptive capacity of a counterparty in its market, most commonly by integrating cost pass-through capacity. Schrodgers, Trucost and Vivid

Economics (Net-Zero Toolkit) model the effects of climate costs passed through to consumers on equity value impact. Similarly, Oliver Wyman's Banking Pilot risk factors include 'change in revenue', a rating of the likelihood of demand decrease due to product substitutions or cost pass-through, based on industry price elasticity of demand and price cross-elasticity of demand relative to high-carbon producers. Carbone 4 examines company expenditures on low-carbon technologies (in other words, emissions abatement) as part of its forward-looking, qualitative assessment of company alignment with a low-carbon transition. Vivid Economics (Net-Zero Toolkit) covers counterparty adaptive capacity along the supply chain and operations and assets by examining sector emissions abatement opportunities quantitatively.

These examples highlight two initial areas for future development of transition risk assessment methodologies: analysis of counterparties' macroeconomic environment and capacity to adapt to transition risk. Impacts of a low-carbon transition on the macroeconomic environment could be significant, especially if the transition occurs not in a gradual and smooth way, but in a delayed and more radical manner. Many of the methodologies considered in this report limit their analysis to company value chains and ignore the potential macroeconomic impacts of a transition—for example, the potential effects of stringent global carbon policy on the economies of countries dependent on high-cost production of fossil fuels. Companies in these countries not directly involved in the production or mitigation of carbon emissions could nevertheless be significantly affected if the economy they operate in undergoes structural change. As a result, coupling company-level analysis with assessment of the macroeconomic environment appears a potential next step for improving transition risk assessment. At the same time, adaptive capacity analysis has not been common in methodologies to date but could significantly alter the potential impacts of a low-carbon transition on countries and companies. Where this analysis is present, it does not rely on company-specific data as this is not available on a large scale. If transition risk assessments are to incorporate company-specific adaptive capacity, more granular data from companies is needed—from TCFD reporting for example.

In addition, there is scope for the development of a bottom-up methodology to transition risk impact assessment for real estate. Apart from Carbon Delta (UNEP FI Investor Pilot), no other methodologies cited in this report examine the impacts of transition risk on individual real estate assets. However, considering their experience with the Carbon Delta methodology, which combines top-down and bottom-up analysis, real estate investors within the Investor Pilot Group pointed out the need for a more intensive bottom-up methodology. This bottom-up methodology should then, for example, address the potential changes to local regulations on energy efficiency retrofitting, the area where investors expect most of the transition risk to be felt in the real estate sector.



2.3.4. Outputs

Most outputs are estimates of financial impacts against a hypothetical baseline, expressed in terms such as Climate Value at Risk. Carbon Delta (UNEP FI Investor Pilot), Schroders, Trucost and Vivid Economics provide outputs in the form of value at risk from climate change at the company level. Schroders provides the share of current EBITDA at risk for global equity markets if a carbon price of USD 100/tCO₂ were introduced immediately. Similarly, Trucost estimates the exposure of companies to future changes in carbon prices and uses this to estimate the Carbon Earnings at Risk. This can then be used to estimate the impact on equity valuations, as is the case in the S&P Carbon Price Risk Adjusted Index Series. Vivid Economics' Net-Zero Toolkit and Carbon Delta (UNEP FI Investor Pilot) rely on similar methods to calculate the value impact for listed companies but also consider the impact of green opportunities on earnings. While Vivid Economics' Net-Zero Toolkit has focused on equity to date, Carbon Delta (UNEP FI Investor Pilot) breaks down these discounted costs into separate CVaR figures for firm equity, debt and real estate.

Other financial outputs take various forms, ranging from impacts on expected returns to gross value added (GVA) and sunk capital expenditure. Carbon Tracker assesses the proportion of company capital expenditure outside of an emissions budget. Ortec Finance calculates impacts on portfolio expected returns at the asset class level. Oliver

Wyman's methodology for the UNEP FI Banking Pilot, in line with the corresponding physical risk assessment from Acclimatise, assesses the impacts of transition risk on probability of default or credit risk ratings. The TRIP framework, also by Mercer, provides estimates of the changes in financial returns during a low-carbon transition, as detailed in Section 2.2.4. Moody's determines the three-notch credit rating ranges (for example, Baa1-Baa3) of sovereigns over time. Vivid Economics' ViEW model produces estimates of annual GVA growth, unmitigated carbon exposure of operations, and improvements in carbon intensity.

Non-financial outputs tend to take the form of temperature alignment assessments (or 'Science-Based Targets').¹² These indicate the emissions pathway of a counterparty relative to a temperature target's carbon budget. Providers rely on different methods to construct these emissions pathways. The TPI Tool uses companies' current emissions intensities in combination with the emissions targets they have set to construct future emissions intensity and compares this to sector-specific emissions intensity benchmarks. Instead of company emission reduction targets, the PACTA tool uses facility-level data on current and planned production capacity and compares future production to the fair share quantity (based on current market share) under a 2°C scenario. Carbon Delta (UNEP FI Investor Pilot) also provides a temperature gauge for clients' portfolios, based on actual sectoral carbon intensity compared with that implied by global carbon budgets of different degree targets. Further details on this methodology are included in Section 3.3. Carbone 4's Climate Impact Analytics does not provide an explicit temperature alignment assessment, but focuses on the calculation of induced and avoided emissions, supplemented with qualitative 'forward-looking ratings' which are based on analysis of company disclosures of investments and R&D expenditures that will contribute to a low-carbon transition, as well as related corporate strategy.



2.3.5. Resolution of analysis

The most granular analysis of most methodologies is at the firm level, which some then aggregate to sector-level and, to a lesser extent, country-level results. Models frequently combine sector- and firm-level assessments, by supplementing sectoral impacts of a low-carbon transition (such as sectoral carbon prices and cost pass-through potential) with company-specific information (such as profitability). To provide an example of this process, for the UNEP FI Banking Pilot, Oliver Wyman starts with a risk exposure assessment at the 'segment' level—subsectors based on characteristics relevant to transition risk—and uses these sensitivities to assess company-level impacts. Two methodologies limit analysis to the country and sector level. Most methodologies providing firm-level analysis also provide aggregate results from this analysis at the sector level. A few providers focus entirely on sector- and country-level assessment: Mercer, Moody's Investors Service, Ortec Finance and Vivid Economics (ViEW).

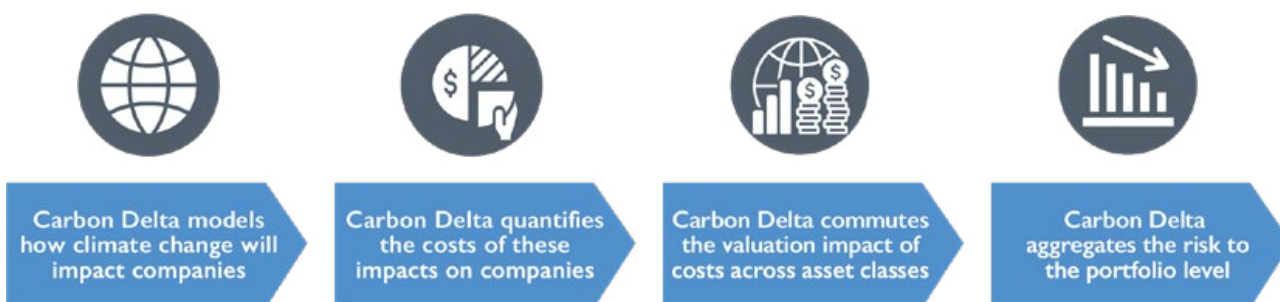
Asset-level analyses are often limited to the oil & gas sector, except for the Carbon Delta (UNEP FI Investor Pilot) methodology, which conducts a bottom-up assessment across sectors using proprietary facility-level data. Carbon Tracker and Vivid Economics (Net-Zero Toolkit) conduct asset-level analysis for individual wells in the oil & gas sector to assess the extent of asset stranding. They do this by constructing product supply curves and assessing the amount of production that is within different carbon budgets. Carbon Delta (UNEP FI Investor Pilot), on the other hand, uses its proprietary corporate location database to assign emission reduction requirements to individual facilities based on a 'fair share' approach. The next section of this report details Carbon Delta's CVaR methodology, including further information on transition risk impact assessment in Section 3.3.

12. Science-based targets provide companies with a pathway to sustainable growth by specifying by how much and how quickly they need to reduce their GHG emissions. Refer to: <https://sciencebasedtargets.org/>

3. BUILDING BLOCKS OF THE INVESTOR PILOT METHODOLOGY¹³

This section provides a description of the Carbon Delta methodology co-developed in the UNEP FI Investor Pilot through iterative consultations between the Investor Pilot Group and Carbon Delta. It lays out a step-by-step framework to calculate the Climate Value at Risk® (CVaR) metric for companies, assets, securities, and portfolios. The CVaR metric assesses the impact of climate change-related risks and opportunities on an asset's market value, under a specified climate scenario over a 15-year time horizon. The risk at the portfolio level is determined through upwards aggregation, taking into account company assets, their location, and the traded securities across different asset classes associated with the enterprise. This section first describes the process by which climate change risks and opportunities are identified, modelled, and quantified into costs and revenues. It then details the methodology by which these costs and revenues are aggregated to a CVaR for equities, bonds and real estate assets. Figure 8 provides an overview of the Carbon Delta modelling process.

Figure 8: The final outputs of the Carbon Delta methodology are quantified costs or revenues and the CVaR



Source: Carbon Delta

Carbon Delta assesses the financial impact of climate change over a 15-year time horizon across two pillars: physical risk and transition risk.¹⁴—Physical risks relate to chronic extreme weather hazards (such as extreme heat), acute extreme weather hazards (such as hurricanes and floods), and opportunities (such as less harsh winters in colder regions due to temperature rise). Transition risk includes the risk from changing policy (such as increasingly stringent climate legislation enacted to meet decarbonisation targets in the country of operation), as well as the opportunities presented by low carbon technologies.

Each pillar is explained in further detail in the following sections. Physical risks and opportunities are covered in Section 3.2, and transition risks and opportunities are covered in Section 3.3. Section 3.4 then discusses the calculation of an aggregate CVaR measure, and how company-level estimates can be aggregated for portfolio analysis.

3.1. SCENARIO ANALYSIS AND INTEGRATED ASSESSMENT MODELS

- **The physical risk analysis considers two scenarios: average and aggressive physical risk.** In order to assess the potential cost imposed by physical risk, the Carbon Delta methodology models the probability distribution of the annual cost from weather extremes for assets at any given location in a BaU world (no action is taken to reduce emissions). The

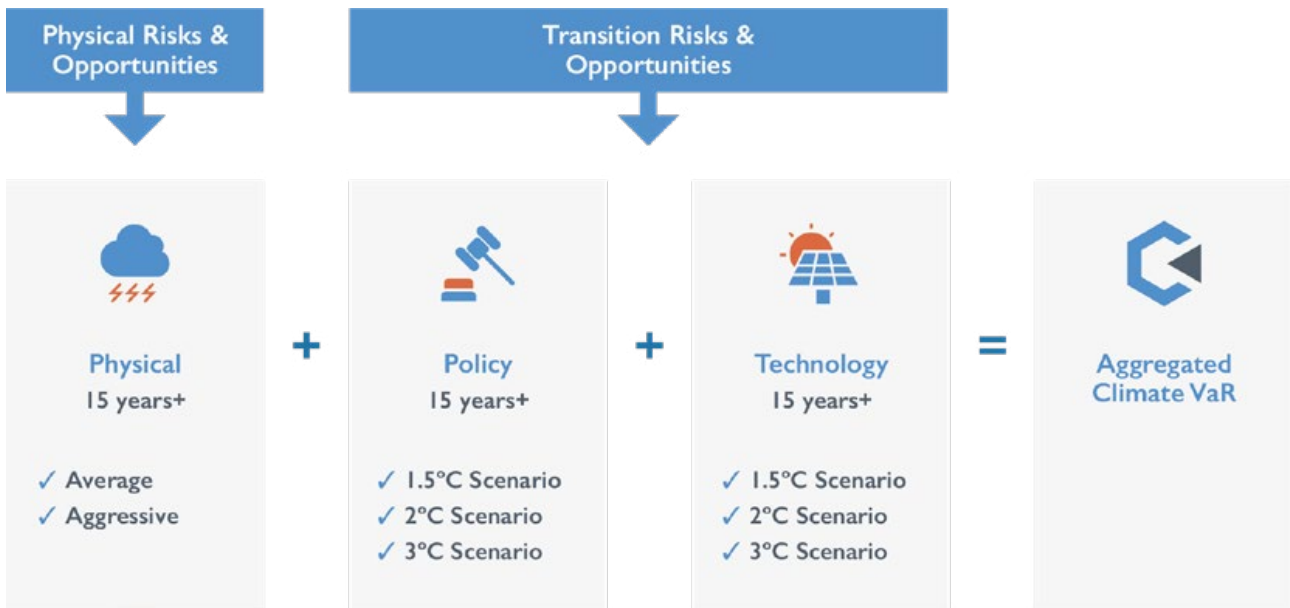
13. This section was authored by Carbon Delta and compiled by Vivid Economics

14. The term 'risk' is used in the Carbon Delta methodology to encompass both positive opportunities and negative outcomes that could potentially arise as a result of climate change.

average scenario refers to the expected value of the cost distribution under BaU. The aggressive scenario is derived from the 95th percentile of the cost distribution for BaU and explores the unlikely but extreme potential outcomes of a climate scenario.

- **The transition risk analysis considers four scenarios: 3°C, 2°C and 1.5°C, and BaU (or 4°C) scenario.** The three temperature scenarios were chosen for due to their central roles in international climate change negotiations.. What is currently committed as part of the NDCs to the Paris Agreement is consistent with a 3°C scenario. The ‘well below 2°C’ is internationally agreed goal under the landmark Paris Agreement, the 1.5°C target gained prominence after the October 2018 IPCC report. The key differences between these three temperature scenarios are the ‘carbon budgets’ that the global economy is permitted to release into the atmosphere. These scenarios are compared with the BaU baseline scenario, which is aligned with 4°C which takes into account historical emissions data and assumes that no action is taken to reduce carbon emissions. Figure 9 summaries the scenarios considered within physical risk and transition risk.

Figure 9: Carbon Delta assesses climate risk across two main pillars; transition effects and physical impacts



Source: Carbon Delta

In transition risk analysis, Carbon Delta utilises forecasts of future carbon prices from three IAMs to calculate the costs on companies under various scenarios. The IAMs used are:

1. **Regional Model of Investments and Development (REMIND).** REMIND is a global multi-regional model incorporating the economy, the climate system and a detailed representation of the energy sector. It allows for the analysis of technology options and policy proposals for climate mitigation. The REMIND model was developed by the PIK in Germany.
2. **Integrated Model to Assess the Global Environment (IMAGE).** IMAGE is an ecological–environmental model framework that simulates the environmental consequences of human activities worldwide. It represents interactions between society, the biosphere and the climate system to assess sustainability issues such as climate change, biodiversity and human well-being. The IMAGE modelling framework has been developed by the IMAGE team under the authority of PBL Netherlands Environmental Assessment Agency.
3. **The Global Change Assessment Model (GCAM).** GCAM is a dynamic-recursive model with technology-rich representations of the economy, energy sector, land use and water linked to a climate model that can be used to explore climate change mitigation policies including carbon taxes, carbon trading, regulations and accelerated deployment of energy technology. The JGCRI is the home and primary development institution for GCAM based in the US.

3.2. PHYSICAL IMPACT ASSESSMENT

The Carbon Delta methodology models two types of physical climate risk: **chronic risks**, which manifest slowly over time, and **acute risks**, which are the result of **extreme weather events such as tropical cyclones**. This methodology covers the economic impacts due to asset damage and business interruption, but not those related to supply chain risks or potential business opportunities to, for example, the insurance sector or those that provide adaptation technology. Impacts are estimated under a BaU scenario, rather than different policy scenarios. More extreme physical risks are covered in the aggressive scenario. Assessment methodologies for chronic and acute risks are discussed in turn below.

3.2.1. Chronic risks

Impacts from chronic risks manifest primarily through business interruption, due to reduction in labour productivity and availability, or changes in the efficiency of production processes. The Carbon Delta methodology considers the effects of business interruption for five climate hazards: extreme heat, extreme cold, heavy precipitation, strong snowfall, and severe wind conditions. Carbon Delta uses a global historical dataset covering the last 39 years from the European Centre for Medium-range Weather Forecast's ERA Interim Reanalysis project to assess the impact of these hazards. Historical data is used to project an annual distribution of the relevant climate variables under a BaU scenario for the coming 15-year period.

The annual cost of business interruption is then estimated according to the number of days on which the hazard intensity exceeds a relevant threshold. The methodology assumes that a fixed proportion of revenue, specific to each sector, is lost on each of these days. Based on scientific publications in combination with information from media reports, Carbon Delta has established a comprehensive matrix of vulnerability factors that translate exceedances to monetary cost. The vulnerability matrix covers all hazard types and defines specific factors for 31 distinct extreme weather sectors and subsectors, provided in the Appendix II.

Furthermore, a regional vulnerability reduction that reflects adaptation to the regional climate is incorporated. The rationale behind this reduction is that the vulnerability to weather extremes is lower in regions where these events are frequent, and the local businesses are experienced in dealing with the consequences. For example, in equatorial regions, days with temperatures over 30°C are more common and therefore there are more likely to be local adaptations to such events. Being a function of the number of annual threshold exceedances, the reduction amounts up to 50% in regions where thresholds are frequently exceeded. Thus, the cost of business interruption per sector and extreme weather type is calculated as:

Cost = number of exceedances × vulnerability × vulnerability reduction × optimal revenue

The impact of climate change on (chronic) physical risks is determined by the change of cost ('delta cost') in relation to a base year. It is important to note that today's climate has already undergone significant changes due to anthropogenic GHG emissions. Looking forward, it is crucial to determine only the projected difference between today's climate and the future climate. Carbon Delta would consider that today's climate with its current profile of physical hazards and exposures is already priced into companies' expectations. Accordingly, the delta of the costs in any given year is calculated as:

Delta cost = cost future year – cost base year

Since both the current (base year) and the future cost (future year) are modelled, a cost reduction over time will manifest as a net gain. An example of this is the relationship between extreme cold and company performance. As large areas of the northern hemisphere are projected to experience a significant temperature increase, cold extremes become less frequent and the corresponding costs are reduced.

3.2.2. Acute risks

Acute climate risks occur from rare natural catastrophes in distinct time intervals and are modelled using physical climate models. Acute physical risks that manifest in the form of catastrophic events such as coastal floods or tropical cyclones are modelled in much greater detail because there is a better understanding of these risks, which have historically been the focus of the insurance industry.

Tropical cyclones

Projections of the future frequency and intensity of tropical cyclones are obtained from the open source natural catastrophe model CLIMADA. The current figures are based on the RCP 4.5 scenario. However, they are strongly aligned with alternative scenarios as differences are small for the same 15-year time frame.

CLIMADA is also used to quantify the severe wind and flood damage caused by tropical cyclones. The model is based on a similar insurance model and is currently maintained by ETH Zurich. CLIMADA uses a stochastic tropical cyclone generator based on an extensive dataset of historical storms. For each business location the distribution of wind speeds is evaluated and combined with regionally calibrated damage functions to obtain a distribution of asset damage costs.

The economic impact of tropical cyclones is quantified as the amount of damage done to fixed assets. The damage expected annually for each business location is calculated as the product of the value of the facility, and the proportion of damage expected. The asset value of enterprise locations is proxied by reported gross fixed assets, and the expected damage as a percentage can be extracted from CLIMADA. The cost delta is again estimated as the difference between future and current costs.

Coastal flooding

The Carbon Delta methodology models both the asset damage and business interruption impact of coastal flooding. In order to determine flood damages, the inundation of an asset at a given site is modelled depending on the local topography and the statistical distribution of extreme sea levels at the coast. The Carbon Delta methodology employs a bias-corrected version of the global digital elevation model SRTM to determine if an asset will be reached and subsequently inundated by a flood event. It then combines the height of the inundation at the asset site with depth damage functions to determine the fractions of asset damage and duration of business interruption.

The occurrence and intensity of flood events is modelled via a Poisson process and extreme value statistics, respectively. Local flood protection levels are incorporated into the model via the related return period of the design flood height. Wherever possible, specific information on the protection height is employed. In the absence of such information, protection against the level of a flood with a 100-year return period is assumed.

For future years, the local distributions of extreme sea levels are shifted according to the expected regional sea-level rise. The shift typically translates into more frequent and intense flood events. The methodology makes use of a large ensemble of sea-level rise scenarios also given in the IPCC's 5th Assessment Report.

The total annual cost of coastal flooding is a combination of asset damage and business interruption cost. The cost of asset damage is the product of annual asset damage and asset value. The extra cost of business interruption is the share of revenue lost due to flooding. Thus, the total cost is given as:

$$\text{Cost} = \text{annual damage} \times \text{asset value} + \text{annual share of revenue lost due to business interruption} \times \text{annual revenue}$$

The cost delta is again estimated as the difference between future and current costs.

Box 2 outlines the methodology for physical impacts on real estate assets.

Box 2: Physical impacts on real estate assets

- Carbon Delta uses the same methodology to assess physical risk for real estate as it does for company assets. It covers the effects of extreme heat, extreme cold, coastal flooding, tropical cyclones and extreme wind for commercial and residential buildings.
- Total yearly damage is calculated as:
- Number of extreme events x percentage of building damaged per event x gross value of building
- Estimates of vulnerability to damage (the percentage of a building damaged per event) come from CLIMADA for tropical cyclones and coastal flooding, and from PIK for extreme wind.
- In addition to physical damage, for extreme heat and cold, the cost of heating and cooling is determined by defining a cost of exceeding a specific temperature threshold (>30°C and >35°C, and <-10°C and <0°C, respectively)
- The total cost of physical risks is the sum of additional heating/cooling costs and damage costs. Total present value of the lifetime cost is estimated as discounted total cost over 40 years (for commercial buildings) or 60 years (for residential buildings) from the last retrofit. The discount rate is 8%.
- Physical Value at Risk is the present value of cost in relation to gross asset value.

3.3. ASSESSMENT OF TRANSITION RISKS AND OPPORTUNITIES

This section focuses on the risks and opportunities that arise from transitioning to a low-carbon economy. Although complying with emission reduction policies will certainly impose a significant financial cost for some companies, the transition to a low-carbon economy also provides untapped growth potential for others. This section describes Carbon Delta's methodology for quantifying the potential policy risks and technological opportunities associated with a range of future decarbonisation pathways.

3.3.1. Policy risk

The Carbon Delta methodology for assessing transition policy risk begins with the quantification of country- and sector-level GHG reduction targets defined by the NDCs and aligned with the REMIND model. The modelling begins with the quantification of country-level GHG emission reduction targets embedded within the NDCs of the Paris Agreement, which would lead to approximately 3°C of warming above pre-industrial levels. These targets are then broken down into sector-level targets based on details within the NDCs as well as recently proposed national-level climate regulations.

Country- and sector-level targets in the 2°C and 1.5°C scenarios are calculated by amplifying the emission reduction targets in the NDC-compliant 3°C scenario, maintaining the sectoral distribution of the target. The baseline 3°C scenario uses current country-level emissions from the World Resources Institute (WRI), forecasting BaU levels in 2030 according to UNEP Risoe and other external sources.¹⁵ These forecast emissions levels are then linearly downscaled to meet 1.5°C- and 2°C-compliant levels in line with the UNEP Gap report (UN Environment, 2018a).

Carbon Delta's company production facility database is used to further disaggregate sector-level targets to the company level. Sector-level targets are assigned to individual company facilities, and then aggregated up to company level in order to establish each company's 'reduction requirement'. Carbon Delta refers to this as a top-down and bottom-up hybrid methodology.

15. External sources include national emissions forecasts, the PIK, the WRI as well as the United Nations Environment Programme (UNEP) Risoe Centre on Energy, Climate and Sustainable Development.

The company-level costs associated with meeting the emission reduction targets, and the resulting policy risk CVaR, are calculated using estimates of future carbon prices. These estimates are calculated using various IAMs Integrated Assessment Models (IAMs) exploring different assumptions, as detailed in Section 3.1.

Country- and sector-level reduction requirements

NDCs are first normalised across countries in order to arrive at consistent and comparable country-level reduction targets. Although NDCs provide a range of information about a country's GHG reduction targets, they are not always directly comparable across countries. Some NDCs are expressed in terms of absolute emission reductions, while others are expressed in terms of emissions intensity in relation to the country's future GDP. The base year and the target year also usually differ across countries. Importantly, there is a 'conditional' component to some NDCs, which hinges on the available climate finance flows and cooperation between countries. Where there is no specific information on whether a conditional target is likely to be enforced, the methodology assumes a 50% enforcement rate for the conditional target.

The sectoral burden-sharing of national targets is inferred from information in the NDCs. Governments have a history of distributing national emission reduction targets across sectors, considering the circumstances of a country's (or region's) economy. For example, the process of initial allocation of allowances in the EU ETS was highly differentiated by sector, considering issues of competitiveness, 'carbon leakage' and potential impacts on the labour market. This pattern is present in NDCs, which often disclose details about the pathway to achieving the national emission reduction targets. In some cases, the NDCs include an explicit sectoral breakdown of the emission reductions; in other cases, the burden-sharing must be inferred from the details of the policy initiatives included in the NDC.

Company-level reduction requirements

Sector-level targets are disaggregated to company level using a 'fair share' principle, under which companies are responsible for reducing their emissions in proportion to their share of the sector's carbon footprint. In this case, the carbon footprint is the level of Scope 1 GHG emissions as per the WRI/World Business Council for Sustainable Development GHG Protocol. Carbon Delta calculates total sector-level emissions for each country using a third-party-verified dataset—specifically, a combination of the National Inventory data submitted to the Kyoto Protocol to the UNFCCC, and the IEA's World Energy Statistics database.¹⁶ The methodology allocates the GHG emissions to company facilities according to their size, location, production capacity, number of employees and revenue market share in the sector.

A company's share of sectoral GHG emissions (equivalent by assumption to their revenue market share) is assigned to individual facilities using Carbon Delta's global database of company facilities. The database has been developed through months of data gathering and data augmentation, integrating several commercial databases and systematic web-crawling and using a proprietary function that combines multi-regional input-output (MRIO), sales data, production capacity, specific location, size and number of employees. The data covers more than 600,000 facilities and contains information on estimated sales, annual GHG emissions, sector and ultimate owner, amongst other fields. Carbon Delta uses this information to estimate facility-level GHG emissions and then aggregate facility level data up to each global company who owns the facilities.

16. The National Inventory data covers GHG Scope 1 emissions from the energy, industrial processes, agriculture, transport, commercial, residential and other sectors in the years 1990 to 2014 for the 42 Annex 1 countries. The IEA's World Energy Statistics database provides production-based sectoral emissions data for all non-Annex I parties as well as annual energy statistics data for 170 countries and regional aggregates.

Translating emission reduction targets to financial costs

To calculate a company's costs associated with reaching emission reduction targets, Carbon Delta uses carbon price estimates from IAMs. To estimate annual emission reduction costs, Carbon Delta accumulates the GHG reduction requirements per company over the next 15 years on an annual basis and multiplies the reduction amount with the carbon price estimates produced by the REMIND, IMAGE and/or GCAM models. This results in an estimated cost associated with reaching a reduction goal, such as the 3°C scenario, in each sector and country over 15 years. The formula is as follows:

Total cost = required GHG reduction amount × price per tCO₂e

Box 3 outlines the methodology for transition impacts on real estate assets.

Box 3: Transition risk impacts on real estate assets

- Buildings play a crucial role in the decarbonisation of countries as they are a key driver of final energy consumption and a significant source of GHG emissions.
- Carbon Delta computes the cost of meeting reduction targets for each facility, combining building specific estimates of emissions and energy consumption with carbon prices from PIK's REMIND model.
- Similar to company-level estimates of transition risk, building-level reduction targets are estimated using a top-down approach of disaggregating countries' NDCs for 3°C and 2°C scenarios. For the 1.5°C scenario, all buildings are assumed to reach carbon neutrality by 2050. A 'floor area growth' factor is added to the building-level requirement since it is assumed that floor area will increase in the future, thereby increasing the reduction requirement.
- Each building's BaU emissions trajectory is calculated using self-reported Scope 1 and 2 emissions, and country- and building type-specific emissions intensity reduction pathways. Where self-reported emissions are not available, a benchmark is assumed based on the start of the reduction pathway.
- The difference between the target and BaU trajectories is the required emission reduction.
- Annual cost is calculated as the emission reduction multiplied by the PIK carbon price for the appropriate scenario. The total present value of the lifetime cost is estimated as discounted total cost over 40 years (for commercial buildings) or 60 years (for residential buildings) from the last retrofit. The discount rate is 8%.
- 1.5°C, 2°C and 3°C Policy Value at Risk is the present value of cost in relation to gross asset value.

3.3.2. Technology opportunities

The Carbon Delta methodology uses patents filed as a proxy for companies' low-carbon innovative capacity in order to identify potential beneficiaries in a world with strict climate policies. Patent databases allow an evidence-based view of which firms will be the likely beneficiaries under 3°C, 2°C or 1.5°C climate policy scenarios. Patent application data is first extracted from 40 national patent offices using the PATSTAT database, then filtered for those that were successful in the category of low-carbon technologies. The model currently examines 65 million unique patents that have been granted from 40 patent authorities worldwide. Carbon Delta uses machine learning techniques to match patent data to companies.

Patents are assessed for quality and assigned a score based on four measures developed in collaboration with the Swiss Federal Institute of Intellectual Property:

1. Forward citations – the number of times the patent has been cited by other patents. This increases the patent's value.
2. Backward citations – the number of times the patent refers to other, older patent technologies. This reduces the patent's value.

3. Market coverage – the size of the market (or jurisdiction) that the patent was granted protection in, scaled by GDP. Therefore, the higher the GDP of total market filing, the higher the patent value.
4. The Cooperative Patent Classification system coverage – this tags patents into relevant groups (such as Construction, Electricity, Emerging Technologies) and subgroups. The higher the number of patent groups tagged, the higher the value.

