GLOBAL WEALTH

Investing in a Time of Climate Change

The Sequel 2019

MAKE TOMORROW, TODAY MERCER

Contents

Foreword

In 2011, Mercer published its first major global research report on climate change and its implications for strategic asset allocation, in partnership with a number of our institutional investment clients. In June 2015, we released a major update, *Investing in a Time of Climate Change* ("the 2015 Report"), another client collaboration. We are now publishing *Investing in a Time of Climate Change — The Sequel* ("the Sequel").

Following our 2015 Report, major developments in late 2015 included two global agreements: The Paris Climate Change Agreement and the UN Sustainable Development Goals. The Paris Agreement reflects a collective goal to hold the increase in the climate's global mean surface temperature to "well below 2ºC above preindustrial levels and to pursue efforts to limit the temperature increase to 1.5ºC."[1] The current aggregate commitments, as measured by each country's nationally determined contributions (NDCs) will not, however, meet the agreed global ambitions unless commitments are significantly improved in the relatively near term.[2]

Since 2015, there have been many environmental, scientific, political and technological developments that continue to evolve our understanding of the climate-change-related investment context. In response to these developments and client demand, Mercer has now updated its climate scenario model and is proud to publish the Sequel. Mercer is recognized globally for its contribution to the investment industry's growing attention to and action on climate change. The Sequel provides practical advice for clients as well as case studies on what peers are doing. Our focus is on what is new and the "why, how and what" for investors as well as providing clients with the flexibility to undertake stress testing.

The Sequel is intended to help investors understand how climate change can influence their investment performance in both the short and long term and what steps they should take to protect and position portfolio assets. Given climate-related physical damages under higher-warming scenarios, we encourage investors to adopt a "Future Maker" approach, a term coined in the 2015 Report. Advocating for and creating the investment conditions that support a "well-below 2ºC scenario" outcome through investment decisions and engagement activities is most likely to provide the economic and investment environment necessary to pay pensions, endowment grants and insurance claims over the timeframes required by beneficiaries. We look forward to engaging directly with our clients to ensure their portfolios are well-positioned for and resilient to the impacts of climate change in the future.

Deb Clarke
Global Head of Investment Research

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Mercer's Actions to Date on Climate Change

Mercer is working to ensure that climate change is integral to our advice and solutions for clients on a global basis, as championed by our industry-leading global Responsible Investment business.[3]

Mercer has evolved internal investment processes to include:

- Specific references to climate change in our global investment beliefs as a "systemic risk" and encouraging investors to "consider the potential financial impacts of both the associated transition to a low-carbon economy and the physical impacts under different climate outcomes"[4]
- Updated global manager research guidance by asset class to incorporate relevant climate change considerations
- Commitments on the Financial Stability Board's Task Force on Climate-related Financial Disclosures (TCFD)[5] reporting, through the regional sustainable investment policies[6] governing Mercer's assets under management (along with other market-leading practices)
- Formal allocations to sustainability-themed equity, private equity and real assets (infrastructure and natural resources) in Mercer's global reference portfolios[7]
- Issuing a first "impact report" in 2018 quantifying the positive environmental contributions of our private markets Sustainable Opportunities strategy[8]

Mercer collaborates with industry groups, including:

- Actively participating in the TCFD as a Task Force member and signing the statement of support[9]
- Signing all G20 investor letters on climate change since 2014[10]
- Producing an in-depth study with Ceres on addressing climate-related considerations for insurers[11]
- Producing an in-depth study on the implications of climate change for public defined benefit plans in the US in collaboration with CIEL[12]
- Focusing on the critical theme of mobilizing private-sector investment in sustainable infrastructure in emerging markets through partnerships with the Inter-American Development Bank Group (IDBG)[13] and the Mobilizing Institutional Investors for the Development of African Infrastructure initiative (MiDA)[14]
- Supporting our sister company Oliver Wyman in 2017/2018 in their climate risk tool development to assess credit risk in bank-lending portfolios[15]

Our parent company, Marsh & McLennan Companies, created Marsh & McLennan Insights (previously the Global Risk Center). This group plays a key role in the World Economic Forum *Global Risks Report* each year and has established Climate Resilience as a key theme[16] and published a handbook on the topic.[17] It has also released a report in collaboration with CDP[18] and recently appointed its first Director of Climate Resilience.

Executive Summary

Humans have never lived in a world much warmer than today; yet the current trajectory of at least 3°C above the preindustrial average by 2100 could put us beyond the realm of human experience sometime in the next 30 years.

Why Is Climate Change Important to Investors?

Investors such as pension funds, insurers, wealth managers, and endowments and foundations typically have multidecade time horizons, with portfolio exposure across the global economy. The implications of climate change are systemic and are already apparent.[19] We have already experienced around 1ºC of average warming above preindustrial levels,[20] and extraordinary weather events with significant financial and human consequences are increasing in frequency.[21] Humans have never lived in a world much warmer than today; yet the current trajectory of at least 3ºC above the preindustrial average by 2100 could put us beyond the realm of human experience sometime in the next 30 years.[22] Investors need to consider both climate-related mitigation and adaptation in an active way to develop climate resilience in their portfolios. Financial regulators, particularly for pension funds, are increasingly reinforcing this message by formalizing the expectation that investors should consider the materiality of climate-related risks and manage them accordingly, consistent with their fiduciary duties.

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How Can Client Scenario Modeling Help Investors?

Investors often use scenario analysis to support strategic asset allocation decisions, as it helps to test portfolio resilience under multiple potential future outcomes. Climate scenario analysis was a key element of the TCFD[23] recommendations released in 2017.

Mercer's latest climate scenario model draws on third-party data that integrates the treatment of economics, energy systems and the environment to capture linkages and feedbacks. The model helps investors analyze the impact of climate-related physical damages (physical risks) and the transition to a low-carbon economy (transition risks) on their expected investment return outlook.

The model assists investors in analyzing the impact of climate-related physical damages (physical risks) and the transition to a low-carbon economy (transition risks) on their expected investment return outlook.

Mercer's three climate scenarios provide investors with analysis of asset-class and industry-sector sensitivities to climate risk factors to quantify a forward-looking "climate impact on return." In addition to calculating long-term annualized impacts, the model also contains a short-term stress-testing component, which enables an assessment of present-value impacts for sudden market repricing events, allowing for changes in view on scenario probability, physical damages likelihood and market awareness.

What's New?