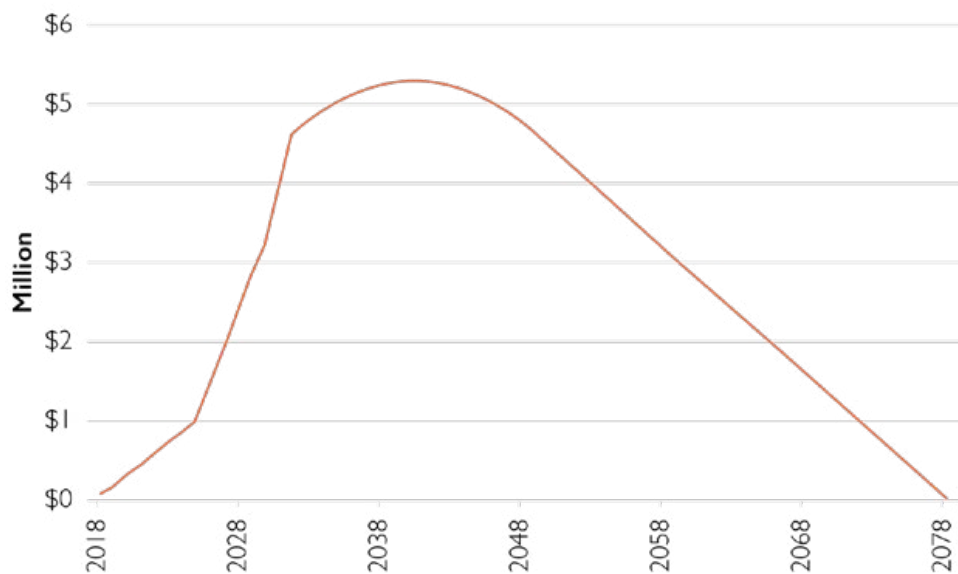
Each company's green profit potential is then forecast for the next 15 years based on patent value, sectoral green revenue and the company's current profit margin. The value of each patent is assessed on the basis of: (i) the quality of the patent (as above); (ii) the date of granting the patent (assuming a 20-year holding period); and (iii) its emissions sector. For each company, the aggregated patent value in each emissions sector represents the share of the technology opportunities it has. Green revenues are subsequently calculated by multiplying the company's low-carbon patent value share of patents in the emissions sector with the total green revenues in this emissions sector. The total green revenues in a sector are equal to the total policy costs in the sector, as calculated in Section 3.3.1 on policy risk. This is based on the idea that green revenues are in essence a shift of the reduction costs to revenue for companies which license or produce low-carbon technologies. Green revenues are converted to green profits by multiplying the revenues by the emissions sector's profit margin. For example, assume Company C's patents in the 'high tech manufacturing' sector obtain a score of 1.243 based on the four criteria described above. Then suppose this sector as a whole has patents with a total score of 3,401 in 2019, making Company C's patents value share 0.037%. Company C's green revenue in 2019 is then 0.037% of the total policy risk cost in the high tech manufacturing sector (say, USD 39,134,411). Finally, its green profit is green revenue multiplied by its profit margin. The green profit is calculated similarly for the next 15 years, to 2033, and then aggregated as outlined in Section 3.4.

3.4. AGGREGATING IMPACTS TO THE INVESTOR PORTFOLIO

3.4.1. Portfolio Climate Value at Risk

The Carbon Delta methodology starts by calculating the climate costs/profits incurred by an enterprise over the next 15 years, for each climate change transition scenario (1.5°C, 2°C, 3°C or 4°C) and each model (physical risks, policy risks and technology opportunities) under consideration. After modelling the next 15 years, the Carbon Delta methodology assumes that such climate costs or profits will grow until middle of the century, eventually peak, and then decrease linearly to zero before the end of the century, at a point when scientists require carbon neutrality to reach the selected scenario objective, as illustrated in Figure 10 below. This is related to the fact that costs or profits related to emission reductions will be highest when the greatest reductions are required and then decrease as emissions fall and eventually reach zero.

Figure 10: Carbon Delta calculates climate costs and profits over the next 15 years, then assumes a linear decline



Source: Carbon Delta

This time series of climate costs and green profits is then discounted to present value. The discounting factors are in line with the current weighted average cost of capital (WACC) of the enterprise, obtained from Bloomberg or Reuters. In the first few years the discounting factors used are essentially the WACC of the enterprise, and in later years correspond more to a sector average of WACC values in order to make the model more robust and stable to short-term fluctuations of the enterprise's WACC.

To compute the CVaR of the enterprise, Carbon Delta divides the present value of future costs or profits by the market value of the enterprise. The formula used is as follows:

$$\text{CVaR}_{\text{Enterprise}} = \frac{\text{Present value of climate costs or profits}}{\text{market value of enterprise}}$$

Where the market value of the enterprise is computed as the sum of the market values of the equity and debt of the enterprise.

In addition to an enterprise-wide CVaR, Carbon Delta also calculates an equity CVaR and a debt CVaR for each enterprise. These correspond to the value at risk for the equity and debt holders of the enterprise. It therefore makes sense to understand how much the present value of future climate costs or profits impacts equity holders, and how much it impacts debt holders. In order to do this, the methodology makes use of a structural model of credit risk known as the Merton model. This was developed in the 1970s and is the starting point of many credit risk models used by financial institutions and rating agencies today. In simple terms, the Merton model considers certain fundamentals of the enterprise (for example, the market values of equity and debt, the average maturity of the debt and a measure of equity volatility) as well as the present value of climate costs or profits computed by Carbon Delta, and outputs a split of these costs or profits into equity and debt costs or profits. The equity and debt CVaRs of the enterprise are then computed as follows:

$$\text{CVaR}_{\text{Equity}} = \frac{\text{equity climate costs/profits}}{\text{market value of equity}}$$

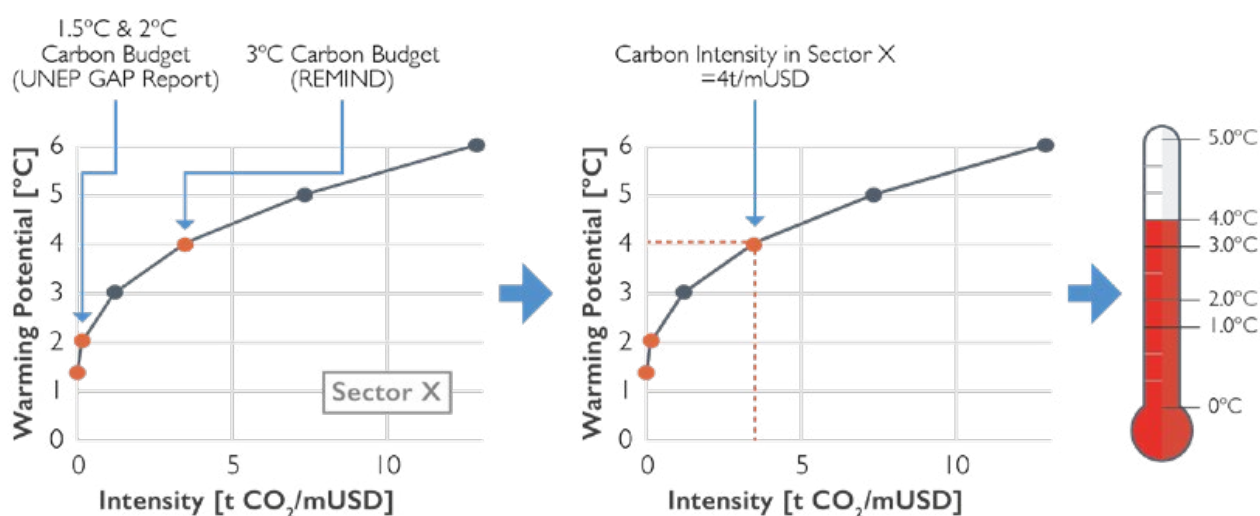
and

$$\text{CVaR}_{\text{Debt}} = \frac{\text{debt climate costs/profits}}{\text{market value of debt}}$$

3.4.2. Portfolio warming potential

The final element of the portfolio-level impact assessment is the measurement of the portfolio's warming potential, which is based on a company-level assessment of emissions intensity relative to various targets. Carbon Delta associates each company with the temperature with which its emission intensity trajectory for the company most corresponds, assuming emissions intensities stay constant over the next 15 years. Carbon Delta determines the relationship between emissions intensity and temperature by sector and uses this relationship to estimate a company's sectoral warming potential. Figure 11 summarises how the warming potential is calculated for a fictional company in Sector X. The remainder of this section explains the underlying computational steps in detail, as well as the method for aggregating sectoral warming potentials first to the company as a whole, then to the entire portfolio.

Figure 11: Schematic display of Carbon Delta's warming potential calculation



Note: Monetary figures in this chart refer to annual revenue

Source: Carbon Delta

The methodology starts by determining sectoral warming functions, which are defined by the relationship between the carbon intensity and the temperature outlined implicitly by carbon budgets associated with different temperature targets. Values that stem from this relationship may in principle be infinitely small or large. Thus, the methodology prescribes minimum and maximum values. The minimum temperature, regardless of sector, has been set to 1.3°C. The IPCC states that *'the globally averaged combined land and ocean surface temperature data as calculated by a linear trend show a warming of 0.85 [0.65 to 1.06]°C over the period 1880 to 2012 [...] the unrealized global warming is about 0.6°C without any further increase in radiative forcing'* (IPCC, 2014a). The maximum temperature is set to 6°C, which is a worst-case warming scenario by the year 2100 that is cited by the IPCC among other leading climate scientists.

Company sectoral carbon intensities are then used to determine a company's temperature alignment in that sector. A company's sectoral emission intensity i is estimated by the following formula:

$$i_{\text{sector}} = \frac{\text{Emissions}_{2030}}{\text{Revenue}_{2030} + \text{Green Revenue}_{2030}} \quad [\text{tCO}_2/\text{US\$ million}]$$

This formula divides a company's sectoral emissions in 2030 by the sum of its current revenue and green revenue in that sector in the same year. The result would be the same if all numbers were expressed in 2018 terms, as an annual growth rate of 3% is assumed for emissions and revenues over the period 2018–30. This emissions intensity by sector can then be used to obtain the company's sectoral warming potential from the relevant curve.

To arrive at the company’s sector-wise warming potential, these sector-specific warming potentials are weighted by the company’s share of total revenue coming from that sector. For each sector in which the company is active, the sector-specific warming potential is calculated as above. To arrive at the company’s sector-wise warming potential T , the following formula is used:

$$T_{\text{sector-wise}} = \sum_{\text{sectors}} \frac{\text{Revenue}_{\text{sector}} + \text{Green Revenue}_{\text{sector}}}{\text{Revenue}_{\text{company}} + \text{Green Revenue}_{\text{company}}} \times T_{\text{sector}}$$

The methodology further calculates a company’s sector-agnostic warming potential, which does not account for the sector the emissions are generated in. A company’s sector-agnostic emissions intensity is calculated as its total emissions divided by its total revenue. This emissions intensity is then used to extract the warming potential from a sector-agnostic curve.

The combined warming potential is assumed to be the average of the sector-level and sector-agnostic warming potential. For example, if a company is active only in the transportation sector and has a sectoral warming potential of 3.6°C and a sector-agnostic warming potential of 6°C, its overall warming potential is 4.8°C.

To arrive at the portfolio warming potential, companies in the portfolio are assessed for their warming potential as above, and a position-weighted warming potential is calculated.

3.5. INNOVATIVE ELEMENTS, GAPS AND NEXT STEPS

This section summarises the Investor Pilot Group’s understanding of the innovative elements of and gaps in the Carbon Delta methodology, as well as Carbon Delta’s perspective on next steps for the CVaR methodology. While investors provide reflections on their individual experiences with the Carbon Delta methodology in the case studies in Section 5, this section provides a high-level summary of the feedback received for Carbon Delta over the course of the Investor Pilot Project in Table 1. It also provides Carbon Delta’s perspective on future improvements to its evolving product offering in Box 4.

Table 1: Key innovative elements, gaps and next steps for the Carbon Delta methodology

Category	Component	Innovative elements	Gaps
Physical risk	Scenarios	Inclusion of both ‘average’ and ‘aggressive’ physical scenarios under BaU	Analysis of physical impacts across different policy scenarios over longer time frames
	Risk assessment methodology	Construction and use of business interruption dataset by sector Demonstration of high degree of geographical variation in physical risk Inclusion of a range of physical risks: extreme heat, extreme cold, heavy precipitation, strong snowfall, severe wind conditions, coastal flooding and tropical cyclones	Accounting for facility-specific risk reduction measures or adaptive capacity Distinction between temporary disruptions and long-term effects of extreme weather events Incorporation of additional hazards, such as droughts, landslides, river floods and others
Transition risk	Scenarios	Inclusion of a range of policy ambitions: 1.5°C, 2°C and 3°C from multiple models	Carbon prices from these models lose the nuance of different policy instruments and their effects Regional carbon prices in the model do not capture the potential differentiation in policy ambition across regions

Category	Component	Innovative elements	Gaps
	Risk assessment methodology	<ul style="list-style-type: none"> Reliance on granular physical location database for policy risk exposure assessment Use of patent data for evaluation of green opportunities Examination of transition risk for real estate assets 	<ul style="list-style-type: none"> Extension to Scopes 2 and 3, including analysis of product substitutability, cost pass-through and abatement potential Bottom-up analysis of the local risks of energy efficiency retrofitting regulation for real estate assets may be more relevant to real estate than emission reduction requirement analysis Patent-based quantification of green opportunities may be skewed towards certain regions and sectors with higher patenting rates
Aggregation	Portfolio-level impact estimation	<ul style="list-style-type: none"> Use of Merton model to disaggregate equity and debt impacts Use of company-specific WACCs Provision of temperature gauge for portfolios in addition to the CVaR 	<ul style="list-style-type: none"> Climate-related risks and opportunities may lead to structural shifts in WACCs

Source: Investor Pilot Group interviews, consultation with Carbon Delta

Box 4: Next steps for the Carbon Delta methodology

- Analysis of climate risk exposure in the supply chain
- Integration of Scope 2 and 3 emissions data into Carbon Delta's models
- Extension of the number of scenarios available for investors with a focus on longer time horizons (utilising Carbon Delta's existing back-end modelling to year 2100)
- Continuation of identification of companies that are climate innovators
- Assessment and integration of data relating to companies' utilisation of renewable energy
- Further expansion of the facility- and asset-level database
- Publication of a follow-up report on real estate elaborating on next steps of this methodology

4. COMPARING CLIMATE VALUE AT RISK ACROSS 1.5°C, 2°C AND 3°C WORLDS¹⁷

Applying the Methodology for Portfolio Analysis

Despite the infancy of leveraging climate scenario analyses for investment decision making, scenario analysis brings to light useful and substantial results that reinforce the need to understand the impact of climate change on investment portfolios more thoroughly. This can yield valuable investment insights with regards to climate-related materiality analysis. It is important to point out that scenario analysis is neither a forecast nor sensitivity analysis. Instead, scenario analysis sheds light on possible futures. For instance, how transition and physical¹⁸ impacts affect an investor's portfolio under a 1.5°C, 2°C, 3°C or 4°C warming world by the end of the century. Furthermore, to what extent investors could face increasing risk levels if policy actions get delayed or if extreme weather impacts reach the upper bounds of estimated ranges.

This chapter highlights results derived from a case study on four portfolios:

- a Market Portfolio of 30,000 companies¹⁹
- a Top 1,200 Companies Portfolio that closely mimics the MSCI World Index²⁰
- a Coal Portfolio, and
- a Renewable Energies Portfolio

The analysis aims to provide insights as to how results can differ greatly depending on the composition of individual portfolios. The analysis is presented first on overall portfolio-level and then further broken out to sector-level analysis to shed light on the portfolio's climate hot spots.

This portfolio analysis section is then followed by Case Studies from participating investors of the UNEP FI TCFD Pilot. In this section, the individual participating investors present a range of scenarios and analysis relating to their unique portfolios, investment scenarios and assumptions which they had identified during the pilot phase.

The dataset of the case study analysis is based on Carbon Delta's analytical results as at the end of February 2019.²¹

17. This section was authored by Carbon Delta and compiled by Vivid Economics

18. There are distinct limitations to physical analysis under the timelines useful for investment decision-making. The modelling being limited to a time window of 15 years, within which the manifestation of physical impacts remain limited and similar between emissions pathways. It is beyond those 15 years that the physical impacts of climate change are forecasted to drastically intensify, especially under higher GHG emissions pathways including a 3°C one

19. Carbon Delta carried out this analysis on 30,000 companies equally weighted

20. Carbon Delta carried out this analysis on a portfolio constructed of the top 1200 companies by global market cap which is a representative and diversified investment universe for the participating investor group members

21. Carbon Delta's methodology and dataset is continuously improved and updated to follow the data releases of external data sources and providers. By way of example, Carbon Delta recently updated the computation of emission reduction targets in line with the 2018 annual UN Environment Emissions Gap Report (UN Environment, 2018a). This report indicates a more stringent 1.5°C target; thus, companies' reduction targets have now increased which has resulted in higher Climate Value-at-Risk numbers as well. Carbon Delta's methodology hence is based on the most up-to-date climate data available in the market.

4.1. THE MARKET PORTFOLIO

Overall, climate change is a material risk which will affect the future performance of investment portfolios

Analysis of a 'Market Portfolio' which consists of approximately 30,000 publicly listed companies and represents the investable market at large highlights climate-related investment risk. The 1.5°C scenario, in line with the latest IPCC special report, exposes a significant amount of transition risk, affecting as much as 13.16% of overall portfolio value (Table 2: Policy Risk, 1.5°C). Considering that total assets under management for the largest 500 investment managers in the world total USD 81.2 trillion,²² this would represent a value loss of USD 10.68 trillion.

The good news is that companies have already actively started working on the transition to a low carbon economy. The resulting creation of low carbon technology opportunities therefore offsets this high policy risk noticeably (Table 2: Technology Opportunity, 1.5°C). The physical risk impact is negative at -2.14%²³ and would increase further, if the world is not successful in curbing GHG emissions significantly over the next two decades.

Of extreme importance are distinct limitations to physical analysis under the timelines useful for investment decision-making. This modelling is limited to a time window of 15 years, within which the manifestation of physical impacts remains limited and similar between emissions pathways. It is beyond those 15 years that the physical impacts of climate change are forecasted to drastically intensify, especially under higher GHG emissions pathways of 3°C and beyond. Therefore, although analysis results for physical risk look similar across the scenarios for the first 15 years shown, much higher costs for physical risk for high warming scenarios (3°C and beyond) out to 2100 should be anticipated when interpreting CVaR at the aggregate level.

Overall, considering that low carbon technology opportunities will help offset the policy risk, and physical risk is minimal for the reasons mentioned above, the total, aggregated value loss under the 1.5°C scenario is substantial at -4.56% or USD 3.7 trillion off the assets of the world's 500 largest investment managers.

The results for the 2°C and 3°C scenarios are further outlined in Table 2 below.

Table 2: Results for the Market Portfolio of 30,000 companies

Model	Degree Scenario	Policy Risk [%]	Physical Risk [%]	Technology Opportunity [%]	Aggregated Climate VaR [%]
REMIND with Average Climate Model	1.5°C	-13.16	-2.14	10.74	-4.56
	2°C	-8.16		6.94	-3.36
	3°C	-2.89		3.21	-1.84

Source: Carbon Delta

Deeper insights into the true climate impacts of this market portfolio are presented below by breaking out the analysis further to sector-level.

22. Willis Towers Watson, 2018

23. As discussed in the previous section, there is little differentiation between scenarios for physical impacts since actual costs are computed over a 15-year time horizon

Utilities, Transportation and Agriculture sectors are undergoing the greatest transformation

Table 3: Sector-level results for Policy Risk illustrate the range of climate-related impacts across the portfolio

Degree Scenario		Agriculture	Services	Manufacturing	Mining & Petroleum Refining	Other Industry	Transportation	Utility Service
	No. of Equities	301	16067	11728	1105	1070	264	713
1.5°C	Sector Average for equities in portfolio [%]	-82.5	-6.6	-16.4	-22.4	-10.7	-61.1	-50.6
	CVaR Contribution [%]	6.0	25.8	46.7	6.0	2.8	3.9	8.8
2°C	Sector Average for equities in portfolio [%]	-68.2	-3.8	-9.9	-12.5	-6.4	-39.6	-35.3
	CVaR Contribution [%]	8.1	24.2	45.7	5.4	2.7	4.1	9.9
3°C	Sector Average for equities in portfolio [%]	-37.9	-1.4	-2.9	-4.4	-1.9	-16.8	-16.3
	CVaR Contribution [%]	12.6	23.9	38.1	5.4	2.2	4.9	12.8

Source: Carbon Delta

Table 3 presents the Policy Risk for each scenario (1.5°C, 2°C and 3°C) and shows the weighted average CVaR (%) for each sector, as well as the sector contribution to the overall CVaR and the total number of companies in the sector. Drilling down the analysis to sector-level highlights those industries that are exposed to a high degree of climate risk. Utilities, Transportation, Agriculture as well as Mining, Petroleum and Refining stand out.

The 1.5°C scenario outlines that the Agriculture sector is clearly undergoing the greatest transformation with Policy Risk at -82.5% and a sector contribution of 6%. Notable is also the manufacturing sector: although the overall climate-related risk is more moderate at only -16.4% this sector makes up almost half of the climate related investment exposure of the overall market portfolio (Table 3: 46.7% CVaR Contribution). For investment managers it is therefore crucial to analyse sector holdings carefully in order to identify those companies that will be successful in tomorrow's low carbon world. A concrete example would be a Utility company that has already changed its overall energy-mix to tilt more heavily towards renewable energies.

The Manufacturing Sector at large is driving low carbon innovation

Addressing climate change and limiting global warming requires economic policies to support the green energy transition. Low-carbon technologies are thus accelerated in a scenario where the world is more ambitious in reducing CO₂ emissions, in line with the latest IPCC report. This could translate into an increased potential in green revenues for companies, which in turn would help to incentivise the transition to a green economy. The analysis presented here highlights the great potential of low carbon technologies and the need to integrate transition opportunities into the analysis.

As outlined in Table 2, overall technology opportunities contribute +6.94% under the 2°C scenario. When adding up all green profits of this 30,000-company universe, this represents approximately USD 2.1 trillion in green profits. Green revenue opportunities, however, vary substantially between sectors. Table 4 presents the sector average (%), the number of companies in each sector as well as the sector's contribution to the portfolio's CVaR (expressed as Share of CVaR). Notably, the manufacturing sector which captures the highest sector technology opportunities at +16.6% also stands out with a share of 77% of overall climate related investment risk. The analysis therefore identifies the sector as a driving force

in the low carbon transition and notes it as crucial to be considered for the analysis and identification of green investment opportunities.

As defined for the purposes of this analysis, the Manufacturing Sector contains a diverse range of companies, such as producers of automobiles, smart grid systems and wind turbines but also information & telecommunication, electronic systems & equipment as well as automotive system manufacturers.

Table 4 presents the sector results at large under the 1.5°C, 2°C and 3°C scenarios.

Table 4: Sector-level results for technology opportunities illustrate the range of impacts across the portfolio

Degree Scenario		Agriculture	Services	Manufacturing	Mining & Petroleum Refining	Other Industry	Transportation	Utility Service
	No. of Equities	20	3414	5410	177	259	49	154
1.5°C	Sector Average for equities in portfolio [%]	5.3	3.9	15.0	9.0	14.5	1.0	9.4
	Share of CVaR [%]	0.36	15.36	77.02	1.84	4.06	0.02	1.34
2°C	Sector Average for equities in portfolio [%]	5.1	2.6	9.5	6.6	8.8	0.4	5.3
	Share of CVaR [%]	0.16	13.58	79.60	1.81	3.55	0.03	1.27
3°C	Sector Average for equities in portfolio [%]	5.0	1.3	4.0	2.9	4.4	0.1	2.5
	Share of CVaR [%]	0.10	12.77	78.40	3.64	3.64	0.05	1.40

Source: Carbon Delta

Delayed policy action results in increasing policy costs

Delaying the implementation of climate policies, in theory, will result in higher costs as companies would need to transition more suddenly. The Integrated Assessment Model GCAM4 SSP4 by the Joint Global Change Research Institute is based on the premise of “Delayed Action”. In Table 5, the results of GCAM4 are shown alongside those from REMIND which as a ‘middle-of-the-road scenario’ and as such, much closer aligned with the conservative assumptions of the well-known ETP model from the International Energy Agency (IEA).

Under the GCAM4 scenario the policy risk increases from -8.16% to -9.13%, potentially costing investors a difference of close to 1% if governments were to delay policy action. For this analysis, the sum of the overall discounted costs from policy risk for each company in this Market Portfolio, covering 30,000 companies, was compared the resulting cost impact for the two models. The costs are enormous; USD 4.3 trillion and USD 5.4 trillion, respectively. Delaying policy action under GCAM4 results in a cost increase of USD 1.2 trillion. Even worse, delaying action would not just increase policy risk, but also result in much greater physical impacts from extreme weather hazards (not included here).

Table 5 presents the overall results.

Table 5: Policy risk for a delayed and non-delayed scenario

Model	Degree scenario	Policy risk [%]	Policy cost
REMIND (immediate)	2°C	-8.16	4.3 trillion USD
GCAM4 SSP4 (delayed)	2°C	-9.13	5.4 trillion USD
Difference		-0.97	1.2 trillion USD

Source: Carbon Delta

Increasing levels of extreme heat will affect business operations in a major way

The physical risk impact of the seven extreme weather hazards analysed are enumerated in Table 6. Results for a well-diversified universe of 30,000 companies identifies increasing levels of extreme heat as the dominant risk affecting business operations in the future. There are many academic studies that have modelled how vulnerable industries are to increasing levels of heat, for example in the construction, food and agricultural sectors. Moreover, extreme heat may also have knock-on effects on employees themselves.²⁴ Coastal flooding is another hazard that affects business operations in a major way, causing significant damage to plants and office buildings.

Interestingly, precipitation risk comes out slightly positive under both the average change and aggressive change scenarios. This seems counter-intuitive at first sight when we read in the news that tropical cyclones are usually linked with heavy rainfalls. For example, during the 3 days that hurricane Harvey caused much destruction in the city of Houston, in excess of 1,000 millimetres of precipitation were measured, more rain than most cities in the world experience during a whole year. However, analysis shows that, particularly in Western Europe and North America, the trend towards drier climates increases actually results in reduced precipitation levels overall.

The table furthermore outlines that the Market Portfolio benefits from decreasing levels of extreme cold and snowfall. This is, for example, the case in southern parts of Canada where less snowfall will lead to less business interruption in such industries as Airlines.

In the process of aggregating from facility to company and finally to portfolio level the analysis considers spatial correlations between facilities of the same company and correlations between different hazards. Due to these diversification effects the overall physical VaR is indeed lower than the sum of all individual VaRs.

Finally, when considering the aggressive physical scenario, the overall risk impact increases slightly from -2.1% to -2.2%. This demonstrates once again the benefit of a well-diversified portfolio in hedging against climate-related physical risks.

Table 6: Physical Risk for the Average and Aggressive climate models and each specific weather hazard.

Physical hazard	Average climate [%]	Aggressive climate [%]
Impact from Physical Hazards	-2.1	-2.2
Extreme cold	0.5	0.4
Extreme heat	-2.3	-2.3
Precipitation	0.03	0.02
Extreme snowfall	0.04	0.04
Extreme wind	-0.01	-0.02
Coastal flooding	-0.3	-0.3
Tropical cyclones	-0.1	-0.2

Source: Carbon Delta

24. Seppänen, Fisk and Lei, 2006

Physical risk expected to be highest in the Services and Manufacturing sectors

Analogous to the transition risk analysis, sector analysis of the physical CVaR²⁵ shows that the risk is distinct for sectors with varying impacts on the overall portfolio. Table 7 presents the sector averages as well as the sector contribution to Climate VaR of the portfolio. The number of companies in the sector²⁶ are also presented to provide an understanding of the contribution of equities in each sector. The results show that the Transportation, Construction and Agriculture sectors have the highest absolute physical risk with 3.9%, 3.3% and 3% respectively, while asset locations in the Services and Manufacturing sectors are predominantly affected by physical risk in the portfolio, with contributions 50.3% and 35.2% (Table 7, Share of CVaR).

Table 7: Physical Risk for the average scenario by sector and contribution

Degree Scenario		Agriculture	Services	Manufacturing	Mining & Petroleum Refining	Construction	Transportation	Utility Service
Average	Sector Average Physical Risk for equities in portfolio [%]	-3.0	-2.2	-2.2	-2.4	-3.9	-3.3	-2.1
	No. of Equities	163	10,960	7,553	756	713	208	484
	Share of CVaR [%]	1	50.3	35.2	3.9	5.9	1.5	2.2

Source: Carbon Delta

The Eastern & Western United States are heavily affected by increasing levels of heat while Indonesian and Eastern Chinese company facilities are exposed to high flooding risk

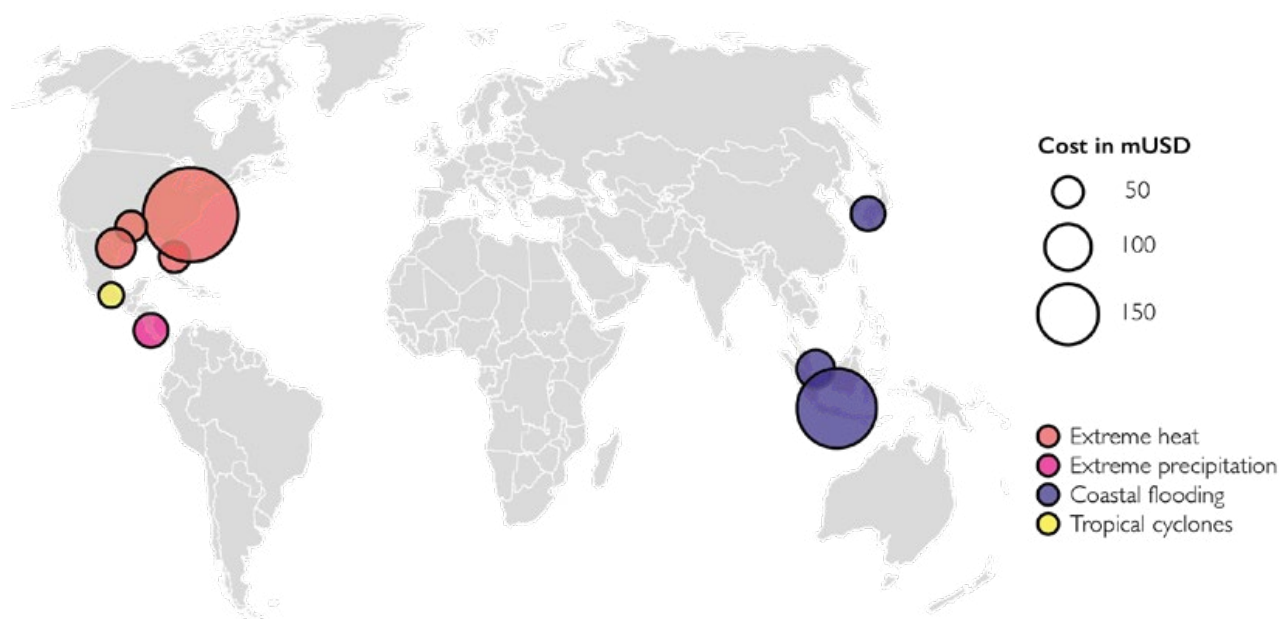
Breaking down the physical risk analysis to facility-level helps investors to understand the direct impacts from physical hazards and gain further insights about the effect of climate change on the portfolio's asset locations.

Figure 12 demonstrates that certain locations are exposed to considerably increasing levels of extreme heat, as for example the Eastern part of the United States, while coastal flooding is a major risk in South East Asia and China. Safeguards to operations from adapting business practices or adopting resilient technologies could limit costs but due to a lack of available data are not considered in the physical risk analysis model applied. The individual location results in Table 7 showcase a production facility of a leading US healthcare company is exposed to above average extreme heat risk, which could lead to costs of USD 150 million for one location alone. Another major oil producer has one facility exposed to flooding risk in Indonesia, which could lead to costs of USD 125 million.

25. For detailed description of what the physical risk implies for each sector, please refer to Section 3.3

26. Note that the number of equities have changes compared to Table 4 and Table 5. This is due to that some equities may have a Policy Risk and/or Technology Opportunity, but no Physical Risk, and vice versa.

Figure 12: Anonymous company locations that are exposed to significant levels of acute physical climate risks



Source: Carbon Delta

Further to note is that 5 out of the top ten high risk locations are based in China. Both increased heat levels and coastal flooding will affect these companies’ facilities in a major way. In Table 8, Mining & Petroleum, Chemicals, Manufacturing and Service sector companies are represented. These insights emphasise the need to drill down to location level, in combination with sector analysis, to fully understand the impact of extreme weather on the portfolio.

Table 8: Top 10 locations exposed to Physical Risks based on Sector and Hazard

Location	Enterprise	Sector	Hazard	Sum of Costs for next 15 Years (million USD)
United States	Healthcare	Services	Extreme Heat	-151
Columbia	Retail Business	Services	Precipitation	-141
Indonesia	Oil producer	Mining & Petroleum Refining	Coastal Flooding	-125
China	Energy company	Mining & Petroleum Refining	Extreme Heat	-112
China	Energy company	Mining & Petroleum Refining	Extreme Heat	-107
China	Energy company	Mining & Petroleum Refining	Coastal Flooding	-102
Indonesia	Communications	Telecommunications	Coastal Flooding	-98.51
China	Energy company	Mining & Petroleum Refining	Coastal Flooding	-90.79
Tunisia	Chemicals manufacturer	Chemicals	Extreme Heat	-89.84
Mexico	Plastic manufacturer	Heavy Manufacturing	Extreme Heat	-89.68

Note: Companies have been anonymised.

Source: Carbon Delta

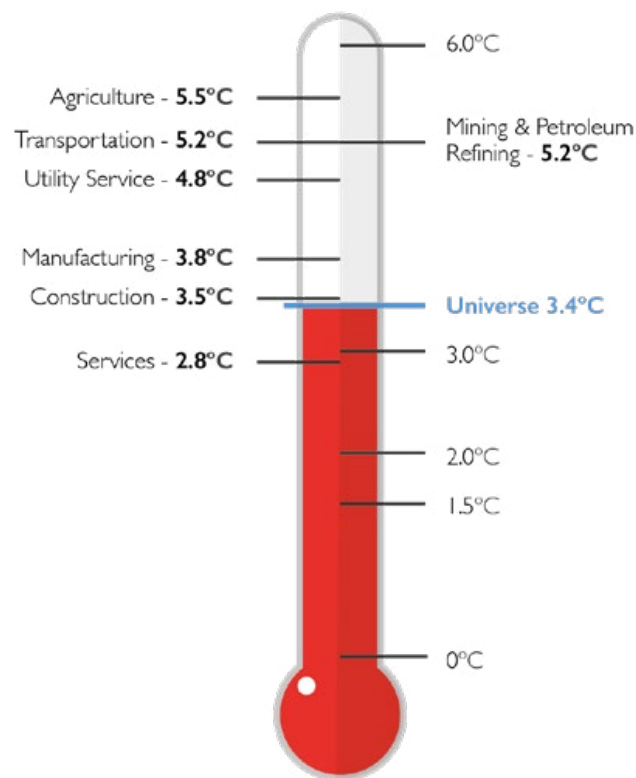
The market portfolio is far from being aligned with a 2°C, let alone 1.5°C world

The need to align with a 2°C world becomes even more apparent when looking at the Market Portfolio results under the Warming Potential analysis. This extremely well diversified portfolio is currently aligned with a temperature of 3.4°C, which is a good distance away off from achieving the 2°C alignment goal defined in the Paris Agreement, let alone the more ambitious 1.5°C goal.

Breaking the warming potential down further by sectors in Figure 13 emphasizes the misalignment. Agriculture (5.4°C), Mining, Petroleum & Refining (5.2°C), Transportation (5.2°C) and Utility Services (4.8°C); all have alarming levels of warming potential. In this context, the model helps investors to shift their investments into more climate-friendly sector of companies in order to set a strategic path for alignment over the coming years to eventually achieve a 2°C or even 1.5°C alignment goal.

Overall, the results clearly point out that more rapid policy action, on the one hand, is urgently needed to prevent climate change beyond 2°C of warming. On the other hand, the analysis also outlines that companies have already started to act and are actively working on the low carbon transition, as evidenced by the significant amount of green technology opportunities in this Market Portfolio universe. This in turn represents important stock selection opportunities for institutional investors, not to be missed.

Figure 13: Portfolio Temperature Gauge



Note: The thermometer shows the warming trajectory of this portfolio and relates it to important target temperatures in global climate change negotiations. This portfolio's warming trajectory (marked in blue) considers the weighted warming trajectory of all portfolio positions. Current and future carbon intensity play a central role in this calculation. The formula for calculating future carbon intensity is projected Scope 1 emission levels divided by current revenues plus forecasted, patented green revenues.

Source: Carbon Delta

4.2. THE TOP 1,200 COMPANIES PORTFOLIO

At first sight, climate-related impacts on a diversified “Top 1,200 Companies” Portfolio appear modest

The “Top 1,200 Companies” Portfolio is comprised of the top 1,200 companies by market cap and closely mimics the MSCI World Index. This analysis is performed in the same way the analysis as was done in the previous section for the Market Portfolio of 30,000 companies.

Interestingly, the overall portfolio-level results come out close to zero for these top 1,200 companies with an overall positive Climate Value-at-Risk of +0.05% for the 1.5°C scenario and slightly negative results for the 2°C scenario at -0.46%. Table 9 presents the overall results.

When looking at the results in the table more closely it becomes apparent that technology opportunities actually outweigh the negative impact from policy & physical risks. Moreover, the average physical risk impact is on aggregate very moderate at -0.72% compared to the Market Portfolio which came out at -2.2% overall.

Table 9: Results for the top 1,200 companies by global market cap

Model	Degree Scenario	Policy Risk [%]	Physical Risk [%]	Technology Opportunity [%]	Aggregated Climate VaR [%]
REMIND with Average Climate Model	1.5°C	-3.79	-0.72	4.56	0.05
	2°C	-2.07		2.32	-0.46
	3°C	-0.84		0.75	-0.80

Source: Carbon Delta

Deeper insights on the true climate impacts of this top 1,200 company universe can be gained by breaking down the analysis to sector-level. See Table 10 below for more details.

At sector level, climate-related risks become acutely apparent

Table 10: Sector-level results for Policy Risk illustrate the range of climate-related impacts across the portfolio

Degree Scenario		Agriculture	Services	Manufacturing	Mining & Petroleum Refining	Other Industry	Transportation	Utility Service
		No. of Equities	3	557	336	52	11	48
1.5°C	Sector Average for equities in portfolio [%]	-71.4	-0.6	-2.5	-8.1	-2.7	-14.1	-50.2
	CVaR Contribution [%]	3.6	8.4	19.2	9.9	0.3	13.1	45.4
2°C	Sector Average for equities in portfolio [%]	-49.7	-0.3	-1.4	-4.0	-1.3	-6.8	-27.2
	CVaR Contribution [%]	4.7	9.3	19.6	9.1	0.3	11.7	45.4
3°C	Sector Average for equities in portfolio [%]	-35.0	-0.1	-0.4	-1.7	-0.5	-2.3	-11.7
	CVaR Contribution [%]	8.1	10.3	14.1	9.4	0.3	9.6	48.2

Source: Carbon Delta

Drilling down the analysis to sector-level in Table 3 highlights those industries that are exposed to a high degree of climate risk while also highlighting how diversification can help to reduce these risks. Utilities, Transportation as well as Mining, Petroleum and Refining stand out. Although the Agriculture sector has the highest absolute risk, under a 1.5°C scenario, the Utility Sector contributes most strongly to the overall Policy Risk with a

contribution of 45% (Table 3, CVaR Contribution: 45.4%). Manufacturing, on the other hand, has a much lower risk of -2.5%, but gets a sizeable contribution of 19.2%, in line with the results in the Market Portfolio.

‘Green Revenues’ under a 1.5°C World are six times that of a 3°C World

As outlined in Table 9 above, overall technology opportunities contribute +2.32% under the 2°C scenario. When adding up the entire green profits of all 1,200-company universe, this represents approximately USD 1.4 trillion and interestingly outweighs the policy cost of USD 1.15 trillion (see Table 12 below). Further, the Top 1,200 companies possess roughly as much as half of the green revenue opportunities as compared to the 30,000 securities of the Market Portfolio (USD 2.1 trillion). For this Top 1,200 Companies Portfolio, green revenue opportunities once again vary substantially between sectors.

Similarly, as with the Market Portfolio, Table 11 outlines that the Manufacturing sector contains those companies with the largest green revenue opportunities, with a contribution of approximately 85% to the portfolio’s CVaR.

Table 11: Sector-level results for technology opportunities illustrate the range of impacts across the portfolio

Degree Scenario		Agriculture	Services	Manufacturing	Mining & Petroleum Refining	Other Industry	Transportation	Utility Service
	No. of Equities	3	377	307	36	9	34	42
1.5°C	Sector Average for equities in portfolio [%]	0.13	0.64	12.01	3.53	3.19	0.32	3.37
	Share of CVaR [%]	0.01	7.7	85.7	3.6	0.3	0.2	2.4
2°C	Sector Average for equities in portfolio [%]	0.05	0.27	6.28	1.55	1.37	0.13	1.39
	Share of CVaR [%]	0.004	6.4	88.1	3.1	0.3	0.2	1.9
3°C	Sector Average for equities in portfolio [%]	0.02	0.08	2.07	0.47	0.40	0.04	0.37
	Share of CVaR [%]	0.0	5.6	89.5	2.9	0.3	0.2	1.6

Source: Carbon Delta

Delayed policy action results in increasing policy costs

For the Delayed Policy scenario, performed in the same manner as for the Market Portfolio, the results show an increase in costs under the 2°C scenario of 140 Billion USD between the GCAM4 and REMIND models. Table 12 presents the overall results.

Table 12: Policy risk for a delayed and non-delayed scenario

Model	Degree scenario	Policy risk [%]	Policy cost
REMIND (immediate)	2°C	-2.07	-1,15 Tn USD
GCAM4 SSP4 (delayed)	2°C	-2.48	-1,29 Tn USD
Difference		-0.41	140 bn USD

Source: Carbon Delta

Physical impacts drive up Climate Value-at-Risk further

The physical risk impacts for the seven extreme weather hazards analysed (Table 13) on the Top 1,200 companies shows moderate risk impacts on aggregate portfolio level.

When considering the aggressive physical climate scenario, the overall risk impact increases from -0.72% to -0.80%. Extreme heat and coastal flooding most heavily affect the portfolio's facilities with -0.7% and -0.1% respectively, again roughly in line with the results of the Market Portfolio. The overall moderate climate risk levels indicates that the majority of company facilities in this portfolio universe are not based in high-risk locations.

Table 13: Physical Risk for the Average and Aggressive climate models and each specific weather hazard.

Physical hazard	Average climate [%]	Aggressive climate [%]
Impact from Physical Hazards	-0.72	-0.80
Extreme cold	0.1	0.1
Extreme heat	-0.7	-0.7
Precipitation	0.02	0.02
Extreme snowfall	0.003	0.003
Extreme wind	-0.003	-0.01
Coastal flooding	-0.1	-0.2
Tropical cyclones	-0.03	-0.04

Source: Carbon Delta

Physical risk expected to be highest in Commercial Buildings and Services and Manufacturing

Analogous to transition risk analysis, sector analysis of the physical CVaR²⁷ shows that the risk is distinct for sectors with varying impacts on the overall portfolio. The sector results for the Top 1,200 companies show that Services and Manufacturing have the highest contribution to CVaR, at 47.2% and 31.9%, with absolute physical impacts of -0.58 and -0.78. By looking at the location-specific impacts next, we can drill down into the underlying risk implications on facility-level.

Table 14: Physical Risk for the average scenario by sector and contribution

Degree Scenario		Agriculture	Services	Manufacturing	Mining & Petroleum Refining	Other Industry	Transportation	Utility Service
Average	Sector Average Physical Risk for equities in portfolio [%]	-4.36	-0.58	-0.78	-1.33	-0.96	-0.83	-1.41
	No. of Equities	2	548	336	51	10	47	49
	Share of CVaR [%]	1.4	47.2	31.9	8.3	0.6	4.2	6.9

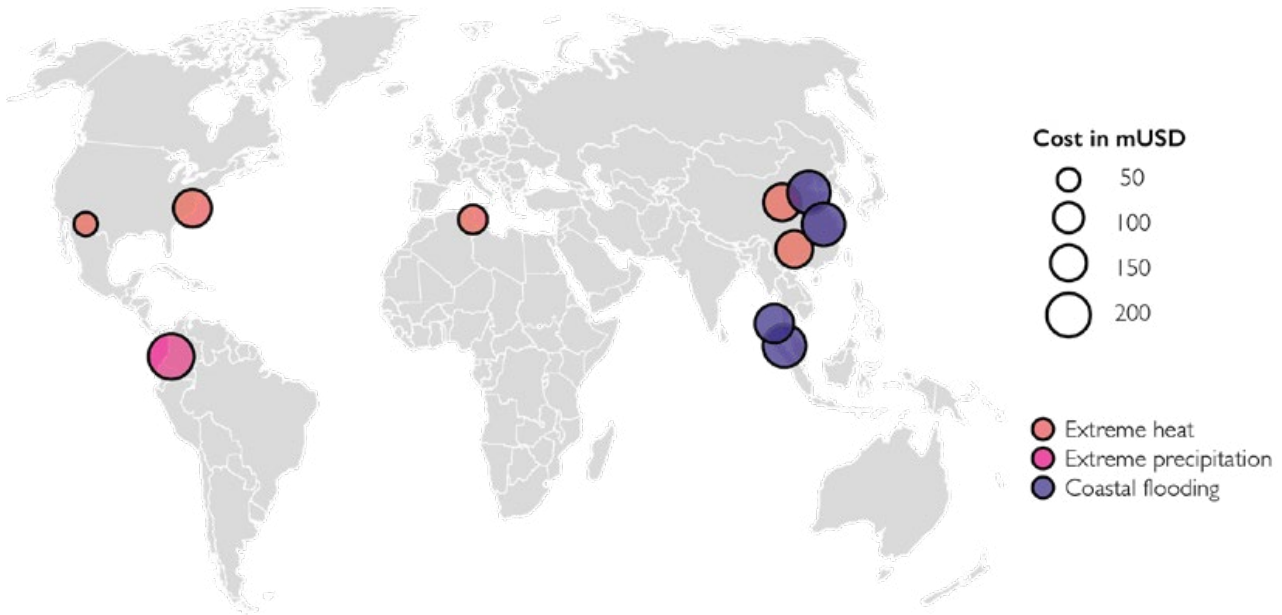
Source: Carbon Delta

27. For detailed description of what the physical risk implies for each sector, please refer to Section 3.3

Location-specific physical impacts could be large

Figure 14 demonstrates that the Eastern part of the United States stands out in terms of extreme heat impact once again, while coastal flooding is a major risk impact in South East Asia.

Figure 14: Anonymous company locations that are exposed to significant levels of acute physical climate risks



Source: Carbon Delta

One important point to note from Table 15, below, is that four out of the top ten high risk locations are from companies in the Services sector. This is in line with the large contribution to the CVaR as presented in the table. As a reminder, Manufacturing has the second largest CVaR contribution, but is not represented in this top ten high risk location list. Instead, Mining & Petroleum Refining and Utility companies are represented but contribute much less to the overall CVaR. These insights emphasise the need to drill down to location specific level, in combination with sector analysis, to fully understand the impact of extreme weather on the portfolio.

Table 15: Top 10 locations exposed to Physical Risks based on Sector and Hazard

Location	Enterprise	Sector	Hazard	Sum of Costs for next 15 Years (million USD)
United States	Insurance company	Services	Extreme Heat	-151
Indonesia	Energy company	Mining & Petroleum Refining	Coastal Flooding	-125
United States	Insurance company	Services	Extreme Heat	-52.03
Singapore	Energy company	Mining & Petroleum Refining	Coastal Flooding	-51.87
Costa Rica	Retail company	Services	Precipitation	-47.94
Brazil	Commodity company	Mining & Petroleum Refining	Extreme Heat	-47.22
Japan	Energy company	Utility Services	Coastal Flooding	-42.84
United States	Telecommunications company	Services	Extreme Heat	-42.55
United States	Energy company	Mining & Petroleum Refining	Extreme Heat	-39.51
Mexico	Energy company	Utility Services	Tropical Cyclones	-36.33

Note: Companies have been anonymised.

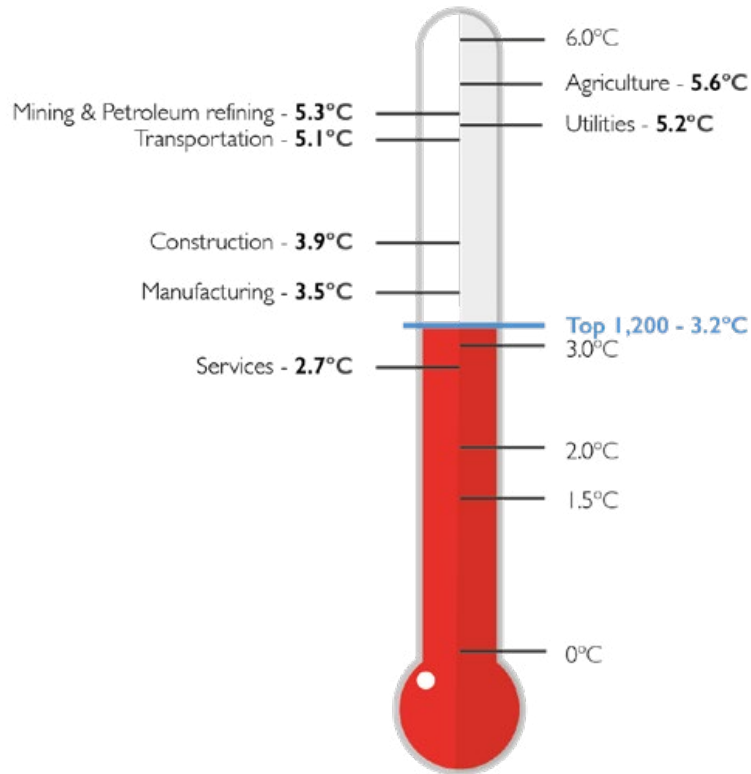
Source: Carbon Delta

How aligned are the Top 1,200 companies with the 2°C world?

The Top 1,200 Companies portfolio tracking the MSCI World Index is currently aligned with a temperature of 3.2°C, roughly in line with the country specific policy pledges of the Paris Agreement, known as the Nationally Determined Contributions (NDCs). However, just as we witnessed in the Market Portfolio, this alignment is still way off from achieving the 2°C or 1.5°C goals outlined in the Paris Agreement.

Once again, similarly to the Market Portfolio, Agriculture (5.6°C), Mining, Petroleum & Refining (5.3°C), Utilities (5.2°C) and Transportation (5.1°C) sectors all have rather alarming levels of warming potential.

Figure 15: Portfolio Temperature Gauge



Note: The thermometer shows the warming trajectory of this portfolio and relates it to important target temperatures in global climate change negotiations. This portfolio's warming trajectory (marked in blue) considers the weighted warming trajectory of all portfolio positions. Current and future carbon intensity play a central role in this calculation. The formula for calculating future carbon intensity is projected Scope 1 emission levels divided by current revenues plus forecasted, patented green revenues.

Source: Carbon Delta

4.3. THEMATIC PORTFOLIOS: COAL AND RENEWABLE ENERGY

While the assessment of the MSCI World Index Tracker resulted in moderate risk finds and a 3.2°C alignment, it is important to note that climate risks and temperature alignment can vary greatly depending on portfolio construction. The below tables and temperature gauges display the results of two additional thematic portfolios. The first is a portfolio of companies with significant coal exposure, such as utilities with coal-fired power generation business segments as well as coal and lignite extraction companies. The second portfolio is formed of companies operating in the renewable energy sector with a focus on solar, wind, wave power and electric vehicles. Comparing these two thematic portfolios reveals a large amount of policy risk coupled with a low amount of technology opportunities in the ‘coal portfolio’, whereas the opposite is true for the renewable energy portfolio. Physical risks happen to be minor risk contributors in both portfolios, with extreme weather CVaRs at just -0.2%.

In the below tables you will find the scenario specific breakdown at portfolio level for the Coal and Renewable Energy Portfolios.

Table 16: Results for a Coal Portfolio

Model	Degree Scenario	Policy Risk [%]	Physical Risk [%]	Technology Opportunity [%]	Aggregated Climate VaR [%]
REMIND with Average Climate Model	1.5°C	-38	-0.2	0.1	-38.1
	2°C	-8.6		0.1	-8.7
	3°C	-4.2		0.1	-4.3

Table 17: Results for a Renewable Energy Portfolio

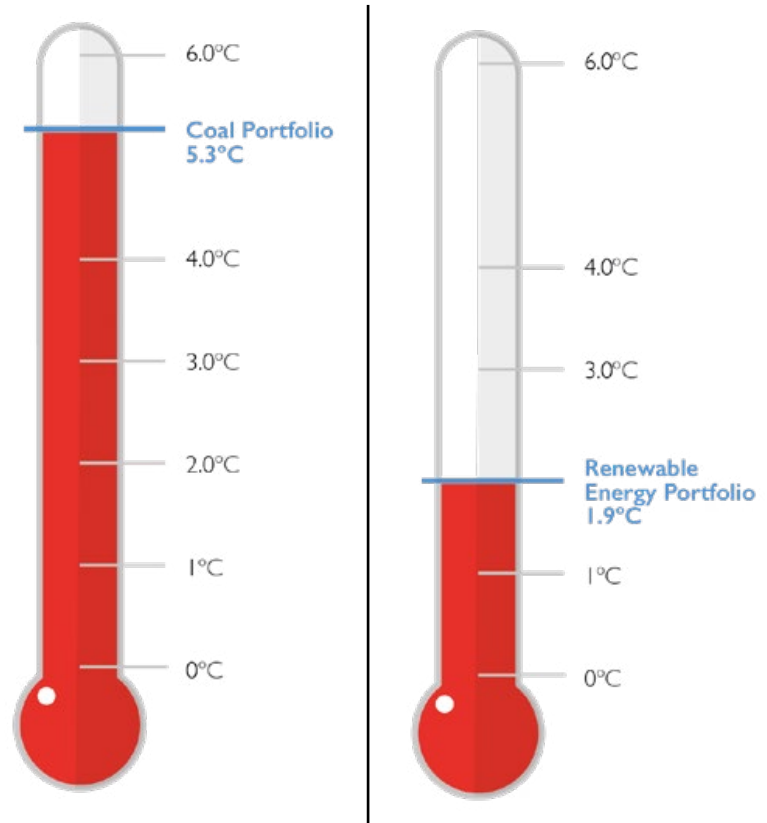
Model	Degree Scenario	Policy Risk [%]	Physical Risk [%]	Technology Opportunity [%]	Aggregated Climate VaR [%]
REMIND with Average Climate Model	1.5°C	-1.1	-0.8	50.7	48.8
	2°C	-0.5		31.8	30.5
	3°C	-0.1		15.4	14.5

Source: Carbon Delta

The warming potential of the Coal Portfolio at 5.3°C is comparable with that of the Mining & Petroleum as well as Utility sector results from the previous Top 1,200 Companies analysis. By contrast, the renewable energy portfolio achieves a warming alignment of below 2°C, which none of the traditional investment sectors currently achieve. However, both portfolios also lack the required levels of diversification for institutional asset owners but are nevertheless interesting case studies to underpin the need to consider climate-related risk analysis in portfolio construction and investment decision-making.

A glance at the below temperature gauges will emphasize the alignment disparity between a coal-focussed and renewable energy-focussed portfolios.

Figure 16: Portfolio Temperature Gauge for Coal and Renewable Energy Portfolios



Note: The thermometer shows the warming trajectory of this portfolio and relates it to important target temperatures in global climate change negotiations. This portfolio's warming trajectory (marked in blue) considers the weighted warming trajectory of all portfolio positions. Current and future carbon intensity play a central role in this calculation. The formula for calculating future carbon intensity is projected Scope 1 emission levels divided by current revenues plus forecasted, patented green revenues.

Source: Carbon Delta

5. OPERATIONALISING THE METHODOLOGY

CASE STUDIES

Case studies were authored by the named financial institutions and reflect the views of the authors, with compilation by Vivid Economics. The statements herewith do not necessarily represent the views of UNEP Finance Initiative or Vivid Economics.

This section presents case studies of investor implementation of the Investor Pilot methodology co-developed with Carbon Delta.

As part of the project, each investor in the Pilot Group was able to analyse at least one portfolio and trial different scenarios in collaboration with Carbon Delta. This section presents the results and evaluation of this analysis from several Pilot Group members, focusing on different aspects of the methodology and the use of results.

Case studies are organised around two key themes:

1. Stress-testing the methodology and results received. These case studies represent deep-dives into the results of Carbon Delta's portfolio analysis for each investor, focusing on the unique areas that institutions chose to explore. These include the expansion of scenarios to more aggressive physical risk and delayed policy response scenarios (Aviva, Nordea), the non-linearity of risk across different temperature pathways (Manulife Investment Management), and the performance of actively managed portfolios relative to relevant indices (Rockefeller). Another case study from CDPQ examines the importance of considering value chains and non-substitutability of products in risk assessment.
2. Integrating scenario analysis into internal processes or external engagement. These case studies focus on the potential integration of the pilot project results into internal processes. They examine the benefits of engaging with scenario analysis (Addenda), highlight the interactions between the methodology and the identification of metrics for future real estate assessment (Investa), explore evolving internal risk management processes surrounding climate-related risks (KLP), compare Carbon Delta results to climate risk signals provided by ESG data providers (TDAM), draw out the implications for internal scenario analysis tools and risk management practices (NBIM, La Française), and elaborate how institutions can utilise the results in engagement with investee companies (DNB).

In the case studies, investors highlight the following key benefits from engagement with scenario analysis using the pilot methodology:

- Considering physical and transition risk together can provide valuable insights into their interactions and results in a more comprehensive and consistent risk assessment tool for investors.
- The diversity of impacts across different scenarios in both physical and transition assessments emphasises the importance of considering a range of scenarios.
- The CVaR measure could facilitate internal discussion by quantifying risk that may have previously have been assessed only through ratings, and can generate more interest internally.
- Some investors, in future engagement with investee companies on the need for disclosure of material climate-related data and risk management, are likely to utilise the results of the assessment as supporting evidence of the need for action. However, investors also noted that scenario analysis should not form the sole basis for corporate or investor decision-making.
- Results highlight that active management could considerably reduce climate-related risk exposure of portfolios.

However, members also emphasise the need to further develop scenario analysis methodologies to more accurately capture the extent of climate-related risks and opportunities for investors. The methodology developed for the purposes of this project presented a comprehensive starting point and allowed many investors a first interaction with in-depth scenario analysis. Yet it also highlighted the need for further improvements to methods of scenario analysis if results are to become increasingly credible and useful for investor decision-making. Suggestions for improvements are discussed in depth in Section 6.2.



AVIVA: AGGRESSIVE PHYSICAL RISK SCENARIOS

Aviva is an asset owner with more than GBP 487 billion in assets, an insurer with gross written premiums of more than GBP 28.7 billion, and an asset manager with assets under management of more than GBP 426 billion. It provides 33 million customers around the world with insurance, savings and investment products. Aviva has committed to implement the recommendations of the TCFD (including conducting climate-related scenario analysis), and we have reported on these recommendations since 2016. Aviva joined the UNEP FI Investor Pilot to support the development of consistent and comparable high-level scenarios (including common elements regarding the modelling of the impact of physical and transition risk) with other insurers and asset owners.

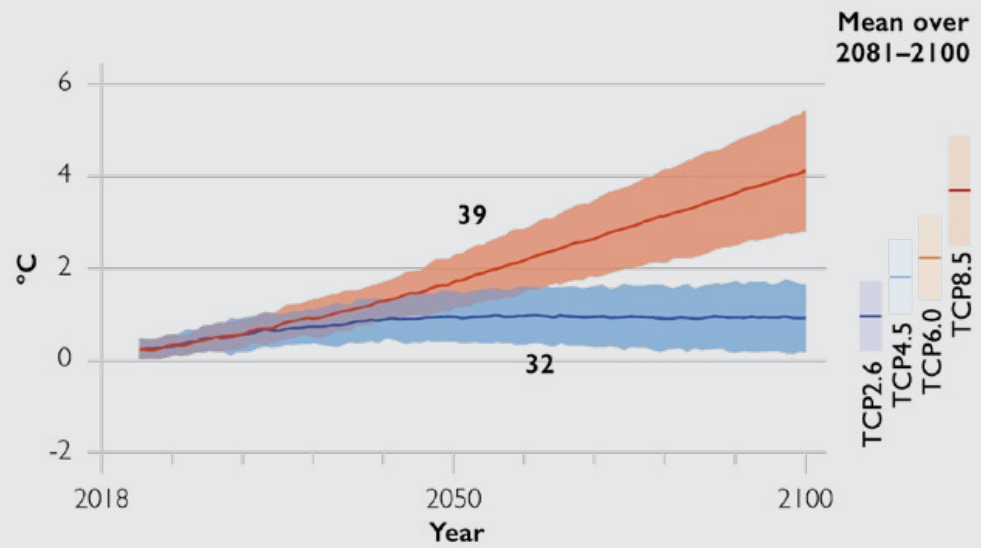
Aviva's TCFD scenario analysis project

Aviva's Chief Risk Officer and the Group General Counsel and Company Secretary are the executive sponsors overseeing our 2018 disclosure. This year Aviva initiated a project to create best-in-class climate-related scenario analysis capability to enhance our disclosure. The project covers the identification of appropriate climate-related scenarios, assessment of those scenarios, and development of reporting formats for the results of the scenario analysis.

Inclusion of more aggressive physical risk scenario

One of the main challenges we identified as part of the project was whether a more aggressive physical risk scenario should be included in the scenario analysis. Under the IPCC RCP 8.5 scenario, which assumes emissions keep rising at current levels, it is considered as likely as not that the global average temperature rise from pre-industrial levels will exceed 4°C by the end of the century, and it is highly likely in this scenario that temperatures exceed 3.5°C.

Thus, a more aggressive physical scenario of, say, 6°C is plausible by 2100, particularly when factoring in the risk of climate tipping points causing runaway warming. However as can be seen from the graph below, the worst physical effects are likely to manifest themselves only in the second half of the century, and in the short-to-medium term there is relatively little difference in temperature rises between each IPCC scenario.