The Sequel builds on the 2015 climate scenario model and approach but evolves it in a number of ways to capture developments over the past three years. New features include:

- **New economic underpinnings:** The 2019 model uses an established econometric model, maintained by Cambridge Econometrics, based primarily on empirical evidence rather than assumptions regarding optimization. This results in a very different treatment of transition risk impacts and a more positive view on the investment opportunity presented by a low-carbon transition than the 2015 model.
- **Updated climate scenarios:** These scenarios use the Cambridge Econometrics transition-risk climate model, which has applied recent econometric research across multiple economic variables to consider three scenarios, 2°C, 3°C and 4°C temperature increases, with evolved pathways and magnitude.[i]
- **Updated climate risk factors approach:** This approach evolves the four risk factors from 2015 — policy and technology to capture transition and resource availability and impact of catastrophes to capture physical damages. In the updated model, the interactions between policy and technology are represented together as "transition" and the rate of investment spending isolated as "spending," better identifying the difference between 2°C and 3°C scenario transitions.
- **Physical damages:** Damages are assessed with results extending to 2100 (rather than 2050 as in the 2015 Report) under the different climate scenarios. Many institutional investors and their beneficiaries have multidecade time horizons that reach beyond 2050. Alternative physical damages views in academic literature are also presented, given the many data gaps and uncertainties in this area, allowing model users to test different assumptions regarding the potential physical damage impact on asset returns.
- **Additional asset classes:** New asset classes have been incorporated, including additional regional flexibility and several sustainability-themed options — for example, sustainable global equity, sustainable private equity and sustainable infrastructure — to improve the mapping of investor portfolios transitioning to low-carbon, resilient exposures.
- **A stress-test component:** This has been introduced to better compare potential climate-related repricing events in the short term (for example, over one year) to other, more "traditional" events tested in strategic asset allocation reviews. These market-pricing events could come from changes in views relating to:
  - Physical damage impact on GDP — the likelihood of physical risk
  - Scenario probabilities — a change in the likelihood of the 2°C scenario occurring
  - Market awareness — the extent to which climate-related impacts are "priced in" by the markets

[i] In October 2018, the Intergovernmental Panel on Climate Change (IPCC) released a new report on 1.5°C and the difference between that and 2°C to illustrate the additional impact that 0.5°C is expected to have, why the Paris Agreement ambition is for "well below" 2°C and how close we are to that window of opportunity closing. Further detail is provided in Appendix 2: Methodology on the scenarios, including the logic for applying a 2°C rather than 1.5°C scenario in the Sequel. However, when 2°C is referenced as an ambition throughout, please take this to mean "well below" 2°C and, ultimately, 1.5°C as the preferred 2100 ambition for the climate.

What Does the Sequel Modeling Tell Investors?

The modeling results have evolved from the 2015 Report given there have been many environmental, scientific, political and technological developments that continue to evolve both our understanding and the climate change modeling data. However, the headline messages remain consistent, reinforce the recommendations made at that time and support greater urgency for action to achieve a well-below 2°C scenario. The relative impacts across asset classes and sectors convey a number of key signals for investors to consider in portfolio construction and asset allocation decisions. Stress-test modeling is also beneficial to demonstrate the potential magnitude of return impacts in the shorter term if changes in policy, market pricing or physical damages are more sudden than currently anticipated.

A key conclusion is that investing for a 2°C scenario is both an imperative and an opportunity:

- **An imperative, since, for nearly all asset classes, regions and timeframes, a 2°C scenario leads to enhanced projected returns versus 3°C or 4°C and therefore a better outcome for investors**
- **An opportunity, since, although incumbent industries can suffer losses in a 2°C scenario, there are many notable investment opportunities enabled in a low-carbon transition**

[ii] In the Sequel, two sample asset allocations were used to illustrate the key findings: 1) the same diversified growth asset allocation introduced in the 2015 Report and 2) a 2019 portfolio that is equivalent to the 2015 portfolio but with explicit allocations to sustainability-themed investments in multiple asset classes. Current limitations in data and methodology available for modeling physical damages, together with the myriad of factors not yet captured and multidecade timeframes, mean the resulting magnitudes are likely to be significantly underestimated and invariably relatively small in absolute terms. The Sequel outlines more on these additional considerations when assessing quantitative results.

The Sequel's highlights include the following:[ii]

1. **The results emphasize the physical damages risks and why a below 2°C scenario is most beneficial**, and the 4°C and 3°C scenarios are to be avoided, from a long-term investor perspective. In the two sample portfolios, there is a return opportunity to 2030 of between 0.10% p.a. and 0.30% p.a. in a 2°C scenario compared to -0.07% p.a. in a 4°C scenario. To 2100, a 4°C scenario leaves each portfolio down more than 0.10% p.a. compared to a 2°C scenario.

2. **Transition opportunities emerge from a 2°C scenario, with transition now expected to be a benefit from a macroeconomic perspective**,[24] including the potential to capture a "low-carbon transition (LCT) premium."[25] Although a 2°C scenario definitely still presents transition risk (especially for portfolios aligned to a 3°C or 4°C+ world), opportunistic investors can target investment in the many mitigation and adaptation solutions required for a transformative transition. In the two sample portfolios, the sustainability-themed version is nearly 0.20% p.a. better off to 2030.

3. **Expected annual return impacts remain most visible at an industry-sector level, with significant variations by scenario**, particularly for energy, utilities, consumer staples and telecoms. Asset class returns can also vary significantly by scenario, with infrastructure, property and equities being the most notable. Variations in results between asset classes and across regions, cumulative impacts, and the emphasis on sustainable opportunities provide multiple portfolio construction possibilities for investors.

Example industry sectors and asset classes	% p.a. to 2030 in 2°C scenario	% p.a. to 2050 in 2°C scenario	% cumulative impact to 2030 in 2°C scenario	% cumulative impact to 2050 in 2°C scenario
Coal	-7.1	-8.9	-58.9	-100.0*
Oil and gas	-4.5	-8.9	-42.1	-95.1
Renewables	+6.2	+3.3	+105.9	+177.9
Electric utilities	-4.1	-3.3	-39.2	-65.7
Developed market equities	0.0	-0.2	-0.5	-5.6
Emerging market equities	+0.2	-0.1	+1.8	-4.0
All world equities — sustainability themed	+1.6	+0.9	+21.2	+32.0
Infrastructure	+2.0	+1.0	+26.4	+39.4
Infrastructure — sustainability themed	+3.0	+1.6	+42.3	+67.1
All world real estate	0.0	-0.2	-0.1	-4.7

* Effective absolute loss of value is expected to occur in 2041 under a scenario in which global warming is limited to 2°C by 2100.