Figure 17: Global average surface temperature changes relative to 1986-2005

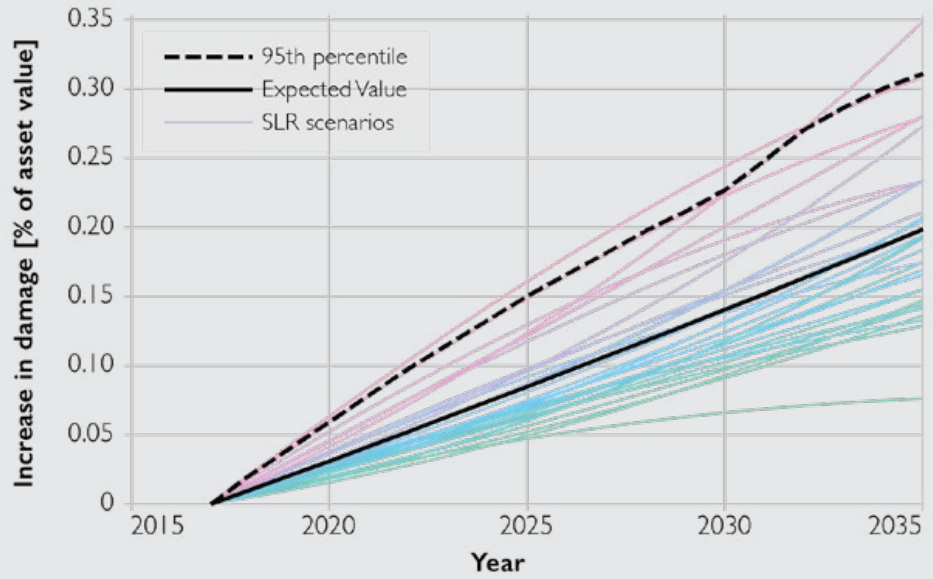
Source: IPCC, 2014a

In contrast, the effects from the transition to a low-carbon economy are likely to be felt over a much shorter time frame and to differ considerably between each IPCC scenario. As a result, if scenario analysis is conducted over relatively short time horizons then the differences in the long-term impact of physical risk in each scenario, as well as the level of physical risk compared with transition risk in each scenario, could be understated and, as a result, inappropriate conclusions drawn about the impact on the business of different strategies.

That said, if physical and transition risks are not being looked at consistently then it is more difficult to understand the combined effect of the aggregate risk in different scenarios, as tackling mitigation and adaptation challenges present several trade-offs. Furthermore, it could be argued that the longer the time horizon used for the scenario analysis, the less decision-useful it becomes. To address these points, it was agreed within the UNEP FI Pilot Group and with the project's consultant, Carbon Delta, to use a consistent 15-year time horizon—with the ability to look at shorter time periods—for both transition and physical risk. In addition, more aggressive physical risks would be captured by looking at a higher 95th percentile of historical extreme weather observations, as well as the expected outcome under an 'average' BaU development scenario. See Figure 18 below for an example of coastal flooding.

To analyse a more aggressive physical risk scenario, at a higher, 95% confidence level, risk datasets were compiled for each hazard. The hazards that Carbon Delta modelled include extreme heat and cold, heavy precipitation (Precip) and snowfall, coastal flooding (CF), wind storms, and tropical cyclones (TC). In addition, unlike in the expected case, a dependence structure was defined between hazards.

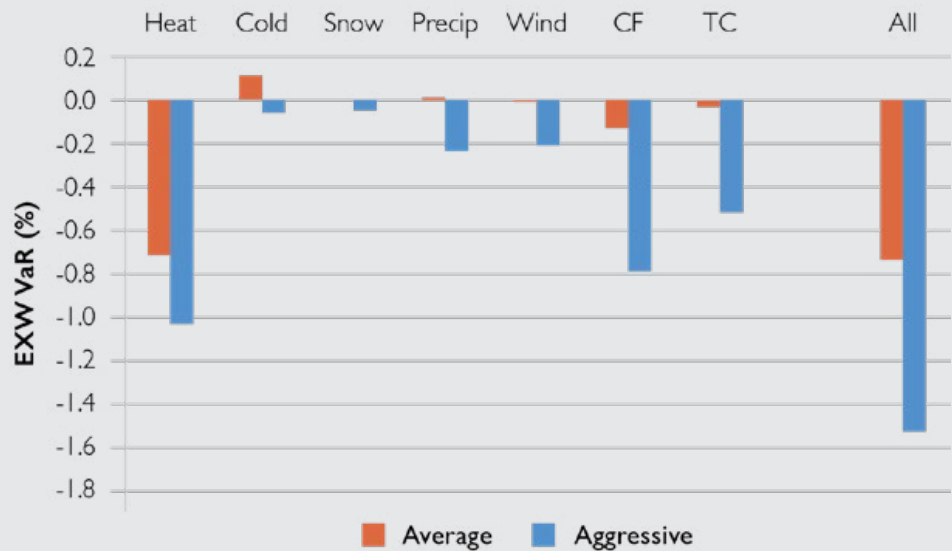
Figure 18: Increase in damages as % of asset value from expected value to 95th percentile for coastal flooding



Source: Carbon Delta

Figure 19 below shows, based on output from Carbon Delta, the difference in estimated impact when comparing the aggressive (95% percentile) scenario to an average BaU scenario on the MSCI World index, presented by hazard. In the more aggressive physical risk scenario, the overall risk almost doubles compared with the expected scenario. However, the difference depends strongly on the hazard considered.

Figure 19: Aviva analysis of differences between average and aggressive scenarios across physical hazards



Source: Aviva, Carbon Delta

Aggressive scenarios for physical risks require further attention

The introduction of a more aggressive physical risk scenario by Carbon Delta enables the potential impact of more extreme physical risk outcomes to be assessed over a decision-useful, consistent and comparable time frame with that used for transition risks. However, we recognise that there is further work to do to refine this methodology, including potentially introducing more long-term, sophisticated scenarios, which could reveal some of the variability in outcomes indicated by climate models. Before this is done the model remains sensitive to assumptions made about growth of physical costs beyond 15 years.

It is particularly important to understand the potential impact of various outcomes when aggregating physical risks with transition risks under different scenarios, or simply comparing the impact of different scenarios. For example, one would expect the costs of physical risks in the BaU scenario to grow much more rapidly than in the IPCC's ambitious mitigation scenario (RCP 2.6). Carbon Delta currently offers nine transition risk scenarios yet only two physical risk scenarios. A more proportionate number of physical risk scenarios could be developed to couple with the various transition risk scenarios. We would recommend adjusting the outputs to take account of this imbalance. In addition, we would expect the modelling of dependencies between hazards to be further refined over time.



CDPQ: VALUE CHAINS AND NON-SUBSTITUTABILITY OF PRODUCTS

Introduction to the CDPQ's strategy to address climate change

Created in 1965, Caisse de dépôt et placement du Québec (CDPQ) is a long-term institutional investor that manages funds primarily for public and parapublic pension and insurance plans. As of December 31, 2018, it held CAD 309.5 billion in net assets. As one of Canada's leading institutional fund managers, CDPQ invests globally in major financial markets, private equity, infrastructure, real estate and private debt. It announced and launched its investment strategy to address climate change in early October 2017. The organisation has built its strategy on four pillars, with a clear effort to make its impact quantifiable and ensure implementation across the whole investment process. These pillars are:

1. Factoring climate change into all investment activities and decisions.
2. Increasing low-carbon investments by 50% by 2020.
3. Reducing the carbon footprint per dollar invested by 25% by 2025.
4. Exercising stronger climate leadership within the industry and with the companies in the portfolio.

This strategy to address climate change was developed following the TCFD's final recommendations in June 2017, which include the 'Description of the resilience of the strategy, taking into consideration different climate-related scenarios'. CDPQ believes that the resilience of its portfolio needs to factor in climate-related risks. The analysis of transition and physical risk modelling is complex at the portfolio level; therefore, CDPQ joined the UNEP FI Investor Pilot Group to develop a more precise methodology.

At the beginning of 2018 up to the launch of the UNEP FI report in April 2018, the internal group responsible for measuring the carbon footprint of the portfolio and piloting the climate change strategy within the organisation was mandated to work on the climate-related scenario analysis with UNEP FI and a dozen other investment peers. As work progressed with Carbon Delta, a few points needed clarifications by our internal groups. Using the constituents of the MSCI World index, the subjects below were analysed and then shared with UNEP FI.

Exploring linkages within the energy sector's value chain

As the energy sector has a rather complex value creation chain that is hard to grasp by standard sector classification, this section focuses on issues encountered while analysing this sector's policy VaR provided by Carbon Delta under a 2°C pathway. Table 11 presents data regarding certain steps of the oil & gas value chain represented by General Industry Classification Standard (GICS) sectors.

Table 18: CDPQ comparison of sectors through specific value chains

GICS sectors	Policy VaR 2° C pathway				
	Av.	Min	Max	Standard-dev	Constituents
Oil & gas equipment & services	0%	0%	0%	0%	7
Integrated oil & gas	-7%	-13%	-3%	12%	14
Oil & gas exploration & production	-4%	-12%	0%	3%	25
Oil & gas refining & marketing	-4%	-8%	0%	3%	9
Oil & gas storage & transportation	-3%	-4%	-1%	1%	12

Note: This table omits one outlier in the Storage sector and another in the Integrated sector

Source: Carbon Delta

These results highlight certain key elements:

- The oil & gas storage & transportation (storage) subsector has a lower average VaR (-3%) than that related to the oil & gas exploration and production (production) sector (-4%), which is in line with the expected result, as a high number of assets in the former have long-term contracts with oil producers, meaning that carbon pricing should have the same impact on Storage and Production.
- We note, however, that oil and gas extracted and transported will need to be refined and distributed to final consumers. Refining in particular is a carbon-intensive business that is largely undertaken by the Integrated oil & gas subsector. It would then be fair to assume that the Storage and Production subsectors should have the same VaR as that of the Integrated subsector since the transition will ultimately affect the entire sectoral value chain.
- Integrated oil & gas (integrated) has the highest average VaR (-7%). As companies in the Integrated subsector will be affected all along their value chain by carbon pricing policies, from extraction to their gas stations, it appears logical that this sector should have the highest policy VaR, especially when compared with the oil & gas producers, which should not be impacted as much.
- There seems to be no policy risk in the oil & gas equipment & services sector. This result is counter-intuitive as companies in this sector provide services to the other players in the Production sector, which should suffer from policy risk and indirectly impact the value chain of equipment & services companies.

We note that the methodology considers only GHG released upon production of fossil fuels and other derived products to assign a transition cost. However, the financial impact of the likely decline in demand for these fuels that is anticipated in the scenarios used in this analysis, which may take the form of stranded assets, lower oil prices, declining sales and declining profitability, is not included in this analysis and it should be at its core, especially for the oil & gas sector. We acknowledge that doing so in a sufficiently differentiated manner to reflect the relative strength, weakness and competitive positioning of individual companies in this vast sector is notably complicated, particularly for outsiders to these businesses.

Non-substitutability of products

Within the next 15 years, some products will be subject to regulatory costs, but it will probably be too short a time frame for the market to find a substitute for these products. Intuitively, products like cement or steel would fit in this category of assets and this section therefore focuses on those sectors.

Table 19: CDPQ total VaR of cement and iron and steel sectors

Carbon Delta sectors	Average regulatory VaR			
	Average	Range	Standard deviation	Constituents
Cement	-32%	-100% to -3%	43%	7
Iron and steel	-11%	-37% to 23%	14%	19

Source: Carbon Delta

Using the IEA's 2°C pathway, two key conclusions were drawn:

- Cement production is expected to keep on growing until 2050, but the global emissions of this sector will have to be reduced through technological means to follow a 2°C pathway. The intuition is that the implied carbon reduction is not going to happen without additional costs, and the presence of technologies not yet commercially available. Considering the highly probable absence of cement substitutes within the next 15 years, the expected policy costs will be passed through to consumers, thus leading to a much lower policy VaR than the sector average of -32% shown in Table 19.
- The IEA's 2°C scenario regarding the Iron and Steel sector also shows an increase in the demand for these products combined with a reduction of carbon emissions until 2050. Even if this sector is highly carbon-intensive, without a substitute it is expected that policy costs will be passed on to consumers. This -11% VaR seems also aggressive, but winners and losers can be easily identified across this industry based on the results obtained by the pilot, as the spread between policy VaRs is high within this sector. These results seem to be more in line with natural transition, even if some companies are shown to be heavily impacted.

Concluding remarks

In conclusion, climate-related scenario analysis of institutional investors' portfolios is very complex and this exercise has been a great opportunity to delve deeper into the matter in a collaborative effort backed by the detailed methodology elaborated through this pilot. The data gathered on physical risks is of interest in differentiating companies as it is based on statistical climate data and a standard methodology across all sectors—an approach well suited to this type of risk.

Transition VaR results are particularly useful in comparing companies within an individual sector as presumably the question of product demand or price (such as in Oil & Gas) and of the ability of companies within a sector to pass the transition costs to their clients (such as in Cement or Steel) are matters that are likely to affect a sector relatively uniformly. The transition VaR results, though imperfect in an absolute investment universe, do provide an insight into which companies may be better positioned in an individual sector. However, aggregating results at the portfolio level is problematic because of likely sectoral distortions resulting from the methodology. We would guess that the oil & gas sector is probably riskier than suggested by the transition VaR obtained with the current methodology because of future product demand and price issues, whereas the transition VaR of sectors such as Steel and Cement, where there are no foreseeable alternatives today, is probably overstated.

Clearly, further research is needed to consider how climate change-related costs will spread through the economy, and to take into account the Scope 3 emissions of fossil fuel producers, distributors and marketers (in priority over other sectors), so that better comparability across sectors can be achieved.

The complexity of the exercise for asset owners, who are outsiders to the companies they own, underpins the urgent necessity for companies to undertake scenario analysis themselves, as they are better placed to know the granularity of their individual assets and business lines, assess demand impacts on their products, their ability to pass the carbon cost to their clients, and their own strategy to address climate change (among other things). We believe that scenarios should be standardised, at least at the sector level, to allow for better comparison between companies.

MANULIFE INVESTMENT MANAGEMENT: THE NON-LINEARITY OF CLIMATE RISK ACROSS GEOGRAPHICALLY DISTINCT PORTFOLIOS

Manulife Investment Management has extensive experience in investing in public markets asset classes globally. As a result, we believe a comparison of geographically distinct equity portfolios can help investors evaluate the potential difference in impact of climate risk on different regions, with implications for asset allocation. Accordingly, this case study analyses the impact of climate risk on companies included in two existing investment portfolios—one composed of Canadian equities, the other of Asian equities—under three climate scenarios.²⁸ Furthermore, it identifies the physical hazards of climate change that carry the highest potential negative impact at the portfolio level and the industries in each portfolio that are potentially most exposed to these risks. Our analysis also offers a discussion of two companies in each portfolio that show greater exposures to climate risk. This analytical work illustrates how Manulife Investment Management currently seeks to integrate the evaluation of climate risk in its investment processes.²⁹

Quantifying climate risk

According to the methodology used in the UNEP FI TCFD Investor Pilot, climate transition risk—or the general cost associated with moving from a current BaU scenario in the direction of a more carbon-neutral future—represents the greatest portfolio risk. This is followed in magnitude by physical hazard risk—or the cost impact associated with extreme weather events, which we identify in these portfolios as extreme heat, coastal flooding, and tropical cyclones. Both climate transition and physical hazard risks may be partially offset by low-carbon technology innovation such as carbon extraction or sequestration—particularly for those companies that have invested in R&D geared towards objectives of sustainability.

In the first two tables, the Canadian and Asian equity portfolios are assessed in terms of transition risk, technological opportunity, and total portfolio VaR. The Canadian portfolio invests primarily in large market capitalisation Canadian equities, benchmarked against the S&P/TSX index. The Asian portfolio invests in equities with primary interest in China benchmarked against an aggregated MSCI China/Hong Kong index. The latter column, ‘Total portfolio VaR in bps’, includes the impact of physical hazard risk, and the details for this dimension of climate risk across the two portfolios are discussed in depth in the case study.

28. This case study includes only Scope 1 carbon emissions from the underlying companies, which measures direct carbon emissions from operations. Scope 2, which includes indirect emissions from the consumption of energy—for example, electricity—is not included in the analysis. Future analyses may be developed to incorporate Scope 2 and Scope 3 carbon emissions. Portfolio holdings were current as of August 8, 2018.

29. This case study is for illustrative purposes only. The investment process may change at any time and the integration of ESG factors, including climate risk, may vary between investment strategies.

Table 20: Manulife Canadian equity portfolio results

Scenario	Unweighted aggregate VaR from transition risk (%)	Multiple of the 3°C scenario	Unweighted aggregate VaR from technology opportunity (%)	Multiple of the 3°C scenario	Total portfolio VaR in bps (portfolio weighted)
3°C	-12.65	n/a	0.77	n/a	-32.0
2°C	-48.78	3.9x	2.87	3.8x	-106.3
1.5°C	-99.77	7.9x	6.91	9.0x	-199.9

Note: VaR from transition risk and technology opportunity represents the aggregate downside risk exposure and upside potential, respectively, expressed as a percentage of the portfolio's market value under three climate scenarios of declining severity: 3°C, 2°C, and 1.5°C increases, respectively, in average global temperatures.

Source: Manulife, Carbon Delta

Table 21: Manulife Asian equity portfolio results

Scenario	Unweighted aggregate VaR from transition risk (%)	Multiple of the 3°C	Unweighted aggregate VaR from technology opportunity (%)	Multiple of the 3°C	Total portfolio VaR in bps (portfolio weighted)
3°C	-16.74	n/a	4.99	n/a	-117.0
2°C	-135.70	8.1x	17.20	3.5x	-315.1
1.5°C	-177.60	10.6x	40.40	8.1x	-390.1

Source: Manulife, Carbon Delta

One of the first conclusions to draw from our initial assessment is that **the Asian equity portfolio is subject to greater relative transition risk under all three climate scenarios**, as well as a **greater potential opportunity from technological innovation**. There are two primary reasons for the Asian portfolio to potentially incur higher risk. First, the average carbon intensity of Asian companies is higher, which could be attributed to multiple factors such as the current greater consumption of coal for energy production at the country level compared with Canada. Second, the risk of physical hazards in Asia is more severe, which is illustrated in the total portfolio VaR column. According to climate firm Four Twenty Seven, China leads the world in coastal risks from climate change, with 145 million people living on land threatened by rising seas (Deutsche Asset Management & Four Twenty Seven, 2017). For the purpose of this analysis it should be noted that a conservative, forward-looking emission price curve was assumed, along with non-aggressive estimates from physical hazards risk; if our analysis had been built on greater severity assumptions, the total impacts on the portfolio would be greater.

However, and perhaps more importantly, we note how the data illustrates the **non-linear impact of transition risk and technological opportunity**. In other words, the more restrictive the warming scenario—in other words, the more stringent the emission decarbonisation required to achieve more limited global average temperature increases—the greater the negative impact on each portfolio. This non-linearity is also evident in the total portfolio VaR. It should also be noted that the sector weights between the two portfolios is likely to account for a portion of VaR differentials, as seen in the table below.

Table 22: Manulife sector weights for Canadian and Asian equity portfolios

Sector	Canadian equity (%)	Asian equity (%)
Basic Materials	5.6	0.7
Communications	7.2	25.6
Consumer, cyclical	5.1	9.6
Consumer, non-cyclical	6.6	9.1
Energy	18.1	6.9
Financial	34.2	38.5
Industrial	14.2	3.1
Technology	9.1	1.3
Utilities	n/a	5.2

Source: Manulife, Carbon Delta

The Paris Agreement's central aim is to strengthen the global response to climate change risk by limiting the global temperature rise this century to 2°C above pre-industrial levels and to pursue efforts to limit the temperature to 1.5°C. The carbon stringency scenario is witnessed in a threefold increase in total portfolio VaR for the Canadian equity portfolio, moving from 3°C to 2°C. Furthermore, reducing temperature rise by another 0.5°C to 1.5°C, identified as a critical threshold by the IPCC in October 2018 (IPCC, 2018), implies an incremental threefold increase in total portfolio VaR. Incremental changes in climate scenarios **imply increasingly large dimensions of risk that dwarf the increasingly large implied technological opportunity impact for both portfolios in the study.**

Physical hazard risk

Regardless of geographical region, the **largest physical hazard is extreme heat**. For both portfolios, extreme heat exhibits the clearest trend under climate change, with hot regions becoming even hotter along with a rising frequency of extreme heat events in virtually every relevant geographical zone. Unsurprisingly, the key cost input driving the portfolio-level impact of this hazard is higher cooling costs.

The underlying data from running the analysis shows that **coastal flooding is next in order of magnitude for the sampled portfolios**. Storm surge and coastal flooding are extremely localised and contingent on the factors of sea-level rise, elevation, and dynamic topography. The key cost inputs driving the impact of this risk are asset damage and business interruption. While it is possible for a company to protect itself from financial loss through insurance, its market valuation will remain susceptible to impairment until its final financial exposure is known.

The third physical hazard risk common to both portfolios is tropical cyclones (hurricanes and typhoons). These storms bring intense wind and rain, which cause property destruction and business interruption, and can compound the effects of coastal flooding.

The table below assesses the total portfolio VaR of these hazards for both portfolios.

Table 23: Manulife total portfolio VaR of these hazards for both portfolios

Physical hazard	Unweighted aggregate VaR for Asian equity portfolio (%)	Unweighted aggregate VaR Canadian equity portfolio (%)	Asian equity portfolio impact relative to Canadian equity portfolio
Extreme heat	-48.9	-12.10	4.1x
Coastal flooding	-9.8	-0.79	12.3x
Tropical cyclones	-2.4	-0.62	4.0x

Source: Manulife, Carbon Delta

Extreme heat

Table 24: Manulife industry ranking by exposure to extreme heat risk

Rank	Asian equity	Canadian equity
1	Electronic equipment	Food & staples retailing
2	Real estate management & development	Oil & gas and consumable fuels
3	Banks	Banks
4	Construction materials	Auto components
5	Oil & gas and consumable fuels	Metals & mining

Source: Manulife, Carbon Delta

While the diversity of industries exposed to extreme heat is important to recognise, the portfolios' largest industry exposures—banks and oil and gas—are affected to different degrees. Notably, the impact on the Asian equity portfolio is three times more severe in both industries. The primary reason driving this result is that climate science indicates that extreme heat will be more significant to the Asia Pacific region than to North America. The United Nations Framework Convention on Climate Change (UNFCCC) states that 'the numbers [of people] affected will be largest in the mega deltas of Asia and Africa'(UNFCCC, 2011).

Coastal flooding

Table 25: Manulife industry ranking by exposure to coastal flooding risk

Rank	Asian equity	Canadian equity
1	Electronic equipment	Banks
2	Oil & gas and consumable fuels	Capital markets
3	Real estate management and development	Metals & mining

Source: Manulife, Carbon Delta

Tropical cyclones

Table 26: Manulife industry ranking by exposure to tropical cyclone risk

Rank	Asian equity	Canadian equity
1	Diversified telecommunications	Oil & gas and consumable fuels
2	Banks	Capital markets
3	Electronic equipment	Banks
4	Oil & gas and consumable fuels	Food & staples retailing

Source: Manulife, Carbon Delta

Companies with the highest levels of climate risk

Within the Asian equity portfolio, the two securities with the largest unweighted VaR are both state-owned enterprises. The first is a cement company, whose industry is one of the largest carbon-emitters globally (Harvey, 2018). However, there is currently no equal alternative to cement that can match its durability and strength, which means this high-climate-risk industry is relatively insulated from competitive market forces. The second company is in the downstream oil & gas market. According to a recent report by the Carbon Disclosure Project (CDP), this company bears the highest risk in terms of physical hazards, driven by extreme heat and coastal flooding (Fletcher, Crocker, Smyth, & Marcell, 2018).

The two companies with the highest VaR in the Canadian equity portfolio reside in the oil & gas industry and heavy equipment services. In the first case, climate transition risk represents the vast majority of climate risk exposure with a slight offset by technology. As carbon prices begin to ascend, this company faces the risk of whether the production of oil will continue to make economic sense. The second company is an industrial company with exposure to the oil & gas and mining industries. Its key risk, with exposure to multiple sectors, will be the stability of demand. The cost of carbon emissions is likely to rise over time, forcing the company to face a high probability of slowing demand for its services.

Integrating climate risk management in the investment process

Climate change presents a complex set of investment considerations that may impact corporate profitability. Companies in all sectors face transition risk and physical hazard risk dimensions of climate change, and these risks can materialise in different and dynamic ways. Manulife Investment Management believes that those companies that are most proactive about mitigating these risks are likely to become the most resilient. Regardless of the strategy adopted, establishing greater resiliency to climate risk will be significant a task for executives and corporate boards of directors.

Consequently, we believe that the evaluation of climate risk in our portfolios will become increasingly important over time. The incorporation of scenario analysis using different warming assumptions can have a dramatic impact on valuation. At Manulife Investment Management, we aspire to integrate the evaluation of ESG factors, including carbon emissions and climate change impacts, throughout our due-diligence and investment decision-making processes. Evidence shows that some industries will be more exposed to either climate transition risk and/or physical hazard risk. In alignment with this conclusion, **we structure our engagement with companies to deepen our understanding of their climate mitigation strategies and to encourage greater climate risk resiliency.** At the same time, we seek to identify opportunities for growth among companies that are positioning themselves for industry disruption and the promotion of a smoother transition to lower-carbon-emission models. Finally, we support engagement activities through company dialogue and collaborative engagement initiatives,³⁰ and **seek to support proxy items that are intended to mitigate climate risks or support company adaptation to climate change**, whether through management proposals or shareholder resolutions.

30. Manulife Investment Management serves on the Steering Committee of the Climate Action 100+, a five-year initiative led by investors to engage systemically important GHG emitters and other companies across the global economy that have significant opportunities to drive the clean energy transition and help achieve the goals of the Paris Agreement. Investors are calling on companies to improve governance on climate change, curb emissions and strengthen climate-related financial disclosures. Refer to: <http://www.climateaction100.org/>.

NORDEA: DELAYED POLICY RESPONSE

Nordea Asset Management is one of the largest asset managers in the Nordics, managing €205 billion in different asset classes. Nordea Asset Management's mission is to deliver returns with responsibility based on active management and thorough risk management. Integrating climate risk as well as other sustainability risks into investment decisions is critical, since neglecting these risks could have a negative impact on investment performance through unwanted risk exposures and missed opportunities throughout the transition to a low-carbon economy. Nordea joined the UNEP FI Pilot together with other investors since we welcome TCFD recommendations and want to contribute to the development of tools to assess climate-related risks through scenario analysis.

Delayed policy response

A global policy response that would limit global warming from rising above 2°C as compared with pre-industrial levels does not seem likely to be reached within the foreseeable future. Thus, we explore what a potential cost curve would look like if a policy response to climate change were to come through in five years. We also compare this cost curve to what a 2°C-aligned policy response would suggest today, as well as against a BaU scenario. All data presented in the case study assumes a policy response that would be aligned with a 2°C world. How realistic that is in itself is beyond the scope of this case study.

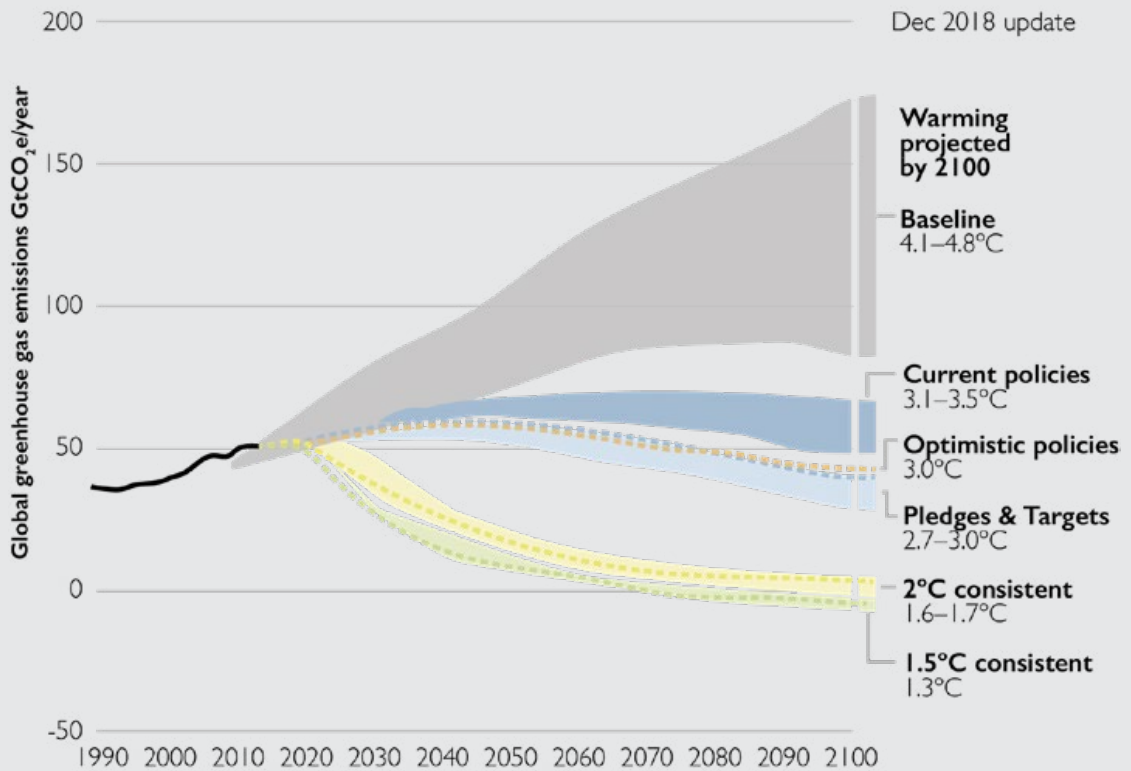
Using the Carbon Delta methodology under a 'delayed policy' response, **we find that costs are higher the later a policy is implemented, and we find strong differences in terms of impact on sectors.** We believe that a sector focus is most relevant in terms of scenario analysis as it is confirmed by this, and other models, that sectors are not equally exposed to climate-related risks. We also believe that there is **substantial difference among companies within sectors.**

Finally, we explore whether policy risk will take the form of an instantaneous impact rather than smooth and gradual pricing. We argue that climate policy, specifically relating to setting **a price on carbon, will be rapidly transmitted to financial assets.**

Current state of affairs: Transition risk is likely three-to-five years out

In this case study we try to explore a way of using the Carbon Delta model for conducting scenario analysis on a global benchmark against a delayed policy response towards climate change. The long-term temperature goal of the Paris Agreement, with voluntary commitments by countries globally, is keeping the increase in global mean surface temperature from rising above 2°C as compared with pre-industrial levels by 2100. However, as shown below, going beyond the current policies in place, and incorporating pledges and targets by countries today, brings the projections of an increase in pre-industrial temperatures within the band of 2.7–3.0°C.