In a 2°C scenario by 2050, there are minor positives as well for materials, telecoms and consumer staples sectors. In 3°C and 4°C scenarios, all sectors, apart from renewables, have negative return impacts, to 2030, 2050 and 2100, with return impacts varying between 0.1% p.a.and 7.7% p.a.[iii]

Real estate is expected to be flat to 2030 under a 2°C scenario, but a 4°C scenario, even in the near term, starts to impact negatively. A 4°C scenario to 2050 sees infrastructure and property down 0.4% p.a. and 0.2% p.a., respectively, developed market equities are down 0.1% p.a. and emerging markets are down 0.3% p.a. In a 4°C scenario, India and China equities are down 0.4% p.a. and 0.3% p.a., respectively. Sovereign debt provides a safe haven and marginally positive results, with fixed income continuing to remain relatively muted overall, with some variations within the asset class.

4. **In reality, sudden changes in return impacts are more likely than neat, annual averages, so stress testing is an important tool in preparing for this eventuality.** Stress testing portfolios for changes in view on scenario probability, market awareness and physical damage impacts can help investors to consider how longer-term return impacts that may appear small on an annual basis could emerge as more-meaningful shorter-term market repricing events.

   Testing an increased probability of a 2°C scenario with increased market awareness can result in sector-level returns where renewables increase by more than 100% and coal decreases by nearly 50%. Positive asset class impacts include infrastructure at almost 23% and sustainable equity at more than 5%. Testing an increased probability of a 2°C scenario or a 4°C scenario with greater market awareness, even for the modeled diversified portfolios, results in +3% to -3% return impacts in less than a year.

What's Next for Investors?

The findings strengthen the argument for investor action on climate change and suggest greater attention is required on how investors will actively support the transition to a 2°C scenario — as Future Makers as opposed to Future Takers.[26]

The recommended Investor Actions from the 2015 Report remain valid — to incorporate climate change considerations as part of good governance and investment decision-making — and are consistent with the 2017 TCFD recommendations. We include several investor case studies, which reinforce how scenario analysis helps prioritize the portfolio risks for some and opportunities for others. The case studies also demonstrate the pace of change by peers.

Consistent with Mercer's thinking on the best way to incorporate ESG and climate change considerations into the investment process, we continue to recommend an integrated approach when setting investment beliefs, policies and processes, and when constructing and managing portfolios, as set out in Mercer's *Responsible Investment Pathway.* This enables climate-related risks and opportunities to be included alongside other investment considerations and for processes and portfolios to evolve over time — grounded in agreed-upon beliefs and policies.

[iii] The strongly negative impacts reflect sectors that are required to essentially discontinue by 2050. Therefore, return would be driven more by the income received within that time period, and this income is not allowed for in these figures.

Why Is Climate Change Important to Investors?

Long-term investors typically have multidecade time horizons, often 50 years or more, with exposure across the global economy. With this time horizon in mind, it is essential to address in the short term both the potential impacts of a low-carbon transition and physical damages associated with climate change to better prepare portfolios for the future.

The Big Picture

The world's climate is already, on average, 1°C warmer than in preindustrial times. The vast majority of climate scientists anticipate that with current action on climate change, by 2100, the world will be between 2°C and 4°C warmer (current commitments made as part of the Paris Agreement, if implemented, put the trajectory at 3°C), noting that averages mask the differences that will be felt regionally.[27] Humans have never lived in a world much warmer than today, and experiencing such a material temperature change in less than a century will have substantial and damaging effects on society and nature.[28]

The recent Intergovernmental Panel on Climate Change (IPCC) report, which compares the expected physical damages under both a 1.5°C and 2°C scenario, demonstrates the impacts associated with a warming climate, even in the "best-case" scenarios.[29] The scenarios modeled in the Sequel are outlined in Appendix 1: Sample Asset Allocations and include physical damages indicators for each warming scenario, all of which have social and economic implications.

As an example, for a 2°C scenario by 2100, the expected physical damages include[30]:

- Increase in average sea level of 50 cm
- Increase in annual maximum daily temperature of 2.6°C; 25% increase in number of hot days
- 36% increase in frequency of rainfall extremes over land

There is scientific consensus[31] that greenhouse gas (GHG) emissions from human activity are being trapped in the atmosphere and creating a "greenhouse effect," which is causing the increase in global mean surface temperature and the consequent effects on underlying weather patterns. Fossil-fuel use is the principal source of GHG emissions, primarily carbon dioxide (CO_2). The second-largest contributor to GHG emissions is methane, primarily related to agricultural activities, fossil fuel production and waste/landfills. Agriculture and the built environment are the principle drivers behind deforestation, which not only reduces CO_2 absorption capacity but also is a major source of emissions as the carbon stored in vegetation and soils is released into the atmosphere.[32]

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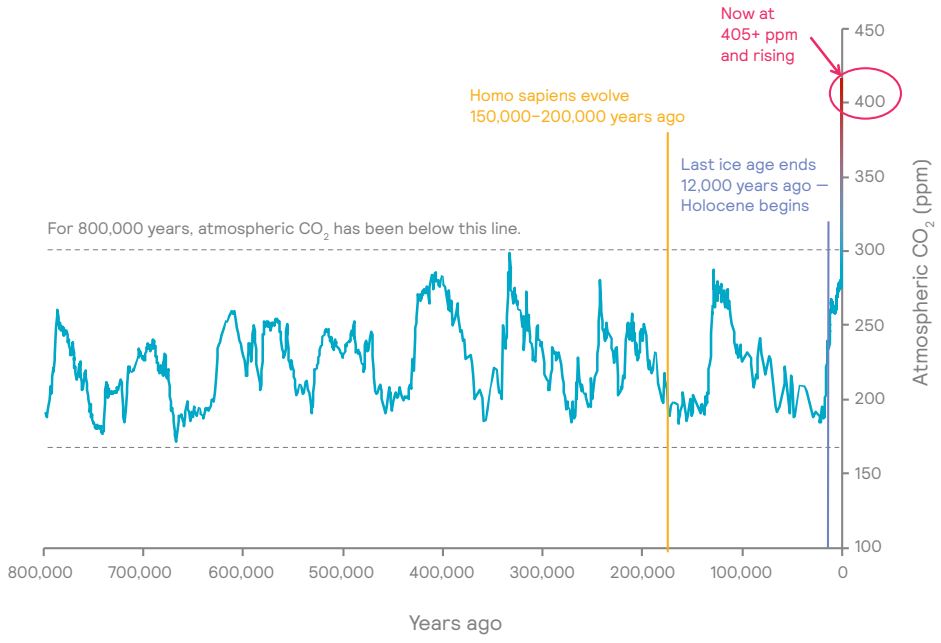
The last time the global mean surface temperature was comparable to today was more than 100,000 years ago. The last time CO_2 concentrations were as high as today (over 400 ppm) was three to four million years ago, and the last time the world was 4ºC warmer was more than 10 million years ago. It is currently possible that we could reach 4ºC of warming by the end of the century.[33]