Figure 20: Warming projections to 2100



Source: Climate Action Tracker, 2019

As reported by Climate Action Tracker, very few countries are living up to their voluntarily submitted NDCs. The US, the world's largest economy, has announced that it is pulling out of the Paris Agreement. While the Paris Agreement does not stand and fall with one signatory, we believe that the current state of affairs signals the order of importance being attributed to climate change from a policy perspective.

Against the context outlined above, we argue that a policy framework in terms of what eventually trickles down to corporate bottom lines most likely lies beyond a three-to-five-year horizon. We argue that it is precisely because of this uncertainty around a policy response that scenario analysis is crucial, given that the associated costs are profound.

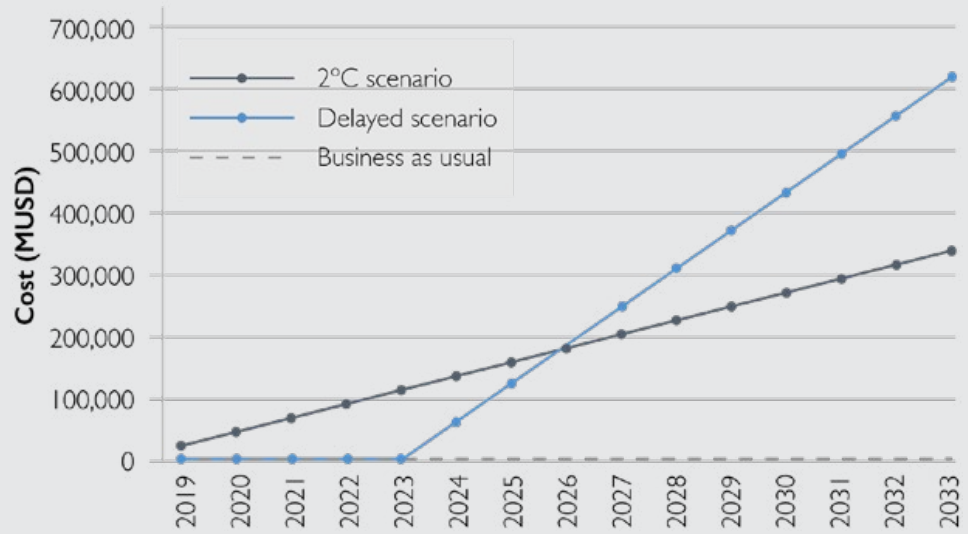
Delayed policy response – more expensive

Within the scope of this case study we explore the risks—defined as costs due to policy responses on a global benchmark—that come into effect in five years. We assume that going into 2024, a global price on carbon will be adopted with the ambition of staying in line with the Paris Agreement. This would, by default, trigger a more aggressive policy framework in terms of decarbonisation of the economy as compared with what a credible response would require today, also shown in the graph as the 2°C scenario. This scenario is represented by the REMIND model and assumes that there is a global price on carbon in effect as of today and is included only as reference. In contrast, **the Delayed scenario represents a 2°C aligned policy framework and comes into effect in five years, using GCAM.** The 2°C policy framework five years out represents the requirements for achieving a 2°C economy and comes at a larger cost compared with implementing policies. The notion of incurring more costs from a more delayed policy response is also discussed in (IPCC, 2018).

Worth noting is that within the scope of this analysis we have not used the full Carbon Delta model that would also include transition opportunities. We are trying to zoom in on the costs induced by regulatory action. Indirect costs and opportunities from both physical circumstances and technological aspects are worth diving into separately as well. Different policy responses (or lack thereof) induce different types of risk and opportunities on both the technological and physical side (extreme weather events, rising sea level, among others).

Cost curves from different policy initiatives

Figure 21: Nordea cost curves of the 2°C and Delayed scenarios

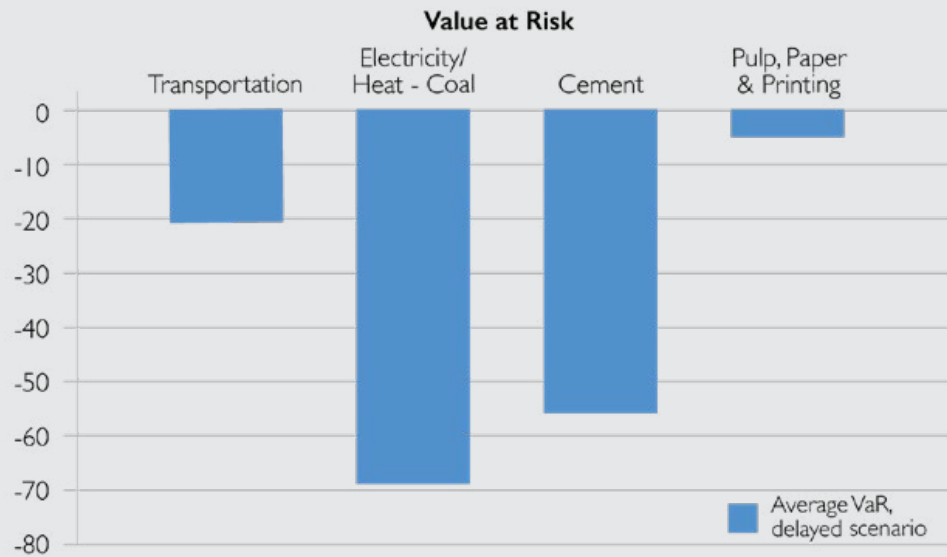


Source: Nordea, Carbon Delta

In addition to the 2-°C scenario and Delayed scenario, we have included a BaU scenario which assumes no costs induced by policies. The possible costs range between USD 0 (BaU) to roughly USD 3.5 trillion, on a cumulative basis, at the end of year 2033 (Delayed scenario).

The difference in the cumulative costs between the Delayed scenario and the 2°C-scenario is roughly USD 0.7 trillion over 15 years. We believe that being in a BaU scenario and looking at the different implications in terms of aggregated costs represents a violent departure from what is currently being priced in. One could argue that in the absence of policy risks, it is rightly so not priced in. However, as far as economics is concerned, we believe that the policy risk module of the Carbon Delta methodology helps us understand and articulate the different distribution of outcomes and demonstrates that policy-related climate change risks, once materialised, represent fat-tailed events that, at the very least, deserve being monitored and conceptually understood.

Figure 22: Nordea VaR across sectors: not all costs are equally spread across sectors, but rather centred



Source: Nordea, Carbon Delta

The figure shows the weighted average VaR across sectors within a global benchmark. Note that we have chosen the four sectors for illustrative purposes. It should roughly be interpreted as the total costs induced by climate change-mitigating policies on different sectors *relative* to the current market values today. The magnitude of costs, as modelled by Carbon Delta, varies significantly and illustrates the importance of understanding where the main risks lie.

An instantaneous impact rather than smooth and gradual pricing?

Climate change has been high on the agenda for Nordea Asset Management for several years and methods/tools for scenario analysis are important to further assess the complex risks related to climate change. The case and the use of the Carbon Delta tool for different portfolios are important steps to further develop our assessment of climate-related impacts on our holdings.

We would argue that since financial markets react rapidly, a policy response aligned with a 2°C scenario would not be a smooth and gradual process under which portfolios can be rebalanced but, in theory at the very least, a relatively quick process of incorporating the whole cost curve represented by a Delayed scenario. It is worth emphasising this as herein lies the risks on financial assets from an investor's perspective.

We want to highlight that Carbon Delta's policy risk module uses numerous assumptions, some more and some less realistic. For example, **potential improvements could include cost pass-through analysis** in the model, which would reduce estimation errors by some margin. However, looking at the implications from the above scenarios on an aggregated level highlights the overarching picture and should help establish focus areas for climate change risk management and active ownership activities. This could potentially focus on pushing companies to reassess the importance being attributed to climate risk management and proper disclosure around these.

As a final note in this study, and in addition to the cost pass-through potential referred to above, Carbon Delta's policy risk module does not currently **capture company-specific efforts** to manage these risks and diversify different business models away from carbon risks, which would provide more granularity in general, and we strongly recommend taking steps to further develop the model in this direction.

ROCKEFELLER

ASSET MANAGEMENT

ROCKEFELLER: APPLYING SCENARIO ANALYSIS TO ACTIVELY MANAGED STRATEGIES

Rockefeller Capital Management L.P. is a global investment advisory and asset management firm that provides an array of services to individuals, families and trusts, as well as pensions, foundations, endowments and other institutions. Rockefeller Asset Management (RAM) offers tailored investment strategies with a global sector focus that incorporates an in-depth ESG analysis. It is an active manager and runs concentrated, long-only portfolios. In 2018, we applied the climate model generated by the UNEP FI TCFD Investor Pilot Project to 90% of RAM's assets under management. Climate change is a key topic of engagement with portfolio companies held in our core investment strategies.

An integrated fundamental approach to assessing climate-related risks and opportunities

A majority of RAM's climate-related risks and opportunities are embedded within its core investment strategies. Climate-related risks and opportunities are assessed by both the Investment Analysts and the Investment Committee for all portfolio companies entering RAM's core strategies, regardless of investment objective. Risks, risk mitigation strategies and opportunities are researched, deliberated and presented on an individual company basis to the Investment Committee alongside other elements of fundamental valuation. The Chief Investment Officer chairs the Investment Committee and sits on both the Executive Management Team and Risk Committee of the Firm.

Climate-related risks to portfolio companies are identified through a bottom-up assessment that considers the company's past emissions performance, strategy to reduce future emissions, regulatory and physical risks within its operations, as well as risks to its product portfolio from demand and technology disruption. RAM joined the UNEP FI Pilot to run our assumptions through climate models that consider the different regulatory and physical risks associated with different emissions pathways. Although we applied the model to approximately 90% of RAM's assets under management, for the purposes of this case study we are focusing on the results from our Global Equity and Global ESG Equity Strategies. These two were selected due to their similar beta and performance track record. In addition to gaining more insight, we thought it would be interesting to see if considering physical and policy risks would create more dispersion between these two strategies, or at least alter our perception of their risk profiles. We also consider the results from our Global ESG Fossil Fuel Free Equity Strategy to examine how excluding the energy sector value chain proves beneficial or detrimental under the pilot project model.

Modelling policy risk: Global Equity vs Global ESG vs Global Fossil Fuel Free

For the purposes of this model, the differences in the scenarios are inherently about determining policy risk and the cost of those risks. The CVaR results were in line with our expectations on a relative basis: our Global ESG Fossil Fuel Free Equity Strategy fared better than both our Global ESG Equity Strategy and our Global Equity Strategy under a 1.5°C and 2°C scenario. This is mostly attributable to the Global ESG Fossil Fuel Free Equity Strategy's exclusion of the energy sector value chain, which should face the heaviest regulatory headwinds under these scenarios. The Global ESG Fossil Fuel Free Equity Strategy does not contain producers, refiners, transporters or vendors of fossil fuels, and excludes utilities that generate power from non-renewable resources, and returned a CVaR of -1.1%.

Table 27: Rockefeller portfolio CVaR results comparison

Portfolio name:	Global ESG Fossil Fuel Free Equity Strategy	Global ESG Equity Strategy	Global Equity Strategy
Portfolio VaR:	-1.1%	-1.4%	-2.6%

Source: Rockefeller; Carbon Delta

As anticipated, the Global ESG Equity Strategy had a lower CVaR at -1.4% than the Global Equity Strategy at -2.6%. As carbon footprinting is the basis for policy risk analysis under this model, we can note the resilience of both the Global ESG Fossil Fuel Free Equity Strategy and the Global ESG Equity Strategy relative to the Global Equity Strategy. This was to be expected given that the Global ESG Strategy has less of an allocation to energy and utility stocks relative to the Global Equity Strategy and the benchmark. Additionally, all energy and utility names that qualify for the Global ESG Equity Strategy must have emission reduction targets in place and a plan to reduce those emissions, and show a track record of meeting or exceeding targets.

However, although the carbon footprint for Global ESG Equity Strategy is *35% less* than that of Global Equity Strategy, it is only *20% more* than the Global ESG Fossil Fuel Free Equity Strategy, despite holding an active weight of energy companies. Looking deeper into the analysis we can understand why: the reliance on Scope 1 emissions data as the basis for the policy risk assessment.

For both the Global ESG and Global Equity Strategies, energy names do not comprise most of the policy risk on an absolute or portfolio-weighted basis. Since the model considers only Scope 1 emissions, there is a sector bias depending on how carbon is consumed along a company's value chain. A majority of emissions for companies in the materials sector fall into the Scope 1 category, whereas the majority of emissions in the energy and transportation sectors would be considered Scope 3. As a result, materials companies contributed the highest policy risk on an absolute and portfolio-weighted basis for all three strategies, followed by transportation and energy for Global ESG, with energy coming in fourth for Global Equity, behind utilities and transportation.

The reliance on current Scope 1 emissions for determining the forward emissions trajectory of a company highlighted a gap in the model that conflicts with our own fundamental research. Carbon footprinting is a backward-looking metric, and it is likely to require more forward-looking nuance to quantify policy risk with more accuracy. Here, the intrinsic and macro context of the sector is critical to consider. For example: **While materials companies would need to evolve their operations away from fossil fuel power and heat generation, energy companies would have to change their business models entirely.** This is a dynamic that clearly shows a greater inherent risk to energy companies as changing an entire business model requires substantially more investment than merely shifting operational infrastructure (such as kilns and power plants). Additionally, demand for materials such as cement is less likely to be disrupted by emerging technologies when compared to the potential demand for fossil fuels to be displaced by renewables and electric vehicles.

The importance of fundamental research

Going a step deeper, our own assessments have concluded that the carbon policy risk profiles of our materials holdings vary widely, whereas the model gave us similar risk and enterprise value figures. As an example: we hold two cement companies, and while they are classified in the same subsector, we deem **one cement company as having significantly higher risk than the other.** While one company commits more than 80% of its R&D budget to developing lower-embedded carbon alternatives and has set a science-based target in line with the 2°C scenario, the other company has historically fallen short of its emission reduction targets. While one company has integrated carbon reduction into its core operational directives, the other has not made asset allocation decisions to that effect, nor does this issue seem to be embedded in senior management's strategic decision-making. This kind of insight and information was gathered through frequent meetings with the C-suites and site visits with operational division heads for both companies. This type of analysis is currently not reflected in the model, leading the policy and enterprise risk for both companies to be relatively in line for all scenarios.

Physical risk: Global Equity vs Global ESG

Given that the emissions concentrations currently in the atmosphere will dictate the climate conditions up to 2035, there should not be much variation in the estimated physical risks across scenarios. Interestingly, the physical risks embedded in both the Global Equity and Global ESG Equity Strategies are quite similar. Coastal flooding and extreme heat make up the majority of the physical risks to both strategies. However, one question this analysis did raise surrounds the 'Extreme Weather Cost on Enterprise' metric, which estimates the reasonable cost to repair damages from certain physical risks. The company with the highest Extreme Weather Cost on Enterprise for both strategies is a consumer health company that owns and operates pharmacies throughout North America. As a result of its exposure to heat, high winds and flooding from hurricanes, the model has determined that it will have the highest costs on an annual basis. Interestingly, 70% of the Global Equity Strategy and 60% of the Global ESG Equity Strategy's top ten companies showing the highest Extreme Weather Cost on Enterprise all have thousands of retail locations.

This raised a question surrounding the real costs to repair retail locations versus the cost and time it would take to repair, say, a semiconductor manufacturer needing to replace expensive, bespoke industrial machinery. There is also the risk to revenue disruption that needs to be considered. Although a business might have fewer locations, which reduces the likelihood of an extreme weather event impacting operations, it could raise the risk that an extreme weather event could stop a critical part of the manufacturing supply chain or require hundreds of millions of dollars in rebuilding capital equipment.

Despite this gap in the model, physical risk data points would be helpful to our process as we engage our portfolio companies around resiliency planning for extreme weather events.

Investment implications

This process has elicited key questions for RAM: should we be investing today to prepare for a future of less likely policy scenarios? Given that increasing climate volatility is a systemic risk to global markets, should we be investing to decrease the likelihood of warming trajectories despite lagging policy? Can we, in fact, do both?

The best we can determine is that pushing emissions-heavy industries to decarbonise could be more effective than divesting. It serves the purpose of both reducing the amount of carbon in the atmosphere and minimising regulatory risk from carbon pricing schemes. The flexibility of active management would allow us to take advantage of opportunities, should the probabilities of the 1.5°C and 2°C scenario increase. Regardless, the physical and policy risk values generated by this model can enable a more precise engagement with our portfolio companies.

Challenges for active managers and concentrated portfolios

The core of RAM's research approach is to work closely with companies in an effort to understand their risk management approaches to climate change, including emissions target setting, remuneration tied to energy or emission reduction, capital expenditure for efficiency improvements, targets for renewable power procurement, and capital allocation toward less carbon-intensive projects, among others. A significant gap in the model is that it does not provide a place to reconcile the information gleaned from this type of research with assumptions from the datasets. The subsequent iteration of this model should include a way to project future emissions trajectories. Such projections could be adjusted to reflect company commitments and not just policy risks.

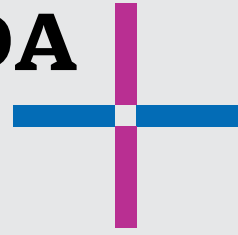
Another issue arises for active managers when it comes to financial modelling for concentrated portfolios. Every company across RAM's core investment strategies has been valued according to our analysts' bespoke proprietary models, with differing assumptions, perspectives and discount rates. The current model does not allow for an adjustment to the WACC or discount rates used to determine terminal values. Therefore, it is difficult to embed the magnitude of the risk to the future value of a company when there is a disagreement as to what that future value will be. Applying blanket modelling for valuation does not fully serve our purposes as an active manager.

RAM's analysts speak with the managers of our portfolio companies on a regular basis to gain insight on the myriad of issues that a changing climate poses to their businesses. A critical part of these conversations is to apply shareholder pressure to challenge their processes, advocate for more aggressive targets for emission reductions, as well as encouraging them to build the internal management structure needed to make real progress on climate issues. In this regard, the underlying data from the model would be very useful as we could use the individual risk metrics and enterprise estimates to better understand a company's own assumptions on the risks they face.

Given the speculation regarding emissions trajectories and the likelihood of the 1.5°C and 2°C scenarios coming to pass, it will be challenging for RAM to practically apply the aggregate CVaR for investment purposes without further customisation. However, we hope that by undertaking this exercise, we can discuss the outcomes of this analysis with our portfolio companies as a way to challenge and encourage them to conduct a similar type of policy and regulatory risk modelling as per the UN TCFD recommendation guidelines. RAM's hope is that this exercise can deepen the conversation between companies and their investors and encourage the systematic disclosure of climate risks and opportunities throughout the public markets.

ADDENDA

CAPITAL



ADDENDA CAPITAL: THE REAL BENEFITS OF SCENARIO ANALYSIS AND DISCLOSURE COME FROM THE PROCESS ITSELF

Addenda Capital is a Canada-based investment management firm offering a broad range of investment strategies across equities, fixed income and commercial mortgages. Addenda's approach to sustainable investing focuses on integrating ESG issues into all its investment processes to deliver higher-quality portfolios. Addenda has been considering climate-related issues in its investment processes for many years. For instance, we have been a CDP climate signatory since 2009 and in 2015 Addenda Capital signed the Montreal Carbon Pledge and was the first Canadian investment manager to publicly disclose the carbon footprint of all its equity funds. We welcomed the establishment of the TCFD in 2015 and have been using its final recommendations to inform both our internal activities and our engagement dialogues with the entities we invest in. We joined the UNEP FI TCFD Pilot Project to help us improve our practices and disclosure.

Preparing our own disclosure drove internal action

When Addenda Capital joined the pilot group, we also made a commitment to address the TCFD's recommendations in a report to our stakeholders about how we are identifying and managing climate-related risks and opportunities. This commitment means that all of Addenda's investment teams should be familiar with the TCFD recommendations. Each team has had an opportunity to reflect upon its existing investment processes and climate-related considerations—some more so than others. Those reflections and enhanced awareness of how other investors have been evolving their approaches to thinking about climate change have triggered some improvements to our own practices and have also led to the identification of new approaches to be developed in the future.

A useful exercise involved our Sustainable Investing team meeting with members of one of our investment teams to review the TCFD recommendations and to discuss how that team's investment process was addressing the actions itemised in the disclosure recommendations. For this exercise, we deemed each team to be the 'organisation' at the core of the TCFD recommendations and discussed the team's current activities, shared the scenario analysis work being developed by the pilot project group, shared examples of TCFD-based disclosure from other investment managers, and discussed possible improvements. Following those interactions, we documented our activities and prepared the content that will inform our disclosure to our clients and other stakeholders.

Some of the climate-related tool and/or process improvements we are considering will take longer to implement, but others were implemented quickly because our investment teams saw the potential value and they were relatively easy to implement. One small example is the development and use of a quick reference guide to climate-related risks, their time frames, and related open-ended questions to consider. This short guide has helped our investment teams clarify their climate-related questions and relate climate considerations to drivers of financial and investment performance.

Scenario analysis is not perfect, but we learn something new with each evolution

Addenda joined the UNEP FI Investor Pilot with the hope that by working with a large group of sophisticated investors, and by appointing an expert consultant to help us with scenario analysis, we could help contribute to the development of the industry's understanding of and ability to implement the TCFD's recommendations including scenario analysis. Unfortunately, we have not established a harmonised, industry approach, but working

with the other pilot project investors and Carbon Delta has improved our understanding of scenario analysis as applied to our own investment processes and as undertaken by the entities we invest in.

Working with Carbon Delta to understand its methodology as it existed at the beginning of the pilot project, and working alongside Carbon Delta and the other pilot project investors as the methodology was improved, was informative for us as we continue to develop our own approach to scenario analysis. For instance, estimates of global and national GHG trajectories based on NDCs and related estimates of carbon prices are useful macroeconomic estimates that we can consider when thinking about how the transition to a low-carbon, climate-resilient society might occur, and the impact that transition will have on national economies and sectors. Considering how carbon prices might evolve, how physical impacts might manifest themselves, and what the economy might look in different scenarios are all useful exercises that we will repeat as our understanding and the tools continue to evolve.

The methodology for translating these high-level estimates and scenario outputs into company-specific impacts is less well developed. Our analysis uncovered several methodological challenges, such as estimating the impact of the ability of a company to pass through carbon costs to its customers or determining its optimal mix of operating and capital expenditures to address carbon costs. We have not yet addressed these challenges quantitatively but we have been able to incorporate some consideration of these issues into our analysis of how companies are responding to climate change.

Working through the challenges and limitations of climate scenario analysis has also informed our analysis of the climate-related disclosure being provided by the companies we invest in. We are better prepared to ask questions about key assumptions that companies are making. For example, when reviewing the scenarios presented by an energy company, we can evaluate the cogency of each scenario's economic growth and energy consumption by fuel output characteristics.

A valuable exercise

In conclusion, developing our own climate disclosure and better understanding climate scenario analysis has helped us improve our own processes and analysis and should help us deliver long-term value for our investment partners.



DNB: PORTFOLIO SCENARIO ANALYSIS AND COMPANY ENGAGEMENT

The DNB Group is Norway's largest financial services group and DNB Asset Management (DNB AM) is a wholly owned subsidiary of DNB. DNB AM is among the leading asset managers in the Nordic region, managing approximately USD 69 billion³¹ in equities, fixed income, multi-asset and alternative investment strategies on behalf of institutional, high-net-worth individuals and retail clients. We offer both actively and passively managed strategies covering Norwegian, Nordic, and global developed and emerging markets.

Climate change has been one of DNB AM's long-term focus areas for many years as we recognise that it can materially impact company value, both positively and negatively. Our ambition is to make a meaningful contribution towards the goals of the Paris Agreement by taking a long-term view and effectively managing the risks and opportunities associated with the transition towards a low-carbon economy. Central to delivering on climate change are the availability and quality of data for use in our investment decision-making process—so-called ESG integration. The TCFD recommendations are therefore welcomed as a framework for increasing the transparency and quality of climate-reporting. The recommendations and the work on scenario analysis provide a systematic approach to structure, and describe and communicate climate risk and opportunities at portfolio level. The investor pilot also works to build competency in the financial effects of climate change.

Investor engagement today

We engage regularly and extensively with Norwegian and international investors on the topic of climate change. Our climate strategy outlines our expectations, how we engage, and when to exclude companies.

As part of a proactive engagement we are conducting together with other Norwegian investors on the implementation of the TCFD recommendations, we have met with or will meet selected Norwegian companies within sectors that are highly exposed to climate-related risks and opportunities: energy, materials, transport, food and beverages, seafood, and banks (with a Nordic focus). Through this work we communicate to companies which metrics are useful inputs to our investment decision-making process, as outlined in our expectations document on climate change. This engagement also serves as a channel for gathering information to determine companies' preparedness for mitigating climate-related risks and opportunities and their strategic direction.

International investor engagements on climate change include our participation in Climate Action 100+. This five-year initiative led by investors targets the world's largest 100+ GHG emitters and other global companies and aims to improve governance on climate change, curb emissions and strengthen climate-related financial disclosures. As collaborating investors in Equinor and Maersk, we have had insightful meetings with these companies and are happy to see that Equinor continues to be world-leading in regard to its scenario analysis work, and that Maersk has recently committed to become carbon-neutral by 2050 (without offsetting carbon). Moreover, we participate in several UNPRI-led investor collaborations on methane emissions and deforestation (for sustainable palm oil, soy and cattle).

The TCFD Pilot is complementary to our current engagement efforts, presenting an opportunity to stress-test our understanding of companies using quantitative indicators, where previous engagement has primarily relied on qualitative assessments.

31. As at December 31, 2018.

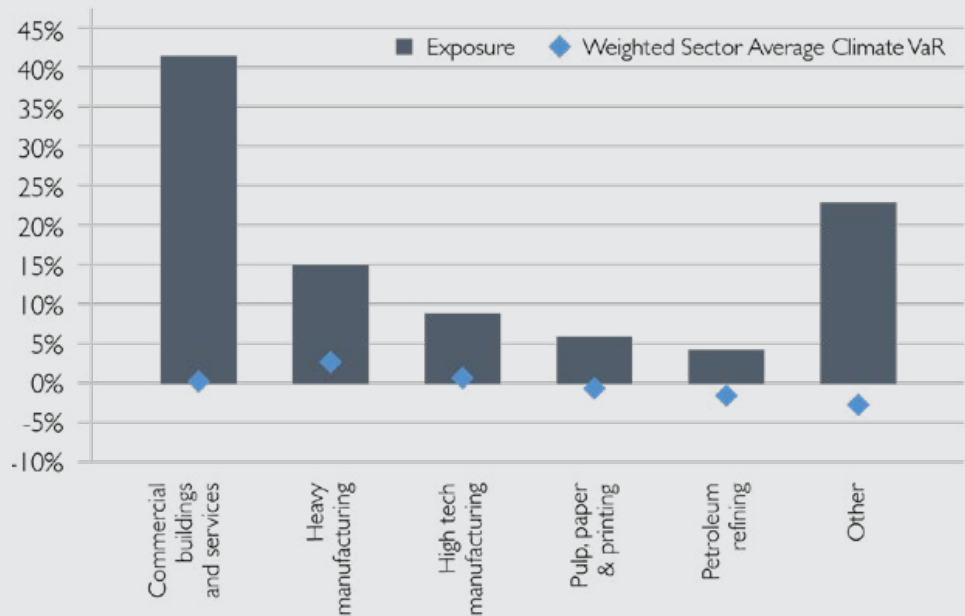
Evaluation of quantitative results

As part of the development process of the scenario analysis methodology, Carbon Delta has analysed our DNB Norden Indeks portfolio. DNB Norden Indeks is a passively managed equity fund that closely tracks its benchmark, VINX. As with all funds we offer, companies that are not in line with DNB’s Group Standard for Responsible Investments are removed from the fund. We selected this fund for analysis as we wished to assess the results in regard to a broad portfolio that invests in markets in which we have detailed company and sector knowledge, such that we were better placed to assess the accuracy of the results. We further wished to check the data coverage of companies of Nordic medium-to-large-cap companies.

In addition to this, we have tested four portfolios in the tool: a global fixed-income fund and three sustainability-themed climate-tilted funds. Our intention was to test whether our climate strategies perform as expected in the tool. In line with our expectations, all three sustainable strategies returned positive aggregated CVaRs. We also observed higher CVaRs for strategies utilising positive screening. Nonetheless, we would have expected the positive contribution to be even higher for our fund which invests in climate solution stocks. The positive impact is likely to have been downplayed as technology opportunities are captured through low-carbon patents, and may not accurately reflect the positive contribution of ‘green’ products and services, including proven renewable energies and energy efficiency. This highlights a potential point of improvement moving forward, where we would expect to see a greater reflection of companies contributing positively to the transition to a low-carbon economy.

The results presented in this case study apply only to the Norden Indeks fund.

Figure 23: DNB portfolio, scenario and results information



Note: Scenario information: 2°C scenario, REMIND (average), combined VaR: -0.7%

Source: DNB, Carbon Delta

Interpreting the results entails first understanding the aggregated, high-level characteristics of the portfolio—sector and country exposure in terms of revenue generated. In addition, it requires in-depth knowledge of the underlying holdings—their business models and regional exposures, among other factors. To understand the drivers behind the results, we deep-dive into the company results using the underlying data and company factsheets from Carbon Delta.

The results of the scenario analysis show relatively minor negative impacts to the portfolio under a 2°C scenario, with an aggregated CVaR of -0.7%. There is good data coverage of the portfolio, with 95% of the holdings covered by Carbon Delta’s data.

At the portfolio level, the results are reasonable relative to other portfolios and the strategies employed by each. Any unexpected results arise at the company level. For example, one of the most exposed companies was a Norwegian fish farming company, which was estimated to be at higher risk than several airline companies. While this was surprising given the respective sectors, on further investigation we find that this is driven by the company's very high estimated Scope 1 emissions. These estimated emissions were significantly higher than the airlines' emissions. Carbon Delta's methodology relies on estimated top-down data, which is beneficial in that it increases the total company coverage available in the tool. However, a weakness of this approach is that accuracy may, in some cases, be compromised. The methodology's reliance on Scope 1 emissions may not fully capture nuances between companies and may therefore provide an incomplete picture of company emissions as Scope 2 and Scope 3 are not considered. Similarly, companies' avoided emissions are not accounted for. We recognise that there is not yet a standard methodology for calculating this. The model's reliance on estimated emissions figures may even be counterproductive in company engagements where the data drastically differs from self-reported data. Companies may begin to question the value of their reporting to investors and may question the validity of the scenario analysis. **Ideally, we would like to see companies using this as motivation to report their emissions where they do not currently.** Moreover, it is the role of investors to communicate to companies which reporting channels are valuable.

Furthermore, the methodology places fish farming companies within in the carbon-intensive agriculture sector. As the emissions profiles of agriculture companies vary significantly—for example meat producers versus fish farmers—it will be necessary to utilise more granular sector breakdowns in future iterations of the model to distinguish between these. Through the pilot modelling exercise, we learnt that it would be useful to compare self-reported company emissions with top-down aggregate estimations where possible. This would help the analyst to understand the company against industry benchmarks.