The current trajectory could put us beyond a temperature that humans have ever experienced sometime in the next 30 years. The last time the global mean surface temperature was comparable to today was more than 100,000 years ago. The last time CO_2 concentrations were as high as today (over 400 ppm) was three to four million years ago, and the last time the world was 4ºC warmer was more than 10 million years ago. It is currently possible that we could reach 4ºC of warming by the end of the century.[33]

The earth's climate has experienced many natural variations over millions of years, including ice ages and periods of warming with much higher sea levels. Humans have flourished in the past 12,000 years (when the current geological epoch, the Holocene, began after the last glacial period ended), and today's societies reflect the benefits of agriculture over the past 8,000 years,[34] thanks in part to the levels of CO_2 in the atmosphere. However, the scale and pace of change poses serious concerns for human adaptation given our dependency on the natural environment for water and food, a growing population with resource-intensive consumption practices and the exposure of our built environment to severe environmental damage. Changes in technology, system design and consumption patterns will be central to human adaptation in a climate-changed world.

Figure 1. Atmospheric CO_2 Levels Over Time



Source: NASA, available at https://climate.nasa.gov/climate_resources/24/graphic-the-relentless-rise-of-carbon-dioxide/

Data: National Oceanic and Atmospheric Administration. Some description adapted from the Scripps CO2 Program website, "Keeling Curve Lessons."

The Global Risk Landscape

Dedicated global institutions were formally established in 1992 to focus on climate change, and since then, awareness of the associated risks has been growing.[35] Acknowledgement of the risks posed by climate change among business and government leaders is reflected in the recent World Economic Forum *Global Risks Report*,[36] which displays the heightened focus on environmental and social risks over time as compared to economic, geopolitical or technological risks. (Note the higher incidence of red and green boxes in recent years in Figure 2, next page.)

Figure 2. Evolving Global Risk Landscape (2009–2019)

Top Five Global Risks in Terms of Likelihood

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	Asset price collapse	Asset price collapse	Storms and cyclones	Income disparity	Income disparity	Income disparity	Interstate conflict	Involuntary migration	Extreme weather	Extreme weather	Extreme weather
2	Slowing Chinese economy	Slowing Chinese economy	Flooding	Fiscal imbalances	Fiscal imbalances	Extreme weather	Extreme weather	Extreme weather	Involuntary migration	Natural catastrophes	Climate change mitigation and adaptation failure
3	Chronic disease	Chronic disease	Corruption	Greenhouse gas emissions	Greenhouse gas emissions	Unemployment/ under-employment	National governance failures	Weak climate change response	Natural catastrophes	Cyberattacks	Natural catastrophes
4	Global governance gaps	Fiscal crises	Biodiversity loss	Cyberattacks	Water supply crises	Climate change	State collapse	Interstate conflict	Terrorist attacks	Data fraud	Data fraud
5	Retrenchment from globalization	Global governance gaps	Climate change	Water supply crises	Aging population	Cyberattacks	High unemployment	Natural catastrophes	Data fraud	Climate change adaptation failure	Cyberattacks

Top Five Global Risks in Terms of Impact

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	Asset price collapse	Asset price collapse	Fiscal crises	Systematic financial failure	Systematic financial failure	Fiscal crises	Water crises	Weak climate change response	WMDs	WMDs	WMDs
2	Retrenchment from globalization	Retrenchment from globalization	Climate change	Water supply crises	Water supply crises	Climate change	Infectious diseases	WMDs	Extreme weather	Extreme weather	Climate change mitigation and adaptation failure
3	Oil and gas price spike	Oil price spike	Geopolitical conflict	Food crises	Fiscal imbalances	Water crises	WMDs	Water crises	Natural catastrophes	Natural catastrophes	Extreme weather
4	Chronic disease	Chronic disease	Asset price collapse	Fiscal imbalances	WMDs	Unemployment/ under-employment	Interstate conflict	Involuntary migration	Water crises	Climate change adaptation failure	Water crises
5	Fiscal crises	Fiscal crises	Extreme energy price volatility	Volatility in energy and agri-cultural prices	Weak climate change response	Critical ICT systems breakdown	Weak climate change response	Energy price shock	Weak climate change response	Water crises	Natural catastrophes

Economic | Geopolitical | Technological
Environmental | Societal

Source: World Economic Forum. Global Risks Report 2019.

Figure 2 outlines the top perceived risks by likelihood of the risk occurring globally within the next 10 years and its negative impact for several countries or industries over the same timeframe. Environmental risks, particularly on climate change, now dominate concerns in terms of likelihood and impact. Many of the risks are also interconnected. For example, survey participants believe weak climate change mitigation exposes business and government to extreme weather, natural catastrophes and water crises. These issues, in turn, are more likely to lead to involuntary migration and conflict. Considering the interconnectedness of these issues will be increasingly important in anticipating and preparing for a changing investor context.

Economic risks are not represented in the top five risks in recently published *Global Risks Reports*. However, another asset price collapse in the short term could significantly distract from the current focus on addressing environmental and social risks or could even be caused by such risks. Current debt levels are also a concern because of the spending potentially required on climate-related mitigation and adaptation. The global economic context and outlook remain fundamental influences for investors, and it is for this reason that some of the foundational inputs to Mercer's climate scenario modeling are economic indicators, such as the overall view on growth, as currently measured by GDP,[37] industry profitability and interest rates.

Climate Change — A Fiduciary Issue

Mercer advises a variety of investors, including those with responsibility for paying pensions, making endowment and foundation grants, paying insurance claims and providing wealth management products. These investors have varying objectives and portfolio allocations and function within different regulatory requirements and contexts.

Typically, though, they are all aiming to deliver substantial returns to members, beneficiaries and stakeholders over many years and even decades. They are true long-term investors, invested across the global economy and collectively managing trillions of dollars.

As the evidence grows that there are climate-related financial implications for investors, financial regulators are increasingly formalizing the expectation that investors should consider the materiality of these risks and manage them accordingly as part of their fiduciary duties — particularly for pension funds.

Two key elements support this fiduciary duty alignment:

1. **Financial materiality of transition and physical damages risks/ opportunities:** Transition risk consists of the technology and policy changes necessary (and to some extent, already underway) to transform the economy away from fossil fuels as the primary energy source and to mitigate additional temperature increases. The financial implications most naturally point to the energy sector, but transformative change will invariably have significant implications for all energy-dependent and high-emitting sectors of the economy.

   Physical risk captures the damages that come with temperature increases that we have failed to avoid. The frequency of storms, wildfires and floods will shift as will the availability of natural resources like food and water. The willingness of and ability for society to adapt to these changes is uncertain. Investors with real asset exposures, such as property, directly or indirectly, will need to increasingly review insurance coverage and uninsured loss implications together with additional capital expenditure requirements. Physical damages are also expected to negatively impact consumer staples and telecoms, as two equity-sector examples.

   The expected financial materiality of these risks is evidenced in the 2015 Report and the Sequel and supported in reports by The Bank of England,[38] the G20 Financial Stability Board[39] and The Economist Intelligence Unit[40] as well as an increasing number of other investment-industry participant reports on recommended actions.[41] The findings in the Sequel show that it is in investors' best interests and therefore consistent with fiduciary duty to actively support the low-carbon transition to avoid the worst physical damages

scenarios, which will have almost entirely negative impacts across sectors and asset classes.

2. **Growing legal and regulatory consensus that material climate-related factors must be considered and managed by fiduciaries:** As awareness of the financial materiality of climate-related factors has increased, financial regulators in a number of jurisdictions have indicated that many investors will need to consider and manage climate-related risks in order to comply with their existing fiduciary duties. In the UK, for example, a 2018 paper by law firm Pinsent Masons neatly summarizes the fiduciary duty debate in recent years given an absence of legislation and case law.[42] However, the conclusion now is that "in cases where climate change has the potential to impact on long-term investment performance, pension scheme trustees have a fiduciary duty to consider climate change risk when making their investment decisions."[43]

The legal argument has been strengthened by recent pension-fund guidance and legislation, particularly in Europe, which recognizes at least the potential for financial materiality and requires climate change to be considered in investment decision-making processes, consistent with the timeframes of beneficiaries; for example, the 2016 EU Directive on Institutions for Occupational Retirement Provision (IORP)[44] and the UK's Department for Work and Pensions.[45] Regulatory activity has also extended across the Atlantic, with the provincial government in Ontario, Canada, requiring pensions to disclose in their statements of investment policies and procedures whether environmental, social and governance (ESG) factors are considered and, if so, how[46] and the insurance regulator in California requiring insurers to disclose their fossil-fuel-related holdings.[47] In a number of other countries, particularly in Europe, laws are also being changed to explicitly require investors to consider and disclose management of climate-change-related risks (for example, the French Energy Transition Law, Article 173). The China Securities and Regulatory Commission issued guidelines requiring listed heavy polluters to give more-specific information on emissions, with all listed firms to disclose environmental impact information by the end of 2020.[48]

Laws and litigation related to climate change also continue to develop.[49] Litigation is primarily being targeted at companies for failure to mitigate, adapt or disclose, but there are examples of litigation against governments[50] and, most recently, pension funds.[51] ClientEarth, a legal advocacy organization, has also been developing legal challenges against pension funds and investors that fail to consider climate-change-related risks.[52] As signals from regulators become stronger and/or more investors take action, those that fail to consider, manage and disclose their potential portfolio-specific risks may be susceptible to legal challenges in the future.

How Can Mercer's Climate Scenario Modeling Help Investors?

The Mercer climate scenario model draws on an integrated assessment model (IAM)[53] for climate change (which combines climate science and economic data) to analyze the return outlook in investor portfolios across asset classes and industry sectors. Three different climate scenarios provide the basis for this analysis of sensitivities to climate risk factors, enabling investors to quantify a forward-looking "climate impact on return." A new aspect of the Mercer model is the ability to "stress test" the impact of sudden changes in scenario probabilities and market valuations in the short term or shifts in the magnitude of physical damages in the long term.

Investors often use scenario analysis to support strategic asset allocation decisions, as they help to model risk and return outcomes under different future scenarios and identify the most resilient portfolios.

In addition to typical scenarios, such as extreme inflation or energy price spikes, investors have been aiming to understand how different climate scenarios could impact the performance of different asset classes, regions, sectors and companies. Challenges include the limited relevance of historical data for modeling future climate-change-related impacts and, therefore, the greater uncertainties in forward-looking climate change scenarios compared with other traditional scenarios that rely on historical data.

Mercer's climate scenario model supplements the traditional investor asset-allocation process, which typically relies to a significant extent on the use of historical data to model the expected risk and return of different asset classes within portfolios. Mercer's model is based on a forward-looking approach that allows investors to consider the effects of both the transition to a low-carbon economy and the anticipated physical damages of climate change. The outputs can be used to report against the recommendations of the TCFD in the "Strategy" component of its four-part framework, covered further in the Investor Actions section on page 65.

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"Part of the process of isolating risks for investors is to identify the factors that signpost drivers of change." (page 27)

"Scenarios provide helpful guides for prioritizing actions when faced with uncertainty." (page 8)

"As noted by the Intergovernmental Panel on Climate Change (IPCC), the 'warming of the climate system' is 'unequivocal.' The extensive uncertainties that still exist include just how much our current practices will contribute to this unequivocal warming by way of emissions, what level of warming will be sustainable and what damages investors need to prepare for, whatever the level of warming." (page 35)

The key benefit of Mercer's climate scenario model is that it can be applied as part of strategic decision-making in relation to asset allocation and/or portfolio construction. This top-down, portfolio-wide scenario analysis can then be combined with further insights from bottom-up analytical tools that assess climate exposures of sectors and companies. For example, carbon footprinting is a bottom-up way of assessing historical carbon emissions volume/intensity relative to benchmarks and targets and is now commonly undertaken (in equities and fixed income).