Scenario analysis results as a useful engagement tool

We view the initial results of our portfolio scenario analysis as an important first step in analysing companies' preparedness and engaging with them on their exposure to transitional and physical risks and opportunities. Engagement with companies will raise awareness of the significance of climate-reporting to investors, allowing us to communicate which reporting channels and metrics are valuable. For companies that do not already disclose or have processes in place, we hope to encourage these to begin disclosing for increased transparency and to avoid their impact being modelled. For those companies that do disclose, we wish to identify if there are any significant differences in our results compared with the companies' own assessments, and to learn what is driving the differences. Differences may result, for example, from varying methodologies, limitations, and assumptions. Understanding different approaches to scenario analysis may uncover new and better ways to approach portfolio scenario analysis, or sector-specific considerations.

Understanding and incorporating the findings from engagements will be useful additional inputs for our in-house company assessments of companies, and necessary in sense-checking and validating the results of the scenario analysis. Engaging with companies provides a systematic approach to assessing company-level results, which has the added benefit of allowing us to gather additional information and clearly communicating the importance of climate-reporting to companies. This data will be used in the investment process as an input for further analysis and valuations considering company impacts of climate-related risks and opportunities, which ultimately inform investment decision-making and portfolio construction.



INVESTA: IDENTIFIED METRICS FOR FUTURE REAL ESTATE ASSESSMENTS

Investa and climate risk

As a long-term owner and manager of commercial office buildings in Australia, the resilience of our cities and the life systems Investa relies on like public transport and healthcare are of key material operational risk to Investa.

Since 2012, Investa has been working with the Australian Business Roundtable for Disaster Resilience and Safer Communities to drive awareness in the property sector of resilience risk and necessary mitigation investment. As Investa's carbon reduction strategy 'Getting to Zero' articulates, Investa aims to expand our boundary of influence to include investors and our broader community.

Pleasingly, the TCFD will enable a direct dialogue around the resiliency of real assets and ultimately the associated financial exposures. During FY18, Investa engaged investors directly to gauge expectation and best practice approaches to TCFD reporting. At the same time, in conjunction with the UNEP FI Investor Pilot, Investa applied climate change scenarios to assess key material risks and the associated financial exposures. Results showed that its portfolio is well positioned to mitigate the transitional risks identified, while more work is required to assess the physical risks (most notably fluvial flooding and heat waves) posed to the assessed portfolio.

Quantifying climate risk for 100% of assets under ownership

To ensure the maximum benefit from insights gained from the programme, Investa submitted 100% of assets under ownership and management to the UNEP FI analysis. This is in recognition of the fact that climate change poses a risk to the whole Investa portfolio, rather than just to particularly vulnerable outlying assets. Assets included are in Sydney, Brisbane, Melbourne, Perth and Canberra.

Investa's proud history of climate change and carbon-reporting has been to include all assets, irrespective of performance, in annual environmental performance reporting, which has been carried out since 2004. Over this time period Investa has reported a 61% reduction in carbon emissions intensity, a tremendous outcome which demonstrates its ability to actively mitigate the climate impact of its portfolio.

Older assets carry risk but can make strong efficiency gains with investment

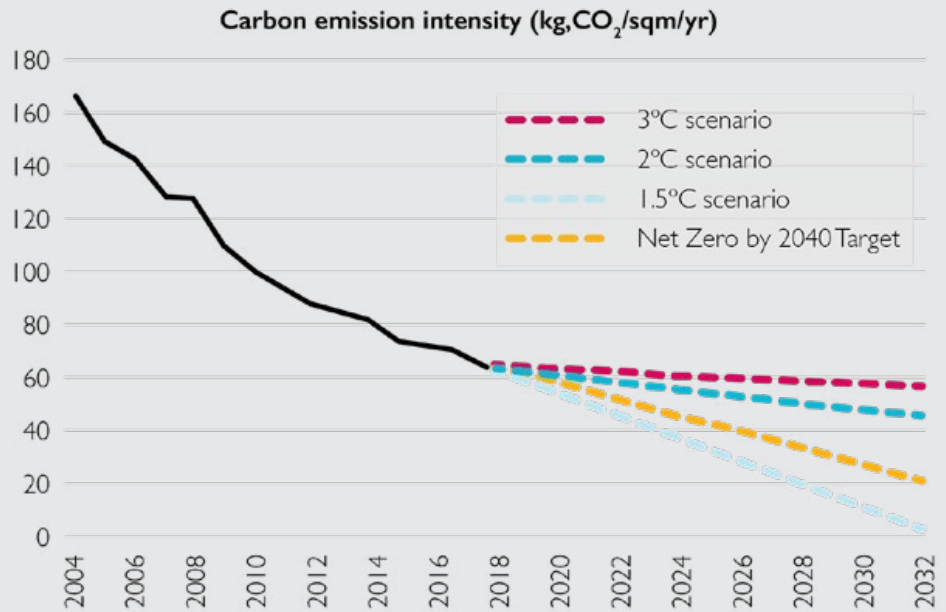
Investa is well placed to achieve the 1.5°C reduction requirements. In 2016, it set a carbon reduction target of net zero carbon emissions by 2040.

Pleasingly, Investa's excellent track record of monitoring and managing carbon emission performance has resulted in the portfolio being well placed to respond to the transitional risks posed by climate change. This is best quantified when considering that Investa's certified Science Based Target of net zero emissions by 2040 is targeting a portfolio-wide emissions intensity of 20.72 kgCO₂/sqm/yr by 2033, well within the range defined by the 3°C and 2°C scenarios, as shown in the figure below.

Mapping the (linear) reductions required to meet the target emissions level by 2033 under the 3°C, 2°C and 1.5°C scenarios for the whole portfolio (as shown in the figure below) illustrates that with a continued 4% annual emission reduction trajectory (consistent with historical reductions), Investa's portfolio is well placed to make these reductions. Since

setting the Net Zero by 2040 target in 2015, the Investa portfolio is presently (2018 dataset) 1.6% ahead of the required emission reductions required to meet this target.

Figure 24: Investa historical emissions performance and projected emissions trajectories under various scenarios



Source: Investa

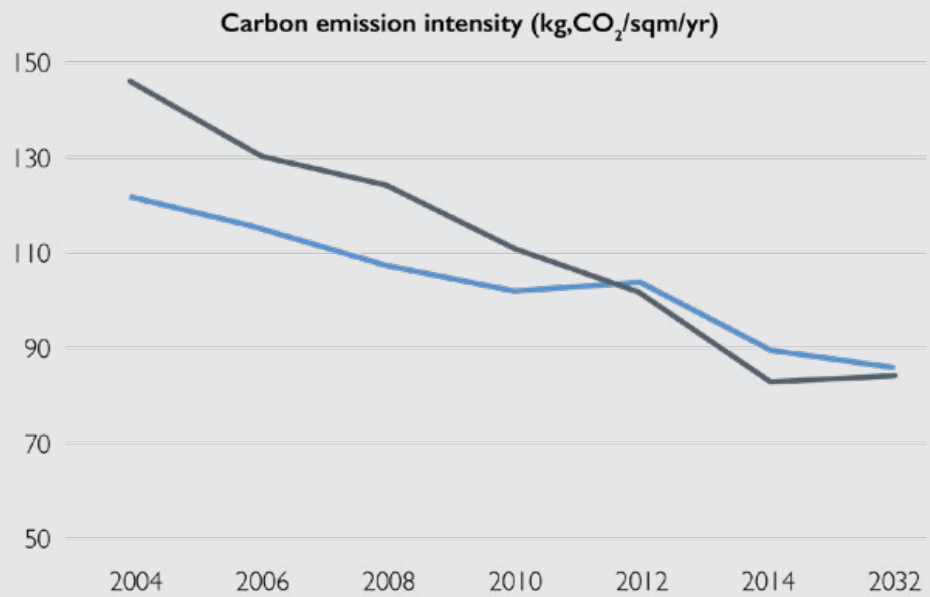
Given that Investa’s portfolio is tracking ahead of the transitional risk posed by the 3°C and 2°C scenarios, the greatest transitional risk is posed by a 1.5°C future.

Across the 28 assets submitted to the assessment, 0.21% of total value was deemed to be at risk in the 1.5°C scenario. Note, this quantified risk represents exclusively the transitional risks posed by a 1.5°C scenario, not the physical climate risks.

Of the total VaR under the 1.5°C scenario (0.211% of total gross asset value), 85% stems from older assets within Investa’s portfolio. This is because these assets possess older forms of building technology and as a result are not as energy-efficient (and carbon-efficient) as newer assets. Despite this, steps have still been taken to ensure that the risk exposure to these older assets is mitigated.

Energy efficiency initiatives, even in the two most carbon-intensive assets, have registered 42% and 29% emission reductions over the past two years, as shown in the figure below. While these two assets are the most carbon-intensive in the portfolio, if the specialist property management teams can continue this progress towards the 2033 horizon of the scenario analysis modelled, the transitional risks posed by a 1.5°C future will be mitigated.

Figure 25: Investa carbon emission reductions at Asset 1 and Asset 2 over the period FY12-FY18



Source: Investa

Enhancing transitional risk models

A potential enhancement to the modelling of transitional risks would be the inclusion of Scope 3 emissions. These are more complicated to measure, and harder still to reduce; however, real action on climate change requires vigilance around the total operational carbon footprint. The Science Based Target Initiative sector-based approach required the measurement and reduction of Scope 3 emissions to achieve an approved target.

Investa will continue to monitor and work with key stakeholders (including tenants, industry bodies such as the Green Building Council of Australia, and international bodies including the Global Real Estate Sustainability Benchmark and the Science Based Targets initiative) to reduce the portfolio's Scope 3 emissions.

Location of assets matters

In addition to the age of assets, the other factor which influenced susceptibility to the transitional risks of climate change is location. Geographical differences provide two important distinctions:

- The local climate determines the work required to condition the asset's indoor environment, with the heat of summer and winter cold experienced to different degrees in different Australian cities. In addition, natural hazards differ acutely between cities, requiring a varying suite of mitigation measures. Brisbane experiences cyclones and flooding; Sydney weathers severe storm events; whereas Melbourne will experience extreme heat waves. The scenario analysis has demonstrated that the impact of the contrasting meteorological context has an immediate effect on VaR.
- Beyond just the climate context, the local energy grid also demonstrated a variance in VaR. The composition of the state energy grid determines the carbon intensity of the assets which draw their energy from the local grid. This is due to differing energy-generating capacity between states, with some states more dependent on high-carbon sources of energy, while others have more renewable energy in the mix. These calculations are made by the Australian Federal Government's Department of Environment whose annual National Greenhouse Accounting (NGA) Factors determine the calculation of carbon intensities of Investa's buildings. The latest NGA factors used to calculate the emissions profile of the portfolio are provided in the table below.

Table 28: Investa NGA factors across Australian cities where portfolio is situated

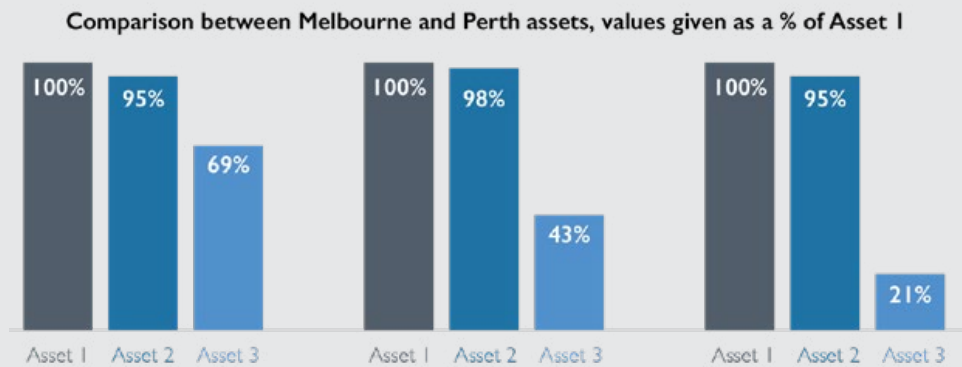
	Sydney	Brisbane	Melbourne	Perth
Emissions factor (kgCO₂-e/kWh)	0.83	0.79	1.08	0.70
Amount of assets	16	6	3	3

Source: Investa

The impact of NGA factors is highlighted when comparing three assets across the portfolio. These three assets share similar characteristics; they are the three largest assets considered by Carbon Delta by NLA—all in excess of 60,000sqm—and are considered ‘Premium’ or ‘A’-grade according to the Property Council of Australia’s classification.

Due to the differences in NGA factors, relatively small differences in energy consumption result in larger discrepancies when comparing emissions profiles, and larger differences still when considering the modelled VaR in a 1.5°C scenario.

Figure 26: Investa variance between energy intensity, emission intensity and VaR across geographies



Source: Investa

This speaks to the need to assess the geography of investments when considering asset acquisition and divestment.

Further, given the nature of the energy grid (and in instances where assets are unable to generate power on site, which is very difficult for commercial assets with limited scope for rooftop solar), energy advocacy has an important role to play. Individual states’ commitment to renewable and low-carbon sources of energy plays a role in reducing the transitional climate risk posed to assets within their geographical boundaries. For example, two assets with similar energy intensities (yet significantly different emissions intensities) are presented below.

Table 29: Investa variance between energy intensity and emissions intensity across geographical differences

	Energy intensity (kWh/sqm/yr)	Emissions intensity (kgCO ₂ /sqm/yr)
Asset 1	101.99	65.53
Asset 2	102.43	85.93

Source: Investa

For this reason, Investa will continue its important advocacy work through industry bodies such as the Property Council of Australia, encouraging both state and federal governments to commit to stable energy policy, integrating climate policy and reducing the carbon intensity of the Australian electricity market. This will help mitigate the transitional risks posed by climate change.

Global analysis applied at a local level

Given that climate risks are geographically dependent, thorough asset- and city-specific analysis is required to adequately identify the climate risks, especially the physical risks, presented.

While the analysis conducted under the UNEP FI Investor Pilot is a wonderful start, the challenges posed by considering multiple asset classes across tens of countries and hundreds of cities poses a unique challenge.

Given the breadth of the task, not all physical climate risks could be assessed in the required detail. With those risks that were assessed, analysis lacked the depth required to properly project and value risk.

For example, the risks posed by fluvial flooding and heaving precipitation were not considered in the real estate model due to the complexity of modelling fluvial flooding. While there are plans to integrate such physical risk into future analysis, it renders the existing analysis incomplete. This is particularly concerning given the prevalence of flooding in Brisbane, where six of Investa’s assets were assessed.

Another example considers heat risk. The analysis returned limited risk posed by heat waves, with some assets returning a positive impact when assessed (meaning extreme heat peaks were decreasing for those assets in question). This is in conflict with lived experience in Australian cities, with 2018 being the third-hottest year on record according to the [Federal Bureau of Meteorology](#). It is difficult to reconcile Carbon Delta’s risk assessment against present trends, with Investa’s assets subjected to increasingly hotter and longer summers.

We will therefore conduct further analysis at an individual asset/city level to consider the full extent of risks not able to be covered by the present assessment—chiefly heat and fluvial flooding.

Conclusion: Future assessment of Scope 3, fluvial flooding and heat waves

The initial results of the UNEP FI’s TCFD Investor Pilot analysis showcases the strength of Investa’s portfolio to respond to the transitional risks posed by 3°C, 2°C and 1.5°C climate scenarios. Whilst the 1.5°C scenario requires the steepest reduction in emissions, Investa’s ambitious carbon reduction target and existing track record of reducing emissions will allow the portfolio to mitigate the risks identified.

Asset location was an identified variable impacting climate resilience, with Investa to consider geography when assessing assets against the physical and transitional risks identified in this analysis.

Finally, while, the analysis conducted to date represents a starting point, Investa is committed to **enhancing the analysis of physical risks (specifically fluvial flooding and heat waves)** and expanding transitional risks to include **Scope 3 emissions**.



KLP: AN EVOLVING FOCUS ON CLIMATE RISK MANAGEMENT

KLP is Norway's largest private pension company. It delivers safe and competitive financial and insurance services to the public sector, and to enterprises associated with the public sector and their employees. Responsible investment in general, and a focus on climate change in all relevant aspects, is at the core of KLP.

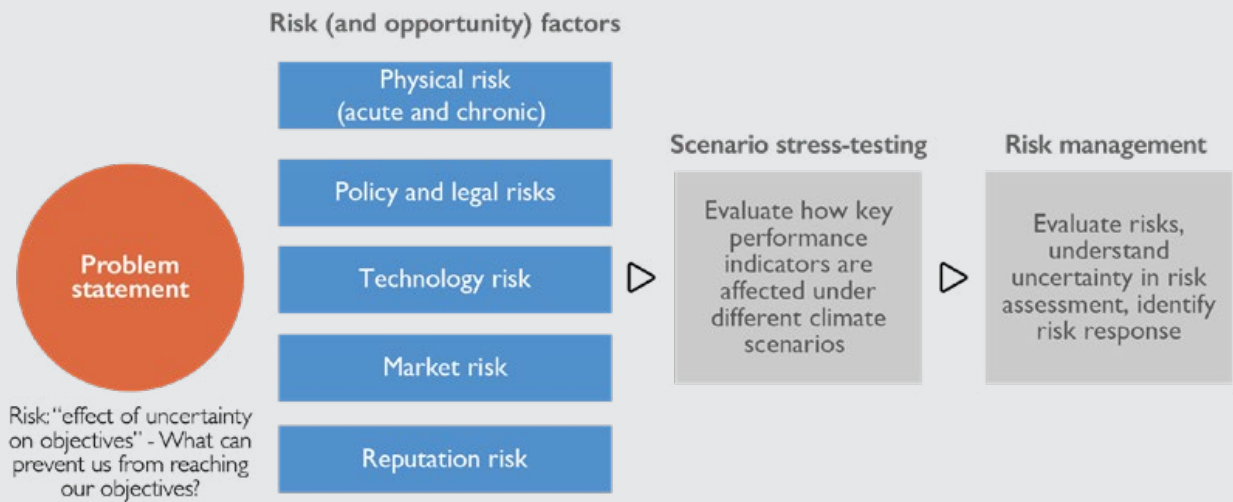
Climate change has been a key sustainability priority for KLP for more than a decade. Based on the lack of company-level GHG emission data and strategies to address these, KLP became a partner to the Carbon Disclosure Project more than ten years ago. This was a first and fundamental step towards improving our understanding of possible carbon risks associated with companies and industry sectors.

In 2014, we implemented an exclusion criterion addressing the most coal-intensive power producers and mining companies. This was motivated by the possibility of reducing exposure to possible future climate risks, as well as of conveying a market signal on acceptable business conduct in light of the need to limit global warming. In 2017, the exclusion criterion was expanded to include companies with activities in bituminous sands (tar sands). In parallel to these exclusions, KLP has increased its direct investment in renewable energy projects such as solar and wind. Currently, our investment in **renewable energy is 2.5 times that of our investment in oil and gas**, and we aim to increase our green investment with USD 1 billion each year in the period 2018–22. On the product side, we offer green credit for fossil-free mortgages and saving products.

In 2018, we initiated a climate risk screening process following an analytical approach designed in alignment with the TCFD recommendations. The objective is to develop our internal climate change competence in order to identify, assess and integrate climate risks in our strategies and operations in a practical and valid manner. KLP's participation in the UNEP FI TCFD pilot group feeds into this internal project.

This project will also form the basis for our first TCFD reporting in our annual report for 2018 and inform the roadmap for our climate risk work in the coming years.

Figure 27: KLP's approach to climate risk assessment is structured in accordance with TCFD recommendation



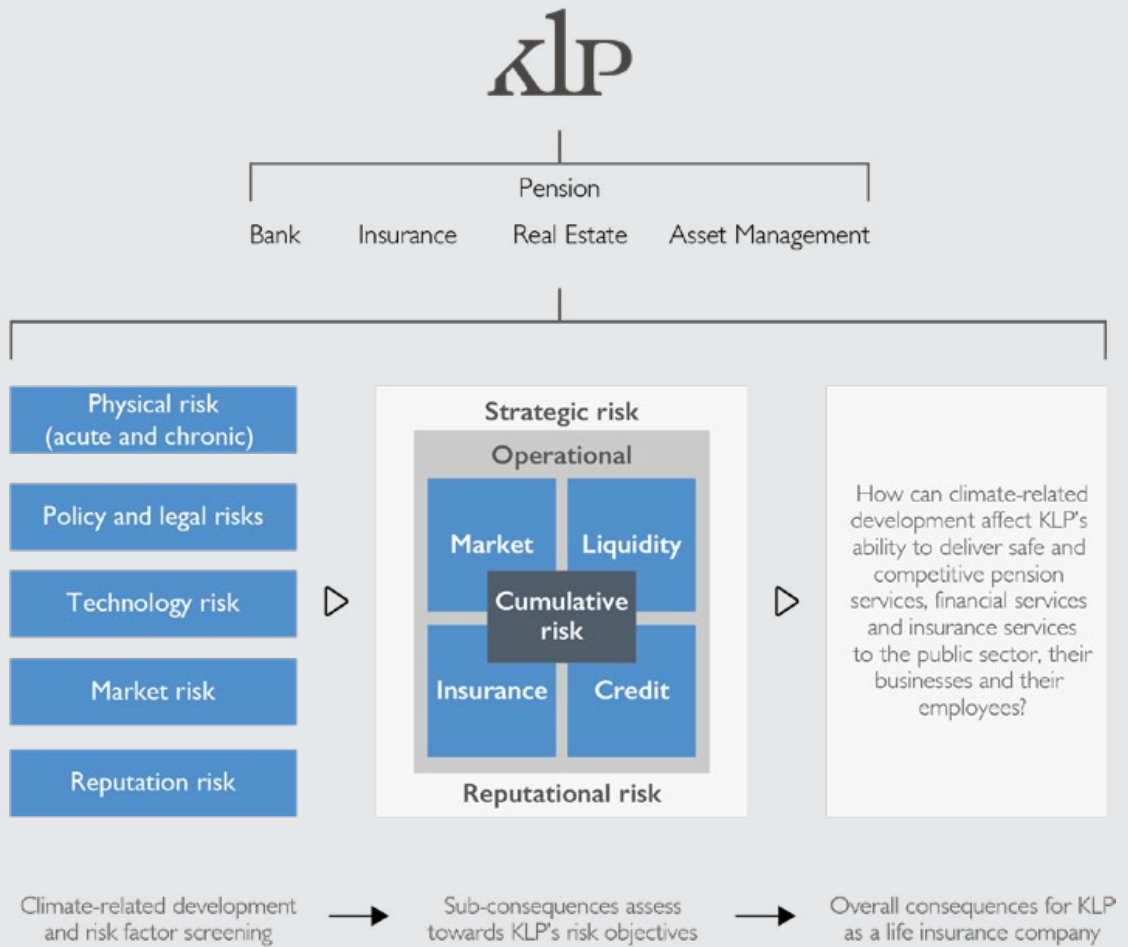
Source: KLP

The term risk screening refers to the identification of material risk factors that emerge and/or change due to climate-related development—in other words, physical climatic and weather-related conditions and a political, societal and technology transition to a low- or zero-carbon economy.

Our approach to risk screening is to (i) identify risk factors; (ii) consider their development in different climate change scenarios and consider whether new risk factors could emerge in the future described in the scenario's depictions; and (iii) undertaken an initial, high-level consideration of the possible consequences to KLP. These steps aim to identify risks and associated uncertainties that can be prioritised for further analysis.

The risk-screening process entails all the key business operations of KLP. Risk identification and consideration of consequences is conducted towards KLP's enterprise risk goals and examined against our integrity as a pension provider in Norway.

Figure 28: KLP's climate risk screening process covers all key business operations



Source: KLP

Aggregated results and a comparison of cumulative equity holdings with a special ESG fund

KLP has analysed the CVaR for all its funds, as well as for the cumulative listed equity and bond holdings of its managed pensions on behalf of its owners.

The cumulative VaR for bonds and equities is summarised in Table 30 for three transition risk scenarios, and the 'worst-case scenario' considering extreme weather. An overall observation of the results is that KLP's globally diversified funds achieve a VaR which is close to 0%. This is perhaps an expected result considering **the 'zero-sum' assumption used in the model, which implies that the cumulative costs associated with carbon prices provide an income opportunity from green technologies equal to the total carbon costs used in the model** (such that total carbon costs = total green revenue potential).

Table 30: KLP estimated VaR for cumulative holdings in listed bonds and stocks.

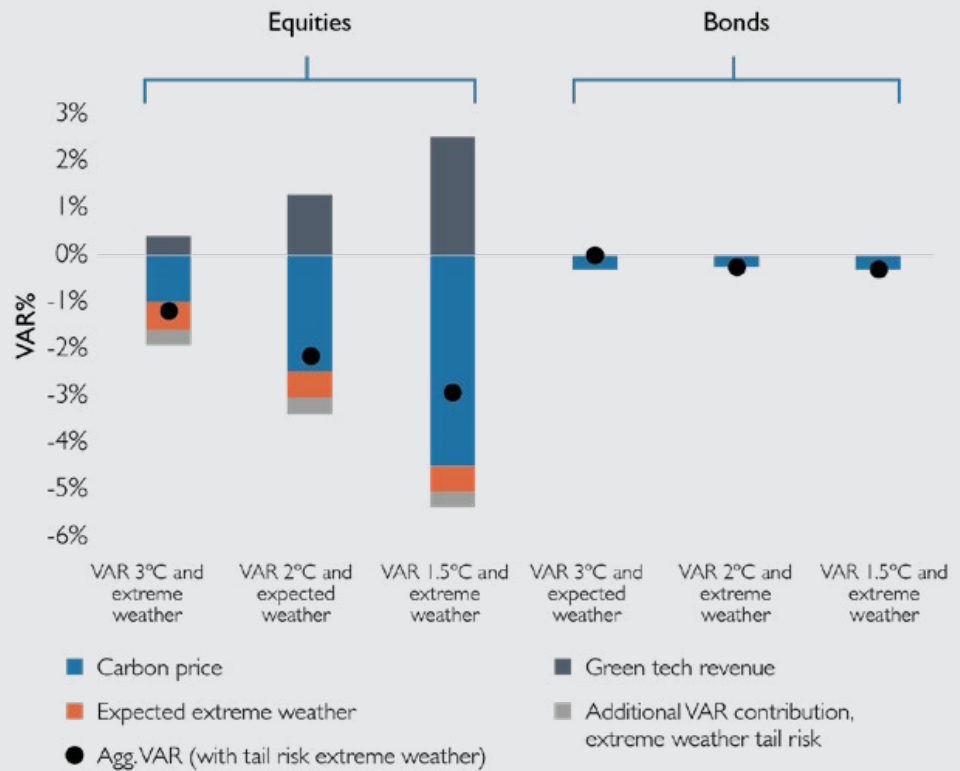
	3°C transition risk scenario & tail risk extreme weather	2°C transition risk scenario & tail risk extreme weather	1.5°C transition risk scenario & tail risk extreme weather
Listed bonds	-0.02%	-0.26%	-0.33%
Listed equities	-1.59%	-2.20%	-2.97%

Notes: Analysis covers approximately 90% of securities, representing approximately 90% of the values.

Source: KLP, Carbon Delta

Figure 29 shows a breakdown of the VaR contribution for KLP’s cumulative holdings. The model assumes that the introduction of a carbon price will always be negative, and for all three transition risk scenarios, this constitutes the largest negative contribution to the VaR. Estimated new income from registered green technology patents is the second most important contribution, while extreme weather has the lowest contribution.

Figure 29: KLP VaR contribution per scenario for cumulative holdings in listed bonds and stocks

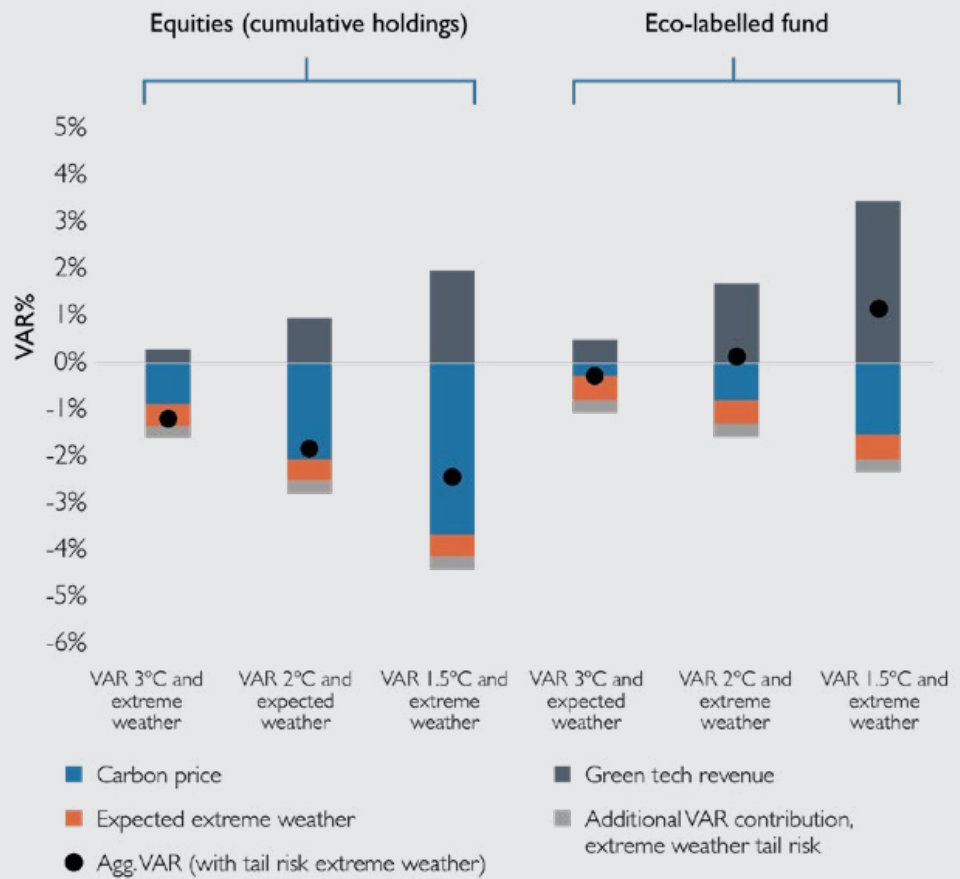


Source: KLP, Carbon Delta

While KLP’s cumulative holdings in equities and bonds has a negative aggregated VaR in all three scenarios, this is not the case for all of KLP’s funds. As an example, Figure 30 compares the VaR of the cumulative equities holdings and KLP’s eco-labelled fund ‘KLP AksjeGlobal Mer Samfunnsansvar’ (benchmarked against the MSCI World index). The latter fund is fossil-free; it excludes companies with low ESG scores, and overweighs those with high ESG scores.

As shown in Figure 30, there are only minor differences between the weighted VaR contribution from extreme weather, while the eco-labelled fund exhibits less negative exposure to carbon price, and a higher exposure to estimated revenue increase from green technologies. The fund has a minor negative VaR of 0.3% in the BaU scenario, but receives a positive VaR when more stringent emission restrictions are introduced in the model.