The methodology for Mercer's climate scenario model is outlined in brief below. Further detail on the inputs behind this update — the climate models, scenarios and risk factors — are included in Appendix 2: Methodology.[iv]

Methodology — Overview

The Mercer climate scenario model isolates transition and physical risk factors and maps the relative impact of those risk factors under three climate scenarios.

Scenarios

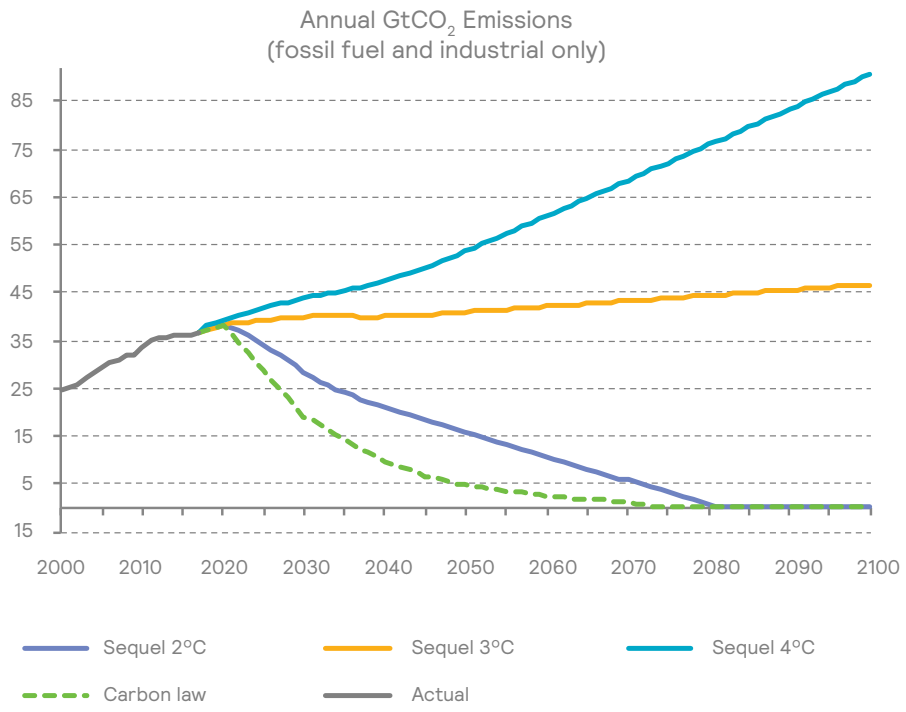
2°C	a low-carbon economy transformation most closely aligned with both successful implementation of the Paris Agreement's ambitions and the greatest chance of lessening physical damages
3°C	some climate action but a failure both to meet the Paris Agreement 2°C objective and meaningfully alleviate anticipated physical damages
4°C	reflecting a fragmented policy pathway where current commitments are not implemented and there is a serious failure to alleviate anticipated physical damages

Note there were two 4°C scenarios in the 2015 Report, differentiated only by the range of physical damages. This range is now being addressed through the stress-testing approach, which includes multiple physical damages pathway options.

In the 2019 model, we kept the same three scenarios, but the construction (for example, emissions trajectory/mix) was modified based on third-party input (Cambridge Econometrics). Figure 3 on the following page illustrates the emissions trajectory for the three Sequel scenarios.

[iv] Mercer clients undertaking climate scenario modeling also have access to a Technical Addendum, which is not public, that provides more detail on the methodology, assumptions and modeling decisions.

Figure 3. Emissions Pathways for Climate Scenarios



Cumulative Carbon Emissions (2018–2100)

Scenario	$GtCO_2$
Sequel 2°C	1,100
Sequel 3°C	3,500
Sequel 4°C	5,100
Global carbon law	650

Emissions in the last decade: 350 $GtCO_2$
Emissions in 2010: 49 GtCO2eq.

NOTE: The CO_2 emissions shown on the graph and above do not include land-use-related emissions, which are currently about five $GtCO_2$ annually, which must also reach net-zero or below, nor does it include the CO_2 equivalent of other GHGs.

Cambridge Econometrics did not model land-use CO_2 emissions and other GHG emissions.

Source: Mercer

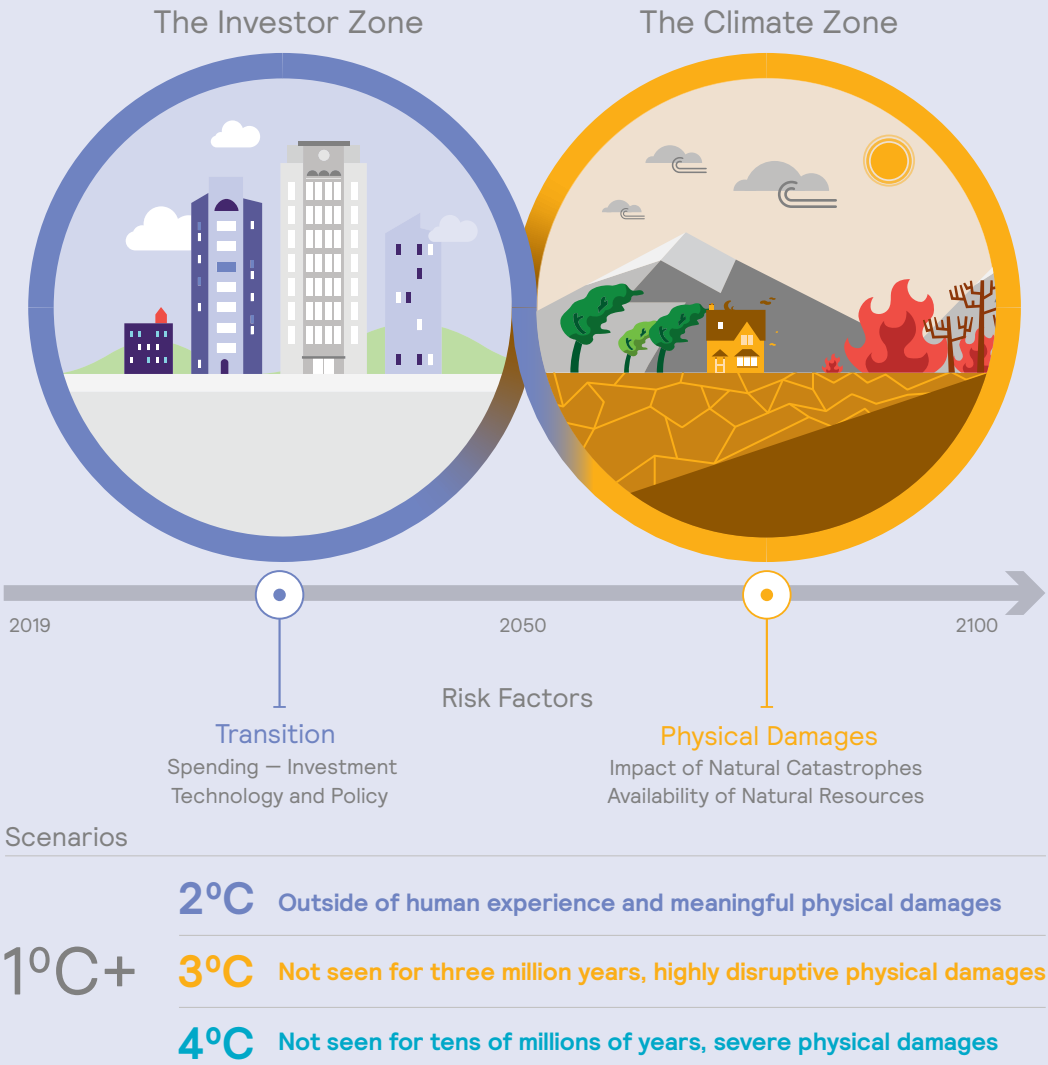
The longer policymakers, companies and investors delay, either a) the less likely we will stay below the 2°C target or b) the more rapid the transition to a low-carbon economy and, ultimately, a zero-carbon economy will need to be. Sudden changes are more likely to be disruptive than an "orderly" transition. A delayed "catch up" to achieve a carbon budget would also require the removal of carbon from the atmosphere, which would require significant areas of land and water to implement afforestation (new forests), reforestation (replacement forests), and carbon capture and storage (CCS), which requires technologies/processes that have not yet been fully commercialized.

The Sequel 2°C scenario represents a 50% chance of staying below 2°C. Given the physical risks associated with warming above 2°C, this is not the preferred target. To have a 66% chance of staying below 2°C, emissions would have to decline more rapidly; for example, in a trajectory known as the global carbon law,[54] which would see emissions peaking in 2020 and halving every decade thereafter. The "carbon law" concept is based on Moore's Law in the computer industry, applied to cities, nations and industrial sectors that would ensure the greatest efforts to reduce emissions happen sooner not later and reduces the risk of exceeding the remaining global carbon budget to stay well below 2°C.

Risk Factors

The climate risk factors identified in the 2015 Report were deemed to be the most climate-change-specific factors relevant for investors. This approach was reinforced by the TCFD recommendations in 2017 that also emphasized the differential nature of transition and physical damages risks.

Figure 4. Climate Change Risk Factors Over Time



Source: Mercer

Note: The world's climate is already, on average, 1°C warmer than in preindustrial times. The Mercer scenarios of 2°C, 3°C and 4°C represent total warming by 2100 relative to preindustrial times.

Figure 4 compares the timeframe of a typical investor with the timeframe of this study and the horizon of climate change impacts. The "STIR" risk factors for the Sequel are founded in the 2015 "TRIP" factors, with an evolved approach to the transition.

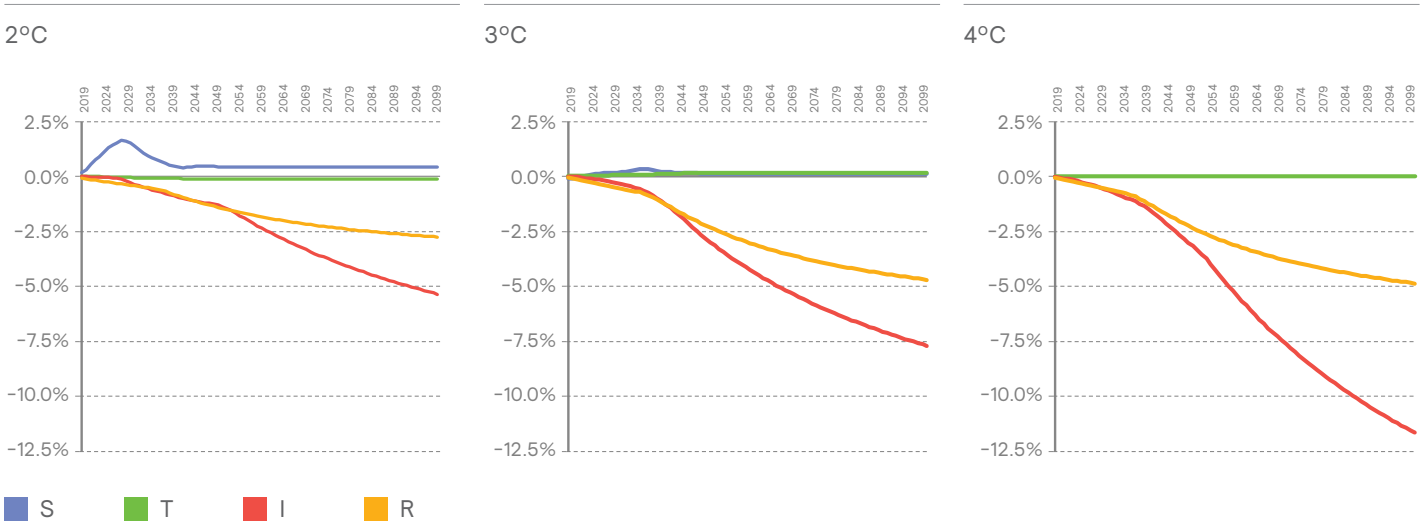
STIR Risk Factors

1. **Spending:** rate of investment spending to catalyze the transition
2. **Transition:** development of technology and low-carbon solutions and the international, national and subnational policy targets, legislation and regulations aiming to reduce the risk of further human-induced climate change
3. **Impact of natural catastrophes:** physical damages due to acute weather incidence/severity — for example, extreme or catastrophic events
4. **Resource availability:** long-term weather pattern changes — for example, in temperature or precipitation — impacting the availability of natural resources like water

In the final 2019 modeling, the policy and technology interactions were captured as a single transition risk factor, with different asset sensitivities in a 2°C and a 3°C scenario. This is an important distinction, because sectors will respond differently to alternate policy pathways (for example, the extent to which coal is replaced and/or the role of gas as a transition fuel). A key difference between the 2°C and 3°C scenarios is captured as spending, the "S" risk factor, highlighting the impact of public and private spending to catalyze the transition and the positive investment implication in the near term under a 2°C scenario.