Figure 30: KLP VaR contribution by scenario for cumulative equity holdings and a specialised ESG index fund

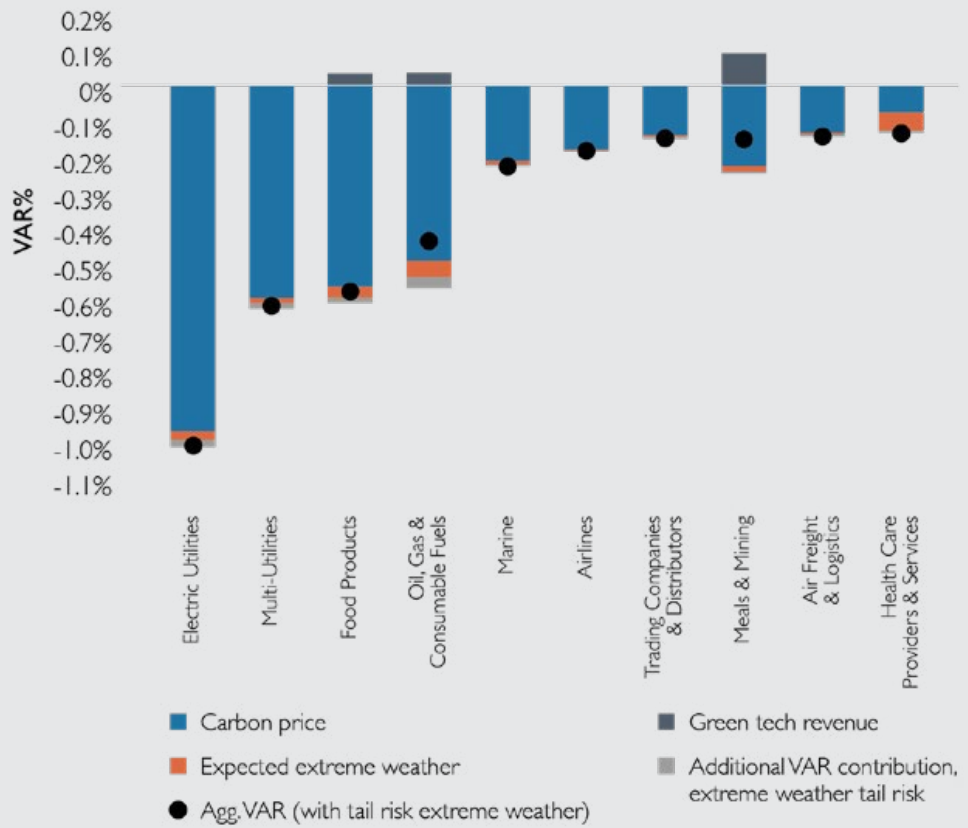


Source: KLP, Carbon Delta

Figure 31 shows the industry sectors (GICS level 3) with the most negative contribution to VaR for KLP’s cumulative equity holdings. The model presents utilities as the riskiest industry sector, which is a logical result considering that the analysis considers only Scope 1 emissions and does not include revenue increase from renewable energy production.

Power producers that rely on fossil energy sources are directly exposed to carbon prices. However, this cost can be pushed down their value chain—for example, to energy-intensive industries such as aluminum, which have a large relative share of its emissions from Scope 2 sources. Similarly, the bulk of emissions from oil and gas comes from Scope 3 sources—in particular, downstream Scope 3 when oil and gas is burnt. A further assessment of the results shown in Figure 31 could focus on whether the risks are underestimated, as market risks associated with a switch from oil & gas to other low-/zero-carbon alternatives are not specified in the model.

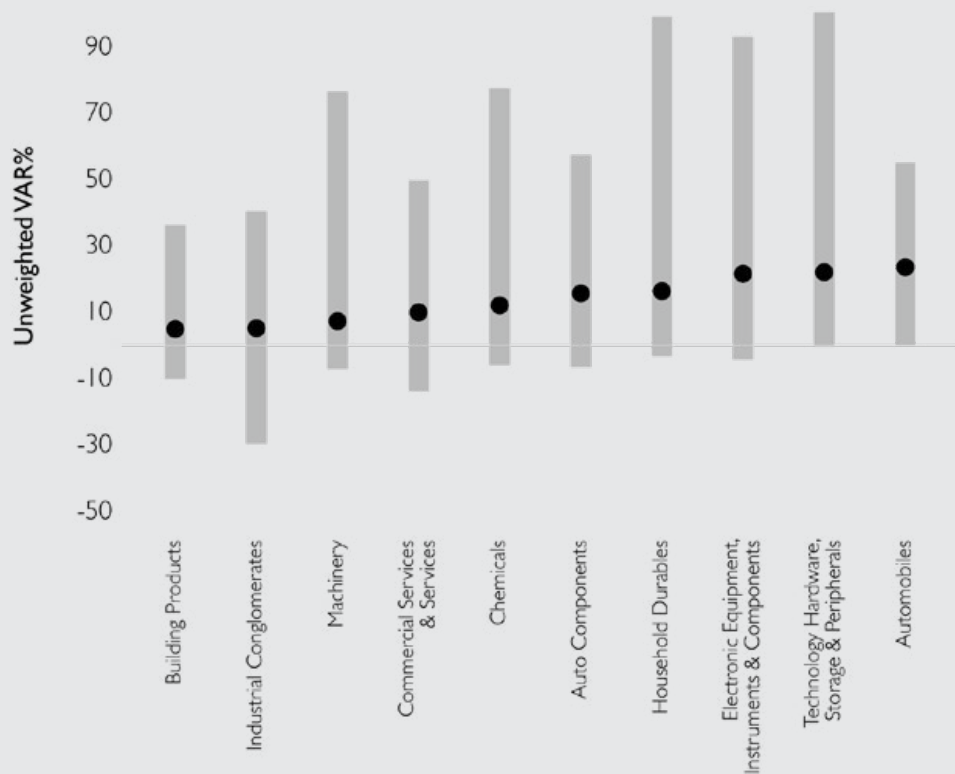
Figure 31: KLP ten industry sectors with the largest negative VaR contribution for cumulative equity holdings



Source: KLP, Carbon Delta

On the opportunity side, Figure 32 show the unweighted VaR for the ten most positive sectors in our eco-labelled fund. The grey bar shows the observed maximum and minimum VaR for individual securities, while the red dot shows the average VaR for securities in the sector. The results indicate an interesting trend whereby various producers of goods used in industrial applications and by consumers are developing greener products, which may contribute to avoided emissions further down the value chain—such as increased availability of greener construction and production vehicles and equipment and electric cars.

Figure 32: KLP unweighted VaR for the ten industry sectors with the most positive average unweighted VaR



Source: KLP, Carbon Delta

Reflections on the results

The cooperation in the UNEP FI project in general, and the work with the service provider to determine the modelling approach in this project, has been an interesting journey for KLP that has raised awareness and stimulated learning. The output from the analysis feeds into our wider project on mapping climate risk factors and assessing their uncertainty for KLP as a whole.

A key takeaway for KLP is the acknowledgement that quantitative climate risks assessment is a highly complex task. This has implications if one intends to adhere to the TCFD recommendations. For instance, the TCFD recommendations require a broad scope of risk factors to be included, such as various political interventions to reduce GHG emissions beyond carbon pricing, change in customer preferences favouring greener products and services, change in commodity prices, technology disruption, and changes in stakeholder expectations to corporate climate stewardship. Only a few subsets of transition risk factors are included in this study, which suggest that while the applied model is a productive step in the right direction, further amendments would be necessary before climate risk assessment can be effectively implemented in our investment strategies and processes.

While it does seem a daunting task to identify and address all material transition risk factors, we are left with a question of how much the validity of the climate risk assessment needs to be improved in order to comply with the TCFD, or alternatively, to add value to our investment processes and risk analysis. **It may seem close to impossible to ‘model everything’, yet, by excluding key factors that may be material drivers of the financial performance of companies, climate risk assessments will remain incomplete.** Looking forward, KLP hopes to see more data present in the market that can expand the climate risk assessment in a credible and practical fashion.

Another dimension which is difficult to model, and which has not been included in this study, concerns how markets, value chains and individual companies are likely to respond to climate risk exposures. Differences in CO₂ intensity and the ability to push carbon costs down the supply chain are examples of datapoints that would allow for a more precise analysis on the security level. Similarly, competition between sectors, such as intermodal transport

shifts (such as more transport through short-sea shipping at the expense of land-based trucks) or a stronger push for more lightweight material such as aluminium at the expense of steel, are market behaviours that are not captured explicitly in the modelling approach of this project. While such dynamics are hard to model with a decent level of precision and credibility, these are still real-world questions that need to be scrutinised when assessing financial consequences from climate-related development on a company level. Failure to encompass key dynamics may result in climate risk assessments being deemed unrealistic and inaccurate.

Notwithstanding these challenges to quantitative climate risk assessment, there is no alternative but to keep working to improve our knowledge base, data, methods and tools. The TCFD itself has stated that a long-term view on maturing the climate risk concept in the financial sector is necessary, and KLP is committed to participate on this journey. We hope that the productive cooperation through the UNEP FI TCFD Investor Pilot project will become even more effective in the future, and that there will be transparency in how individual companies conduct their climate risk assessment so that we can learn from each other. In this way the global business community can work collectively towards standardisation on how climate risks are analysed and reported.



LA FRANÇAISE
investing together

LA FRANÇAISE: CLIMATE VAR METRICS PROVIDE RELEVANT INVESTMENT SIGNALS

La Française Group has been integrating climate-related risks in investment analysis for a long time. This integration was facilitated by the Paris Agreement (Conference of the Parties, COP 21) and resulting initiatives. Responsible investment is at the heart of the Group's investment strategy and we believe that climate change is a key component of future economic growth and social stability—in other words, tomorrow's society will be based on a low-carbon economy.

La Française has shown ESG strategic commitment and developed an industry leading in-house expertise on responsible investment with Inflection Point by La Française. This is the Group's research and expertise centre on ESG topics and strategic investment factors. La Française is convinced of the benefits of integrating ESG and climate factors into investment processes. We acknowledge that climate change is a key issue for our portfolio companies. Therefore, the Group has developed a range of products addressing the energy transition challenges including the move towards a low-carbon economy. The Carbon Impact Global Equity strategy was launched ahead of COP 21 in June 2015. This investment strategy has since been applied to other geographies and to fixed income. The Group has also pioneered responsible real estate since 2010. Socially responsible investing real estate funds were developed in 2012 and 2014, and an impact real estate fund in 2017.

We are eager to use forward-looking indicators and, as such, we are delighted to be part of the TCFD Investor Pilot. We are supporters of the TCFD but experienced the implementation challenges of the respective recommendations first-hand when reporting under Article 173 of the French Energy Transition law during the past three years. The work of the Pilot group helps us identify more precisely climate change-related risks and opportunities. It facilitates the respective integration in our investment decisions and supports the dialogue with investee companies. As we aim to enlarge the scope of our responsible investment solutions and the impact-reporting of our investments, we believe that CVaR could be a useful metric in this regard.

Carbon Impact Global Equity strategy

This case study provides the CVaR results for our Carbon Impact equity strategy that we have been managing since 2015. This strategy invests in all global sectors. The portfolio manager selects companies belonging to three broad categories: (i) companies in high-emitting sectors that are transitioning to a low-carbon economy; (ii) enabling companies that provide products and services in support of the energy transition; and (iii) companies that are already part of the solution, such as renewable energy companies.

We measure the impact of this strategy by the carbon footprint of the portfolio, which has demonstrated significant low-carbon performance since inception—about three-quarters below the global reference index at the end of 2018. Furthermore, we calculate avoided emissions for the renewable energy companies in the portfolio as an important impact measure.

Since both of these carbon measures are based on reported data or equivalent estimates, they offer limited insight into future carbon performance. At the company level, we can achieve better results through fundamental analysis. Here we cover a company's governance, strategy and risk management as well as targets and metrics related to climate change on a case-by-case basis.

However, there is a growing need to develop more systematic forward-looking climate impact metrics. This is one of the reasons we joined the TCFD Investor Pilot and why we have chosen this strategy for the case study.

Another important reason for choosing the Carbon Impact strategy is our ambition to include additional information in our research process from sources that are independent of corporate disclosures. Examples include big datasets for measuring innovation capacity based on patents and datasets for assessing physical risks based on the location of physical assets like production facilities or infrastructure. Our in-depth knowledge of the portfolio companies should enable us to critically assess the results.

The portfolio in this case study, the Carbon Impact Global Equity strategy, has the following profile:

- Asset class: equities.
- Sector exposure: all sectors.
- Geographic exposure: global developed and emerging markets.
- Investment strategy: actively managed equity portfolio with a low-carbon footprint; focus on companies that are in transition to a low-carbon economy.
- Portfolio composition as of Q3 2018.

The CVaR analysis was prepared by applying the PIK REMIND model. We selected the standard 2°C scenario because it is widely used and well-rehearsed, and creates a reference point before conducting further stress tests.

The **aggregated CVaR of +4.0%** is shown in Table 31. This positive outcome supports the investment idea behind the Carbon Impact strategy. It will encourage us to roll out the CVaR tool in the appraisal process of new investment ideas and to consider the CVaR as a forward-looking metric in portfolio reporting.

Table 31: La Française CVaR portfolio analysis – summary results

Scenario	Weighted Climate VaR	Monetary Risk	Coverage
Transition Scenarios. Selected: REMIND	4.7%	0.05 mUSD	
Policy Risk (2°C)	-0.2%	-0.002 mUSD	95.5%
Technology Opportunity (2°C)	4.9%	0.05 mUSD	75.7%
Physical Scenarios. Selected Model: Average	-0.7%	-0.007 mUSD	
Aggregate Climate VaR	4.0%	0.04 mUSD	

Source: La Française, Carbon Delta

The portfolio’s CVaR confirms our expectations when considering the three components individually:

- The **transition risks** are close to zero with a CVaR of -0.2%—such that on aggregate the portfolio holdings have a low exposure to transition risks or they seem prepared to mitigate the expected impact from higher carbon prices. This is in line with the low-carbon profile that the carbon footprinting is measuring. However, it is a much more comprehensive result given that a dynamic carbon price is an integral part of the VaR model.
- The portfolio represents a dedicated climate strategy with a focus on transition opportunities. This is clearly visible with a 4.9% CVaR for **technology opportunities**. This positive value is driven by transition opportunities from companies active in areas like energy efficiency, electric vehicles, battery technology, digitalisation and renewable energy. Our assessment is based on a comparison of the companies identified with the largest technology opportunities by the CVaR model and our existing investment cases of the enabling companies in the portfolio. Since there is a significant overlap, we consider the CVaR tool as suitable for identifying and valuing enabling technologies in this case.
- The portfolio is exposed to **physical risks** with a respective CVaR of -0.7%, which is an important insight given that physical risks turn out to be three times larger than transition risks (-0.7% versus -0.2%).

A detailed analysis of the extreme weather scenarios included in the physical risk assessment shows positive and negative exposures. The driving factor is extreme heat with -0.7% CVaR, whereas each of the remaining six components are significantly smaller in magnitude, thereby offsetting each other.

It is worth noting that it has been difficult to assess physical risks arising from climate change. Therefore, the new metrics provide useful information for our stock selection and potentially for engagement. For example, we are likely to investigate next what measures companies have in place to mitigate their physical risks—be it through capital investment, insurance policies or both.

Table 32 provides the respective results for a global equity index (developed and emerging markets) that we typically use as a reference for performance analysis of the Carbon Impact Global equity strategy. The aggregated CVaR of this index is -0.7%, compared with +4.0% for the portfolio. The main difference is a much higher policy risk for the index and a much lower contribution from technology opportunities, again highlighting the stock selection of the Carbon Impact strategy.

Table 32: La Française CVaR global reference index – summary results

Scenario	Weighted Climate VaR	Monetary Risk	Coverage
Transition Scenarios. Selected:REMIND	0.1%	0.001 mUSD	
Policy Risk (2°C)	-2.3%	-0.02 mUSD	96.6%
Technology Opportunity (2°C)	2.4%	0.02 mUSD	80.2%
Physical Scenarios. Selected Model: Average	-0.8%	-0.008 mUSD	
Aggregate Climate VaR	-0.7%	-0.007 mUSD	

Source: La Française, Carbon Delta

The results for the Carbon Impact Strategy as shown above are supportive of the stated investment strategy; however, we are mindful that these results are subject to change in the short term due to further model adjustments. Furthermore, we need to gain significantly more experience working with such a tool to better understand and interpret the different metrics. Therefore, more time will pass before we would allow taking corrective action in the portfolio construction phase based on the results.

This case study has shown that the CVaR metric provides relevant investment signals. It could ultimately lead to portfolio adjustments. It immediately supports the decision-making process by raising awareness within the investment team and by asking new questions.

CVaR—a useful risk management tool with early stage advancement potential

An immediate benefit from using the CVaR tool will be the possibility to run alternative climate scenarios in order to conduct critical reviews of those findings—especially at the company level and to compare different portfolios. As discussed above, the tool has already highlighted some less obvious risk factors like physical risks. These insights are likely to become even more pronounced as we apply more aggressive scenarios.

Looking at a number of alternative scenarios will also mitigate the ‘interpretation risk’ implied by a single metric like the aggregate CVaR—suggesting a level of measurement accuracy that is not currently available. At this stage, we therefore consider such metrics as additional forward-looking indicators that are certainly useful in challenging existing investment beliefs. A measure like the CVaR enriches our analytic capabilities rather than replacing existing tools and metrics.

As active investors, we want to know significant details about company-specific situations. Therefore, we need to ensure that the measurement methodologies discussed here reflect the available information set. Unless the results are robust at the company-level, there is little credibility for aggregating information at the portfolio level. When a Climate VaR model passes the ‘credibility test’ of the portfolio management and research teams it will be put to use. We will advocate for a widespread adoption of TCFD reporting by corporates from all sectors. The application of forward-looking climate metrics will help our investment decision process by providing new insight.



NORGES BANK INVESTMENT MANAGEMENT: SCENARIO ANALYSIS IS A USEFUL TOOL FOR ASSESSING RISKS

Norges Bank Investment Management (NBIM) is responsible for investing the international assets of the Norwegian Government Pension Fund. Climate change has been a strategic focus area for NBIM since 2006. This is reflected in board principles and our responsible investment policies.

Our management of the climate risks and opportunities in our investments is largely aligned with the TCFD recommendations, which broadly reflect our climate change expectations towards companies. We joined the UNEP FI Investor Pilot to work with peer investors to develop guidance and methods on TCFD-aligned disclosure. We seek to contribute to the development of methodologies that can help us better assess climate risks and opportunities.

Pilot Project equity modelling results

As part of the pilot, Carbon Delta assessed potential transition and physical climate change impacts on our equities portfolio through to 2032.³² Its model calculates the portfolio's VaR by aggregating the potential impact of policy risks and technology opportunities under a 2°C scenario and extreme weather events (physical impacts) on companies' revenues. The outputs suggest our equities portfolio could have a potential downside risk of 1.3% under such a scenario. The aggregated VaR from transition risks and opportunities suggest a potential downside of 0.4%. Extreme weather events suggest a potential downside of 1.0%—for example, from extreme heat and coastal flooding.

Evaluating the potential financial implications of climate outcomes is useful in providing a view on potential climate risks and opportunities, but it is important to understand the context of markets, sectors and companies and their business models when analysing these results.

The relevance of Scope 1, 2 and 3 GHG emissions differs across sectors. One of the limitations of the scenario analysis methodology of this pilot study is that the model calculates climate transition risks and opportunities based on Scope 1 GHG emissions, without accounting for Scope 2 and 3 GHG emissions. This limits investors' ability to draw conclusions—for example, on the potential implications for some sectors such as oil & gas, coal mining, banks). In addition, the model does not tell us who will bear the carbon costs (whether companies are able to pass carbon costs through to consumers).

Modelling the extent to which companies can capture opportunities from the low carbon transition is not straightforward. Carbon Delta's model uses companies' low-carbon patents as a proxy to estimate the potential revenues from climate-related opportunities. Although this methodology may be more applicable to some sectors than to others that do not necessarily rely on conducting low-carbon R&D, it is one of the few methods available to estimate companies' revenues from the low-carbon transition.

Companies' plans can provide investors with a view of how prepared companies are to mitigate and adapt to climate issues; however, there is limited disclosure on companies' forward-looking plans. WWF, in collaboration with 2° Investing Initiative, conducted a study on the climate alignment of European asset owners' portfolios, based on the Paris Agreement Climate Transition Assessment (PACTA) tool (WWF, 2018). The methodology considers companies' five-year production and investment plans. This methodology provides different insights to investors—for example, on the expected future technology mix of investment portfolios and whether they are aligned with specific climate outcomes.

32. Equities portfolio as of December 31, 2017.

NBIM's internal scenario analysis tool

As illustrated by the UNEP FI Pilot, we consider scenario analysis to be a valuable tool to assess uncertain outcomes—for example, the potential implications of different climate outcomes for different sectors, companies and assets. We are developing an in-house model for analysing the potential impacts of climate scenarios on the equity portfolio, sectors and companies. The objective of this work is to understand how climate risk could affect the portfolio's return in the long term. We look at future cash flows and GHG emissions at a company level and explore how future regulations such as carbon pricing mechanisms could affect different companies, industries and regions. We incorporate carbon price estimates from five IAMs: IMAGE, MESSAGE-GLOBIOM, REMIND, WITCH and GCAM. The models consider projections from different Shared Socioeconomic Pathways (SSP) (IIASA, 2018).

One of the challenges we have faced in the development of our tool is the lack of high-quality and comparable data from companies. In addition, quantifying the impact of climate risks on companies' earnings and valuations with a long-term horizon presents its own set of challenges—for example, considering the much longer time frame compared with traditional financial analysis.

Learnings from the pilot

As envisaged by the TCFD, there is still some way to go before investors and companies can fully implement the TCFD recommendations—for example, on methods for scenario analysis and the availability of high-quality data to conduct these. The UNEP FI Pilot provided a useful forum to debate the complexities of conducting scenario analysis across different asset classes and translating these results into meaningful financial information.

Carbon Delta's model integrates scenarios from the REMIND model, one of the various internationally recognised IAMs. When disclosing information related to scenario analysis, it is important to be transparent around the assumptions of the scenarios and models used and to understand how these can drive results. **Scenario analysis is a useful tool to assess potential risks in our portfolio and can also be used to support our company engagements.** Depending on the intended use of scenario analysis results, different levels of data accuracy may be needed—for example, it is important to have a high degree of accuracy when engaging with companies and conducting fundamental investment analysis on securities or real assets.

Carbon Delta's model aims to overcome the challenges of insufficient and inconsistent disclosure among companies by estimating their GHG emissions. This model also addresses some of the complexities of conducting physical scenario analysis—for example, by integrating asset-specific information and modelling the potential effects of extreme weather events in those locations. **This emphasises the need for companies to disclose material climate data, including asset-level data, in a consistent and comparable way.**



TD ASSET MANAGEMENT: COMPARING VARIOUS CLIMATE RISK APPROACHES

TD Bank Group is taking an enterprise view of climate-related risks and opportunities and starting to assess business segments more materially exposed to climate risks. In addition to the UNEP FI TCFD Investor Pilot Project, TD has participated in two other UNEP FI pilot studies—lending and insurance—and actively participating during this critical time when methodologies for assessing climate risk are being developed.

TD Asset Management (TDAM) is a wholly owned subsidiary of TD,³³ having assets under management of USD 268.6 billion.³⁴ This North American investment management firm serves a large and diversified client base, including pension funds, corporations, institutions and high net worth and retail individuals, and has leading market positions in passive, quantitative, and active portfolio management.

The discussion below reviews two TDAM portfolios using Carbon Delta's scenario analysis tool under a 2°C scenario—a warming level in line with that agreed in the Paris Agreement on climate change. For the portfolios analysed, **the utilities sector stands out as a major contributor to climate risk.** We delve into this sector and note how climate data of different providers can send different signals at the industry level. As we proceed in our endeavour to assess bank-wide climate risks, lessons from all three pilots will help refine our processes and build consistency in climate risk analysis across bank activities.

Portfolio results: Utilities drive the majority of CVaR

To trial Carbon Delta's climate scenario tool, TDAM provided holdings data for two equity portfolios—one that holds global equities (with its largest revenue exposures in Asia Pacific, Europe, the US, and Canada) and is benchmarked against MSCI ACWI; and the second one predominately consisting of Canadian equities and benchmarked against the S&P/TSX Composite Index. Both portfolios are generally tilted to smaller-cap, dividend-paying names with lower volatility and beta metrics. With respect to industries, these portfolios are concentrated in staples, telecommunications, utilities, insurance and real estate.

The results are given in the table below, with transition risk and physical risk adding up to a total CVaR, or the potential loss a portfolio could face given the costs that the underlying companies would incur to achieve a global warming of 2°C. For the Global Equity portfolio, Carbon Delta's model estimates a CVaR of -5.2%, with the main drivers of loss coming from policy risk (-5.5%) and the physical risk from extreme heat (-0.9%). The Canadian Equity portfolio has a lower CVaR of -3.2%, with similar drivers (policy risk VaR of -3.2% and -0.4% from extreme heat).

33. The TD Bank Group means The Toronto-Dominion Bank and its affiliates, who provide deposit, investment, loan, securities, trust, insurance and other products or services. All trademarks are the property of their respective owners.

34. Assets under management as of December 31, 2018 for TD Asset Management Inc., TDAM USA Inc., TD Greystone Asset Management and Epoch Investment Partners, Inc. TD Asset Management operates through TD Asset Management Inc. in Canada and through TDAM USA Inc. in the US. TD Greystone Asset Management represents Greystone Managed Investments Inc., a wholly owned subsidiary of Greystone Capital Management Inc. (GCM). All entities listed are affiliates and wholly owned subsidiaries of The Toronto-Dominion Bank.

Table 33: TDAM results under a 2°C scenario

Scenario	Global equity	Canadian equity
Transition scenarios VaR (model: REMIND)	-4.4%	-3.1%
Policy risk	-5.5%	-3.2%
Technology opportunity	1.5%	0.08%
Physical scenarios VaR (model: average)	-0.9%	-0.1%
Aggregated CVaR	-5.2%	-3.2%
Portfolio warming trajectory	3.4°C	3.5°C

Note: Carbon Delta figures are as of January 21, 2019. The results presented in this table are calculated on a weighted basis

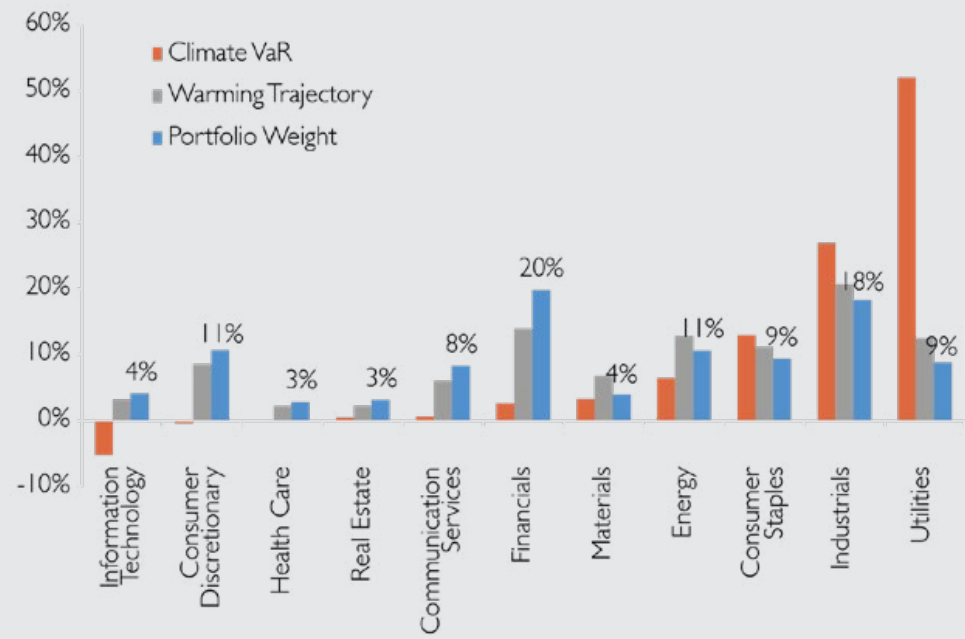
Source: TDAM, Carbon Delta

Utilities drove the majority of CVaR, making up 73% in the case of the Canadian Equity portfolio and 52% for the Global Equity portfolio. This is to be expected given that the utilities sector has high carbon emissions and carbon intensity (total tCO₂e/sales) relative to other sectors, demonstrating the significant part utilities will need to play in decarbonising the economy. Energy and industrials were also major contributors to CVaR, with industrials more impactful to the Global Equity portfolio given its greater portfolio weight (18% vs 11% in the Canadian Equity portfolio). Consumer staples also contributed to the CVaR of the Global Equity portfolio, with two Southeast Asian agriculture producers seen as high contributors to risk. Agricultural activities are known sources of GHGs, with agricultural companies typically having high carbon intensity.

Carbon Delta also predicts the portfolio’s warming trajectory, which assumes underlying companies go forward with BaU, without regard to a policy target. Warming is largely a function of a company’s Scope 1 carbon emissions before considering the financial implications for that company. Though the Canadian Equity portfolio has lower transition risk than the Global Equity portfolio, the Canadian Equity portfolio has a slightly higher warming trajectory at 3.5°C. Where the utilities sector is the primary driver of transition risk and CVaR, financials (banks and insurance companies) drive the warming trajectories for both portfolios.

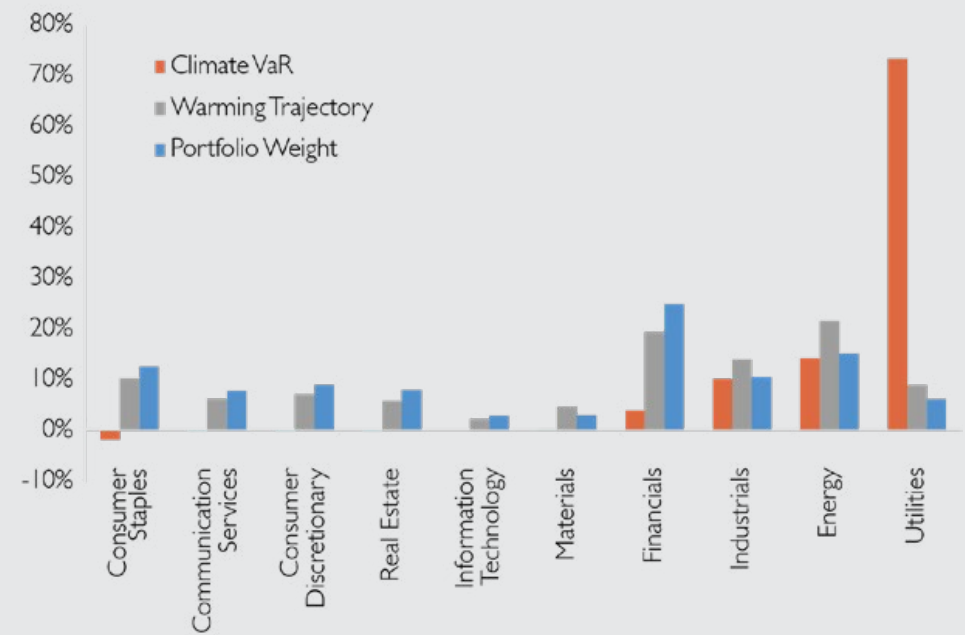
The figures below show a comparison of the sector proportions of CVaR, warming trajectory, and portfolio weights to demonstrate which sectors have an outsized impact compared with their weight in the portfolio. Financials comprise the largest portion of both portfolios, 20% for the Global Equity portfolio and 25% for the Canadian Equity portfolio, but contribute only a small amount to the CVaR (or transition risk when considered in isolation). However, financials make up 14% and 19% of the Global Equity and Canadian Equity portfolios’ warming trajectories respectively.

Figure 33: TDAM CVaR, warming trajectory and weights by sector – Global Equity portfolio



Source: TDAM, Carbon Delta

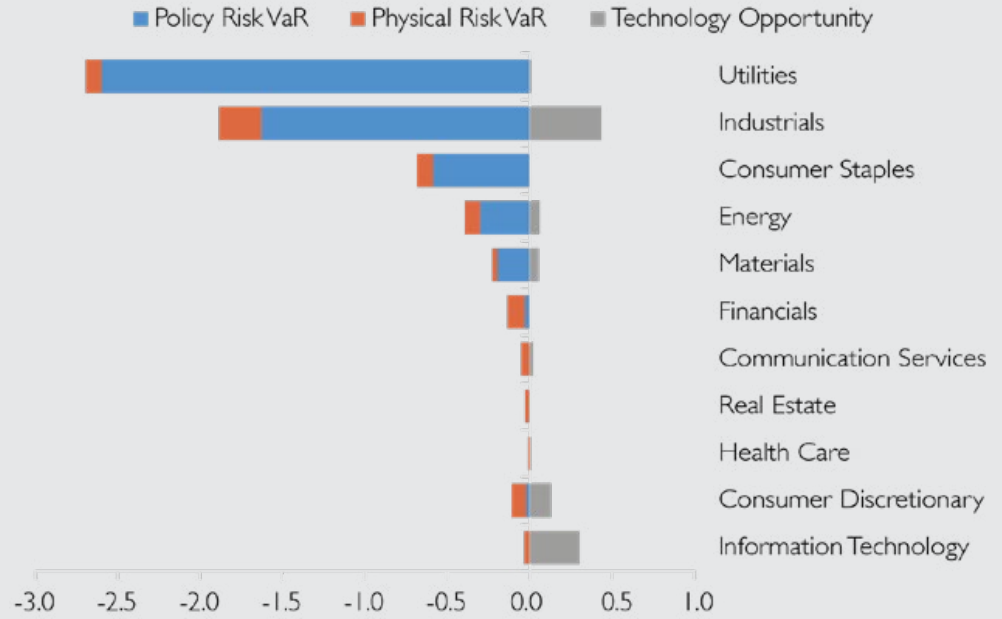
Figure 34: TDAM CVaR, warming trajectory and weights by sector – Canadian Equity portfolio



Source: TDAM, Carbon Delta

In the Global Equity portfolio, a few sectors appear to present greater green revenue opportunities based on the Carbon Delta analysis, as seen in Figure 34. Green revenue opportunities are measured by the quality of a company’s portfolio of low-carbon patents, which help guide the transition to a lower-carbon economy. The companies projected to benefit most from green revenues in this portfolio include industrials, information technology, and consumer discretionary. Innovative technologies for more efficient production processes, lower exhaust equipment and vehicles, and industrial emissions monitoring tools are some of the solutions that these companies are a part of, all of which could make these companies more competitive in a low-carbon economy.

Figure 35: TDAM breakdown of CVaR (Global Equity portfolio) by sector and factor



Source: TDAM, Carbon Delta

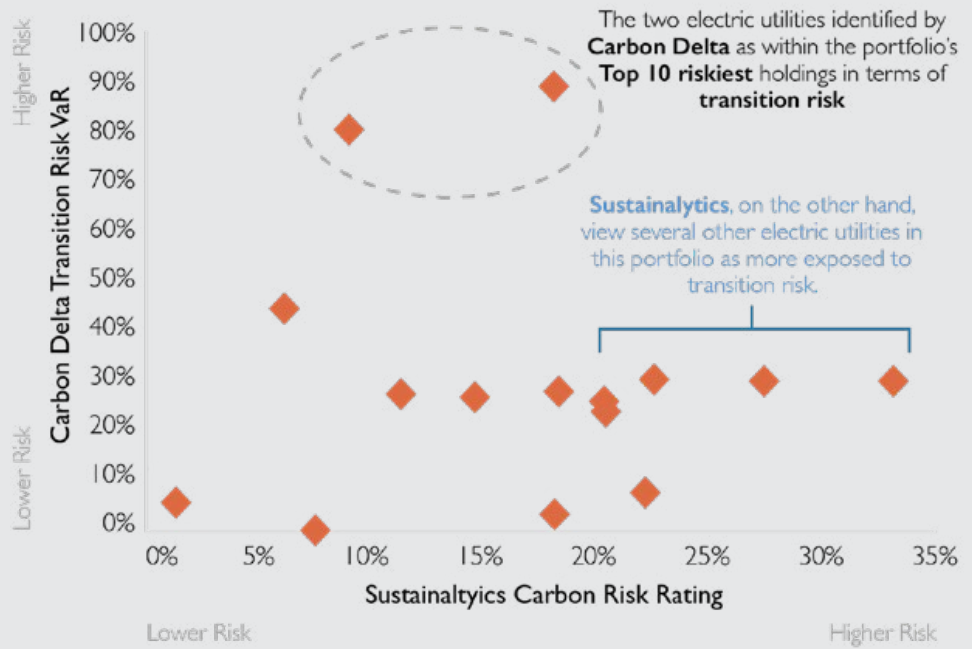
Comparing climate risk signals

As environmental questions from clients are becoming more detailed, the tools to supplement fundamental research and existing ESG data have become more important. Those tools allow us to bring in the expertise of organisations that have studied environmental issues and know how best to think through the associated climate risks. The discussion below takes some of the Carbon Delta results for the Global Equity portfolio and compares them to the signals given by Sustainalytics data. The hope is to spur additional conversation to decipher the various signals of major environmental data providers.

Sustainalytics is a provider of ESG data, providing various metrics and ratings to better understand where companies fall on each of those three pillars. As part of these offerings, Sustainalytics provides a Carbon Risk Rating, indicating a company’s financial exposure to and management of material carbon risks. **Though this approach is different from scenario analysis, it does provide an informed assessment of transition risk** through its comprehensive coverage of a company’s current emissions (Scope 1 and 2); a distinction between manageable and unmanageable risks (risks that are intrinsic to a particular subindustry that cannot easily be managed); and an evaluation of how a company’s climate risk mitigation strategy helps manage the risks that are within its control. This is a forward-looking rating that incorporates transition risks that are driven by climate regulation, carbon pricing, alternative products, shifting consumer preferences, and supply constraints.

Several of the top ten companies identified by Carbon Delta as contributing to transition risk for the Global Equity portfolio come from the utilities and industrials sectors. In Figure 36, we focus in on electric utilities, plotting each electric utility according to how it stands on both of these climate risk measures, and looking for parallels between which holdings Carbon Delta deems most risky versus Sustainalytics. As displayed, the measures deviate according to which electric utilities are considered to be the most exposed to transition risk, which calls into question which factors are most critical and perhaps being left out of one measure or the other.

Figure 36: TDAM comparison of climate risk signals within utilities – Carbon Delta vs Sustainalytics



Note: Graph is based on unweighted figures

Source: TDAM, Carbon Delta, Sustainalytics

The additional climate data and scenarios provided by Carbon Delta have further enriched the way TDAM thinks about climate risks. However, continual comparison of the more highly used environmental data providers could be worthwhile in order for the industry to become more acutely aware of the similarities, differences, and areas seeing or in need of improvement when it comes to measuring environmental risks to investments. The transparency that develops from making these comparisons could encourage greater comfort in, and faster adoption of, necessary climate risk analysis, particularly given TCFD’s recommendations.

6. FUTURE DIRECTIONS

6.1. INTERNAL CAPACITY DEVELOPMENT

Investors should consider building in-house capacities and tools to integrate scenario analysis in line with the TCFD recommendations. The TCFD recommendations emphasise the use of scenario analysis in assessing the impact of climate change on the entire business over time and in enhancing critical strategic thinking within the organisation. It also highlights the importance of assessing a range of scenarios that challenge conventional wisdom about future developments, or significantly change the state of the world from 'business as usual', including a 2°C-compliant scenario. If scenario analysis is to become a component of climate risk management and company strategy as envisioned by the TCFD recommendations, investors may need to develop the internal capacity to integrate these assessments for their own decision-making, while at the same time establishing standardised and comparable disclosures that support regulatory assessments aimed at ensuring financial system stability.

The pilot project highlighted that there are a range of capacities required to effectively conduct scenario-based analysis, centred around four key areas:

- **Technical.** Conducting scenario analysis requires significant technical expertise, starting from the vast amount of data required, to designing the methodology and interpreting the results generated. For many investors, this technical expertise does not exist in-house, and would require considerable time and resources to build up. External providers of scenario-based analysis, such as those presented in Section 2, offer readily available support to investors. However, some in-house technical capacity will remain essential, as results received from external providers will need to be interpreted and stress-tested to draw out the key lessons for the individual investor.
- **Risk management.** Linking the results of scenario analysis into core risk management practices, as recommended by the TCFD, requires risk management teams to be involved in scenario analysis. This would allow them to advise on what types of outputs would be most useful in interaction with existing risk assessment methodologies, provide feedback on modelling elements where relevant, as well as stress-test results against existing risk databases and practices at the company and portfolio level.
- **Strategy.** To ensure that scenario-based analysis provides valuable lessons for strategic asset allocation, and to action these lessons where appropriate, active asset managers or other staff involved in strategic decision-making should also be involved in the process. This involvement could include managers highlighting the level of information they would find useful to consider in strategic decisions, as well as the required scope and depth of analysis for results to be relevant to the wider corporate strategy.
- **Governance.** Top-level buy-in to scenario analysis is essential to enable all the above capacities to be developed within the organisation. Executive officials need to be convinced of the benefits of scenario-based analysis to provide the resources required to build up the above capacities. Further, actioning the lessons from scenario-based analysis in strategic decisions will need to be overseen by an executive official.

These focus areas illustrate the importance of involving the entire organisation in scenario-based analysis. To cover all the capacities required, investor teams should include technical, risk management, and corporate strategy experts, with appropriate governance capacity.

Some pilot group members intend to use the results of the pilot primarily in engagement with investee companies, while others felt results were not yet credible enough for this purpose. Results from the pilot project have been useful to investors in identifying drivers of relative performance of investee companies under different climate pathways. Some members indicated that they intend to use these results in future engagements with companies, particularly those with relatively poor performance or data disclosure. However,

other investors also indicated that results are not yet sufficiently mature to be used for this purpose, as they were doubtful that investee companies would find the results credible and accept them as evidence for discussion.

Investor Pilot Group members agreed that scenario analysis methodologies should not inform strategic asset allocation decisions, however, some felt they may be able to do so in the future. It was commonly agreed that analysis from the pilot project should not be used as a basis for investment or divestment decisions, as results for individual companies did not always reflect the information investors held—for example, on emission reduction targets or strategic vision in relation to climate change. While some investors indicated that with further improvements, the analysis could be used for this purpose in the future, others felt that this would conflict with their fiduciary duty. **This latter group of investors highlighted the importance of engagement over divestment, which could leave gains or profit unrealised and leave the whole system worse off as a result.**

6.2. IMPROVING THE SCOPE AND DEPTH OF ANALYSIS

The pilot project highlighted several key areas for development of scenario-based analysis for investors in the future. This section highlights the most common areas of feedback from investors on what future developments they consider necessary to improve the credibility and granularity of results. It combines this feedback with the lessons learnt from the evaluation of available methodologies for physical and transition risk to date, to arrive at a clear set of recommendations for further build-out of existing methodologies:

- **The set of examined scenarios should include scenarios that effectively capture the key risks around climate change, including tail risk events and uncoordinated or delayed policy action.** It is insufficient to examine only ‘smooth’ transitions to a low-carbon economy, in which universal global carbon prices start rising today and develop gradually over time, with perfect information on this schedule available to all companies in the market. In reality, sudden increases in carbon pricing that may result from delayed policy action or lack of regional coordination could present considerable threats to financial stability. When considering the physical impacts of climate change, particularly over shorter time horizons, many methodologies focus on ‘average’ impacts over a given period. However, given the potentially catastrophic effects of ‘tail risk’ events, exploration of these events can help illustrate the importance of considering low-risk, high-impact events in long-term investment decisions.
- **To ensure that interactions between physical and transition risk are sufficiently captured, analyses should extend beyond the next 10–15 years.** While changes to the climate in the short-to-medium term will vary little across different climate policy pathways, the potential impacts of these policies on technologies and markets could be vast. In other words, physical risks in the 2020s will vary little across different temperature pathways, and divergence will become significant only beyond the 2040s. The number of scenarios considered in physical risk assessments is therefore likely to depend on the assessment time horizon: the longer the horizon, the more the physical impacts of different temperature pathways will diverge. At the same time, some investors pointed out that due to the high discount rates applied in the financial sector, even if analyses are extended, the potentially catastrophic physical impacts beyond 2050 will appear small today. Therefore, these impacts should be reported and considered before and after discounting to give an idea of the relative magnitude. Other investors cautioned that horizons beyond the next 15 years might not be applicable for sectors with shorter typical asset lifetimes and production horizons.
- **Scenario-based analysis should consider the entire value chain of a company as well as the broader macroeconomic environment.** Many methodologies to date have focused on the immediate impacts of physical or transition risk on companies’ operations and assets. However, the impacts of these risks on the broader value chain can be significant: price shocks to key inputs and shifts in consumer behaviour can translate into considerable financial impacts on a company. At the same time, physical and transition risk will impact the macroeconomic environment in which companies operate, as changes to key variables like sectoral composition and international competitiveness could have significant effects on company performance.

- In doing so, methodologies should distinguish more clearly between Scope 1, 2 and 3 emissions in order to capture company carbon footprints and associated risks with greater accuracy. For many existing methodologies for scenario analysis, Scope 1 emissions have formed the basis for calculation of the future cost increase a company may face under stringent climate policy. However, companies are likely to face further costs from their Scope 2 emissions through the generation of purchased energy, as well as other repercussions from their indirect Scope 3 emissions.
- **Analysis needs to extend beyond exposure assessment to the sensitivity and adaptive capacity of individual counterparties and facilities.** Limiting assessment to company exposure to risk ignores the company-specific characteristics that could mitigate or exacerbate this risk. Some sectors will be more sensitive to physical or transition risk and there will be further differences between companies in the same sector. In particular, companies that have already adapted to risks or have greater capacity to do so—for example, through resilient infrastructure or emissions abatement—should outperform their competitors when these risks materialise.
 - As part of this extension, future analysis, particularly of physical climate risk, could also explicitly consider company insurance cover in impact assessment. Another component of a company’s adaptive capacity to climate-related risks is its existing insurance cover. Companies in climate disaster-prone areas with good insurance cover are unlikely to experience the full negative impacts of these events.
- **For the purposes of investors, scenario analysis methodologies should continue to expand on the range of asset classes covered, including, for example, commodities, sovereign debt and infrastructure.** To date, many methodologies focus exclusively on the climate-related risks and opportunities for listed equity and corporate debt. Others focus exclusively on sovereign debt or real estate and infrastructure. However, diversified portfolios today include many more asset classes which may be affected differently across climate pathways. As a result, methodologies that consistently examine the impacts of various scenarios on the entirety of the diversified portfolio need to be developed if results are to become more decision-useful for investors.

In the interest of pursuing these improvements, there is a clear need for better disclosure of climate-related data from investee companies. The more granular the data disclosed by investee companies, the more informative scenario-based analysis can be for investors. Analysis to date has relied on sectoral indicators of resilience, such as natural resource dependence and abatement potential. However, these could vary significantly across a sector, and more data on individual companies’ sensitivities and adaptive capacity to physical and transition risk is needed. Companies should therefore expand their reporting not only of carbon footprints, but also of variables like key inputs and location of vulnerable suppliers, insurance cover, and planned abatement and resilience investments and their costs. In addition, fossil fuel extraction companies’ production timing and volume under different scenarios could, if publicly reported, enable more granular analysis of the risk of asset stranding.

This includes data on individual facilities such as production sites and real estate, which should cover location, as well as key climate-related characteristics such as flood resilience or energy efficiency. To date, many scenario analysis providers either do not use this type of data or rely on proprietary location databases to conduct facility-specific assessment. If scenario analysis is to become more commonplace, particularly for smaller-scale investors, data on individual facilities needs to be collected and made available more comprehensively.

6.3. FUTURE COLLABORATION AND ALIGNMENT OF KEY ACTORS

Industry collaboration played an invaluable role in the pilot project as investors pursuing their unique interests resulted in a more holistic methodology, and future efforts could encourage investors to continue stress-testing methodologies for scenario analysis collaboratively. Continuous engagement with Carbon Delta on the pilot methodology contributed significantly to investor understanding of the key elements of scenario-based analysis and allowed investors to collaboratively suggest improvements to the methodology. For example, over the course of the pilot project, investors highlighted

the need for additional scenarios, resulting in the inclusion of more aggressive physical risk, as well as delayed policy action scenarios. Multiple investors working together while pursuing their unique interests therefore resulted in a more holistic tool than if each investor had undertaken the analysis separately. Pilot group members further pointed out that using the same methodology as other investors provided them with some reassurance that results would be comparable and informative in TCFD reporting across the industry.

There remains an open question around the role of standardisation of scenarios, modelling frameworks and outputs, for the purposes of investor TCFD disclosure around scenario-based analysis. While many pilot group members agree that some degree of standardisation would be helpful, opinions diverge on how extensive this standardisation should be, and whether it should apply to scenarios, modelling frameworks and outputs. Investors voiced concerns around intellectual property and competitive advantage when discussing complete standardisation; however, many highlighted that a list of common scenarios as well as format of outputs could be helpful without affecting these areas of concern. In addition, investors pointed towards the lack of standardisation in the field of other climate-related risk management tools, such as ESG risk ratings, where many external providers offer very different products. To advance, the TCFD will have to consider the issue of standardisation and its purpose in enabling comparability more thoroughly.

As part of a move towards including climate change in stress-testing, financial regulators could provide a set of shocks or scenarios they would like investors to use in scenario-based analysis of their portfolios. As outlined in the Introduction to this report, regulators are moving towards including climate change in regular stress-tests of the financial system. The NGFS is also planning to develop voluntary guidelines for scenario analysis. This could be supplemented by providing investors and the broader set of publicly reporting companies with a set of scenarios to examine using their own methodologies, based on a common set of assumptions. Companies could then supplement these common scenarios with their own, unique scenarios to explore further assumptions of interest. Investors noted that this may be particularly relevant to industries most likely to be affected by climate change, such as those in the oil, gas and coal sectors. Imposing a set of scenarios could ensure companies consider sufficiently unfavourable scenarios and provide investors with more valuable information about their investee companies than if these were to choose their own scenarios.

Some transparency of modelling methodologies—rather than full standardisation—would further enable comparability, while reducing the risks of correlated model errors and preserving the incentive for methodological improvements. While some members proposed standardisation of modelling methodologies, most disagreed based on the risks of ‘herding’ previously on financial stability, and the disincentives to developing better methodologies (and the associated intellectual property) that might provide a potential competitive edge.

In addition, pilot group members agreed additional guidance on disclosure of climate scenario analysis would help investors interpret others’ results, be it investee companies or other investors. The more companies that incorporate scenario-based analysis in climate-related reporting, the more important it will be that their results are comparable, even if using separate methodologies. To enable investors to interpret these results, guidance from regulators on what key assumptions to disclose, what elements of the methodology to detail, and what types of outputs to report would be valuable.

Finally, output standardisation could aid investors in interpreting results from different companies, by allowing them to examine the same set of impact measures throughout. To date, those conducting scenario analysis have provided a range of different outputs, as Section 2 highlighted. This can make it difficult for investors to compare investee companies’ scenario-based risk assessments. Output standardisation might involve recommending one type of well-defined output, such as a quantitative value at risk figure, to become the focus of future scenario-based analysis. Providers could then continue to offer their existing output types but supplement these with the ‘recommended’ output. The most useful format of outputs for investors should be explored further in future industry collaboration, which could form a logical next step for climate-related reporting standards.

APPENDIX I

Full list of providers of physical and transition risk assessments referenced in this report

Provider	Name of methodology and source	Type(s) of risk
2° investing initiative (2dii)	PACTA tool (2° Investing Initiative, 2016)	Transition
Four Twenty Seven (427)	Equity, fixed income, sovereign and municipal risk scores (Deutsche Asset Management & Four Twenty Seven, 2017)	Physical
Acclimatise	Aware for Projects (Acclimatise, 2018)	Physical
Acclimatise	UNEP FI Banking Pilot (UNEP FI & Acclimatise, 2018)	Physical
Carbon Delta	Climate Value at Risk (UNEP FI Investor Pilot)	Physical and transition
Carbone 4	Climate Impact Assessment (Carbone 4, 2016)	Transition
Carbone 4	Climate Risk Impact Screening (Carbone 4, 2017)	Physical
Carbon Tracker Initiative	2 degrees of separation (Carbon Tracker Initiative, 2017)	Transition
ClimateWise (with Vivid Economics)	Managing the physical risks of climate change (Cambridge Institute for Sustainability Leadership, 2019)	Physical
Mercer	TRIP framework (Mercer, 2015)	Physical and transition
Moody's Investor Service	Sovereign risk ratings (Moody's Investors Service, 2016, 2018)	Physical and transition
Ortec Finance	Climate-savvy scenarios set (Ortec Finance, 2019)	Physical and transition
Oliver Wyman	UNEP FI Banking Pilot (UNEP FI & Oliver Wyman, 2018)	Transition
Schroders	Carbon Value at Risk (Schroders, 2017)	Transition
Transition Pathway Initiative (TPI)	TPI Tool (Transition Pathway Initiative, 2018)	Transition
Trucost	Carbon Earnings at Risk (Trucost, 2019)	Transition
Vivid Economics	Net-zero toolkit (HSBC Global Asset Management & Vivid Economics, 2019)	Transition
Vivid Economics	ViEW (EY & Vivid Economics, 2018)	Transition

Source: Vivid Economics

APPENDIX II

Carbon Delta's extreme weather business sector system

Sector		Code
Agriculture		EXW-AG
Agriculture	Livestock	EXW-AG-LS
Agriculture	Other Agriculture	EXW-AG-OA
Agriculture	Maize Agriculture	EXW-AG-MA
Agriculture	Wheat Agriculture	EXW-AG-WA
Commerce and Services		EXW-CS
Commerce and Services	Insurance	EXW-CS-IN
Commerce and Services	Laboratory	EXW-CS-LA
Commerce and Services	Healthcare Services	EXW-CS-HS
Commerce and Services	Luxury Service	EXW-CS-LS
Commerce and Services	Indoor Leisure	EXW-CS-IL
Commerce and Services	Office	EXW-CS-OF
Commerce and Services	Real Estate	EXW-CS-RE
Commerce and Services	Retail	EXW-CS-RT
Commerce and Services	Storage	EXW-CS-ST
Commerce and Services	Basic Service	EXW-CS-BS
Industry		EXW-IN
Industry	Construction	EXW-IN-CO
Industry	Infrastructure	EXW-IN-IF
Industry	Mining	EXW-IN-MI
Industry	Production Plant	EXW-IN-PP
Power		EXW-PO-PO
Power	Coal Power	EXW-PO-CP
Power	Fossil Other Power	EXW-PO-FO
Power	Hydro Power	EXW-PO-HP
Power	Natural Gas Power	EXW-PO-NG
Power	Nuclear Power	EXW-PO-NU
Power	Solar Power	EXW-PO-SP
Power	Wind Power	EXW-PO-WP
Tourism		EXW-TO
Tourism	Outdoor Leisure	EXW-TO-OL
Transportation		EXW-TR
Transportation	Inland Shipping	EXW-TR-IS
Transportation	Rail Transportation	EXW-TR-RT
Transportation	Road Transportation	EXW-TR-RO
Transportation	Sea Transportation	EXW-TR-SE
Transportation	Air Transportation	EXW-TR-AT

Source: Carbon Delta

APPENDIX III

INTERVIEW QUESTIONS

The following questions were posed in interviews to investors involved in the Investor Pilot. Interviewees from other organisations were sent tailored questions.

Context: the role of investment in investors' perspectives on climate change and the emerging understanding of long-term exposure

- How does your organisation define its own impact on climate change? Do you have climate-relevant KPIs?
- To what extent do you think the finance sector as a whole is starting to realise (and mitigate) its own impact on climate change? Where has the most progress been made and what is the highest priority area now compared to 5 years ago?
- Which institutions/organisations encourage you as an investor to consider the impacts of your investments on climate change? How so?
- TCFD is currently recommended practice; how do you view the potential for mandatory climate-related disclosure?
- TCFD is about long-run financial system stability. How does your organisation view *and address (if at all)* the 'tragedy of the horizon'?
- Do you see any relevance for TCFD approach in the wider context of achieving the Paris Agreement? If so, what developments do you expect in the next 5 years?

Operationalising the methodology: lessons learnt from the piloting

- If you had to identify three key lessons from the investor pilot, what would they be?
- In what way has the pilot advanced your existing or planned climate-related disclosure practices?
- Where do you see climate-related scenario analysis sitting in your organisation now and in the future?

- Do you foresee concretely integrating scenario analysis into decision making, and if so, how?
- What additional elements would you find useful in a scenario analysis methodology? Which issues do you feel have not been (sufficiently) addressed in the Carbon Delta methodology?
- What kind of tools, platforms, or other support mechanisms aid your organisation in incorporating the TCFD recommendations? What kind of tools, platforms, or other support mechanisms to aid you in incorporating the TCFD recommendations could be developed in future?
- What role (if any) do you see for standardisation or harmonisation in conducting scenario-based disclosure? How might such standardisation be achieved in your view?

State of implementation of the TCFD recommendations

- What pressures do you receive from clients to disclose on climate change, or to address climate-related issues in your interactions with them more generally?
- How do you report on climate-related considerations? In a sustainability report?
- What is some of the most advanced climate-related reporting you have seen to date, by a financial or investee? Why?
- How/when do you use (investee or other financials) climate-related disclosure?
- Do you have any general observations on the climate-related reporting you have received from investee companies to date? What are the prevailing issues?
- Have any of your investee companies disclosed scenario analysis results? If so, what was your opinion of this disclosure?

ACRONYMS

BaU	Business as Usual	NBG	Non-Binding Guidelines
CAPRI	Common Agricultural Policy Regionalised Impact	NBIM	Norges Bank Investment Management
CDP	Carbon Disclosure Project	NDC	Nationally Determined Contribution
CDPQ	Caisse de dépôt et placement du Québec	ND-GAIN	University of Notre Dame Global Adaptation Index
CGE	Computable general equilibrium	NFRD	Non-Financial Reporting Directive
COP	Conference of the Parties	NGA	National Greenhouse Accounting
CVaR	Climate Value at Risk	NGFS	Network for Greening the Financial System
DNB AM	DNB Asset Management	PACTA	Paris Agreement Climate Transition Assessment
EBITDA	Earnings before interest, tax, depreciation and amortisation	PIK	Potsdam Institute for Climate Impact Research
EIOPA	European Insurance and Occupational Pensions Authority	R&D	Research and development
ESG	Environmental, social and governance	RAM	Rockefeller Asset Management
ETS	Emissions trading scheme	RCP	Representative Concentration Pathway
GCAM	Global Change Assessment Model	REMIND	Regional Model of Investments and Development
GCM	Global Climate Model	SSP	Shared Socioeconomic Pathway
GDP	Gross Domestic Product	TCFD	Task Force on Climate-Related Financial Disclosure
GHG	Greenhouse gas	TDAM	TD Asset Management
GICS	Global Industry Classification Standard	TEG	Technical Expert Group
GLOBIOM	Global Biosphere Management Model	TIAM	TIMES Integrated Assessment Model
GVA	Gross value added	TPI	Transition Pathway Initiative
IAM	Integrated assessment model	UNEP	United Nations Environment Programme
IEA	International Energy Agency	UNEP FI	UN Environment Programme Finance Initiative
IIASA	International Institute for Applied Systems Analysis	UNFCCC	United Nations Framework Convention on Climate Change
IMAGE	Integrated Model to Assess the Global Environment	(UN)PRI	United Nations Principles for Responsible Investment
IPCC	Intergovernmental Panel on Climate Change	VaR	Value at Risk
IRENA	International Renewable Energy Agency	ViEW	Vivid Economy-Wide
JGCRI	Joint Global Change Research Institute	WACC	Weighted average cost of capital
KPI	Key performance indicator	WRI	World Resources Institute
MAgPIE	Model of Agricultural Production and its Impact on the Environment		

GLOSSARY

Acute risk	Risk from rapid onset weather events, often highly localised with immediate impacts
Business As Usual	Scenarios that are based on a set of assumptions that build on historical norms in projecting the global energy system
Carbon leakage	Displacement of emissions from one location to another owing to shifting trade patterns following the introduction of a carbon price in one jurisdiction but not in others
Chronic risk	Risk from slow onset, incremental weather changes, often with gradually accumulating impacts
Climate Value at Risk (CVaR)	Term used to specifically describe Carbon Delta's physical and transition risk assessment tool.
Counterparty	Entity to which an exposure to financial risk might exist. In this report, describes entities affected by climate-related risk, ranging from countries to companies and individual facilities.
Legal risk	Risk from climate-related litigation
Market risk	Risk that counterparties' supply and demand patterns, and relative competitiveness change during a low carbon transition.
Physical risk	Umbrella term for risks from the physical effects of climate change
Policy risk	Risk from climate-related policy changes (such as carbon pricing)
Radiative forcing	Influence of climatic factors on the amount of radiant energy affecting the Earth's surface.
Reputation risk	Risk to counterparty reputation from actions it takes related to climate change
Scope 1 emissions	Direct emissions from sources that an organisation controls or owns
Scope 2 emissions	Direct emissions from the consumption of electricity, heat or steam
Scope 3 emissions	Indirect emissions from an organisation's activities, including both upstream and downstream emissions
Technology risk	Risk from changes in relative technology costs due to innovation
Tragedy of the horizon	Misalignment between regulatory and economic actors' time horizons and the impacts of climate change.
Transition risk	Umbrella term for risks from the transition to a low (or zero) carbon economy
Value at Risk	Measure of the risk of investment loss. In this report often used as 'Value at Risk from climate change' when referring to scenario analysis methodologies other than Carbon Delta (for whom 'Climate Value at Risk' refers specifically to their proprietary tool).

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