The relative overall cumulative impact on global GDP for each scenario for each risk factor is shown below, with S = spending, T= transition (2°C and 3°C versions — T2 and T3), I = impact of natural catastrophes and R= resource availability.

Figure 5. Risk Factor Pathways — Cumulative GDP Impacts by Scenario



Source: Mercer

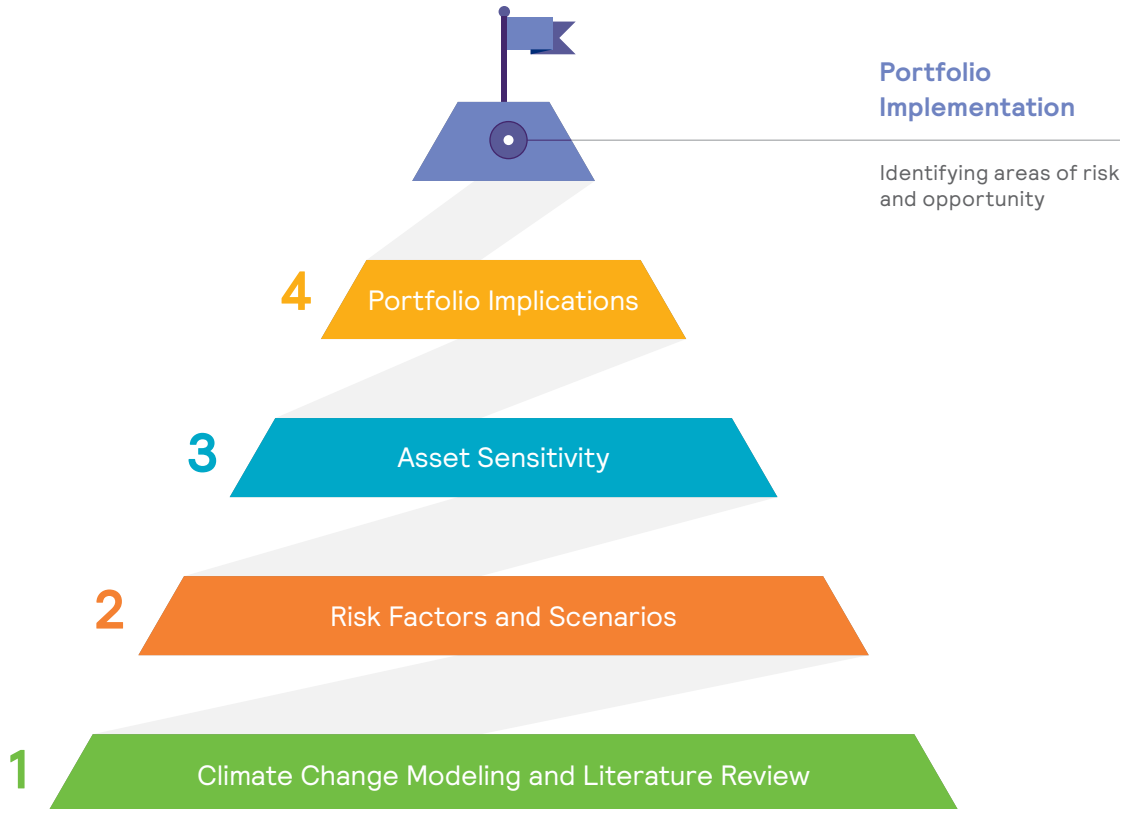
More detail is provided on the scenarios in Appendix 2: Methodology on pages 76-83.

Calculating the Climate Impact on Return

The diagram on page 24 summarizes how the various inputs fit together. The IAM forms the foundation for the work, along with a qualitative literature review, which, in turn, informs the magnitude of physical damages risk in the macroeconomic modeling. The IAM is used to develop the scenario pathways and the climate risk factor sensitivities that are the two key inputs to the Mercer climate scenario model. The relative impacts of each input and their interaction enables the additional climate impact on return to be calculated.

The longer policymakers, companies and investors delay, either a) the less likely we will stay below the 2°C target or b) the more rapid the transition to a low-carbon economy and, ultimately, a zero-carbon economy will need to be.

Figure 6. Illustrative Approach for Modeling the Investment Impacts of Climate Change



Climate Change Modeling and Literature Review

The modeling foundations are provided by a third-party macroeconomic model, E3ME, which draws upon the "GENIE" integrated assessment model (IAM). IAMs combine climate science and economic data to estimate the costs of mitigation, adaptation and physical damages.

Risk Factors and Scenarios

Three climate change scenarios provide a framework for the relative impacts for identified climate change risk factors over time.

Asset Sensitivity

The sensitivity to the climate change risk factors is determined for different asset classes and industry sectors.

Portfolio Implications

The sensitivity and scenarios are integrated into Mercer's investment modeling tool to estimate the impact of climate change on investment portfolio returns.

Source: Mercer

The scenarios modeled are deterministic, which is necessary given the gaps in scientific research and our current understanding of climate change (not to mention the complexity of conducting investment analysis 80 years into the future). However, the interactions are likely to be much more complex than we can ever model.

The two modeling approaches on the following page are used to calculate climate impact on return.

Modeling Approach 1: Long-Term Return Impact Analysis

Portfolio implications are generated by calculating the average annual climate impact on return for different asset classes and industry sectors across the three scenarios over different time periods (for example, over 10 years, to 2050 and to 2100).

Figure 7. Annual Return Impact Analysis Inputs and Outputs

Annual Return Impacts

Scenario Pathways		Asset Sensitivity		Annual Return Impacts
• How will each risk factor change over time for each scenario? • A quantitative pathway is developed for each risk factor and scenario.	x	• How sensitive is each sector and asset class to each risk factor on a relative basis?	=	• How are different sectors or asset classes impacted on an annual, average basis over multi-year time periods? • What are the risk and opportunity priorities?

Source: Mercer

Modeling Approach 2: Short-Term Stress-Testing Analysis

Many clients requested that we consider how longer-term return impacts could manifest as shorter-term climate-related market repricing events (for example, reflecting short-term changes in how the market prices climate change risks and opportunities, including changing views on the probabilities of different climate scenarios).

As a result, we have developed a climate stress-testing addition to the model, which immediately capitalizes expected future impacts in present-value terms using a dividend discount modeling (DDM) approach, driven by a change in view on scenario probabilities, market awareness and/or physical damages.

Figure 8. Stress Test Inputs and Outputs

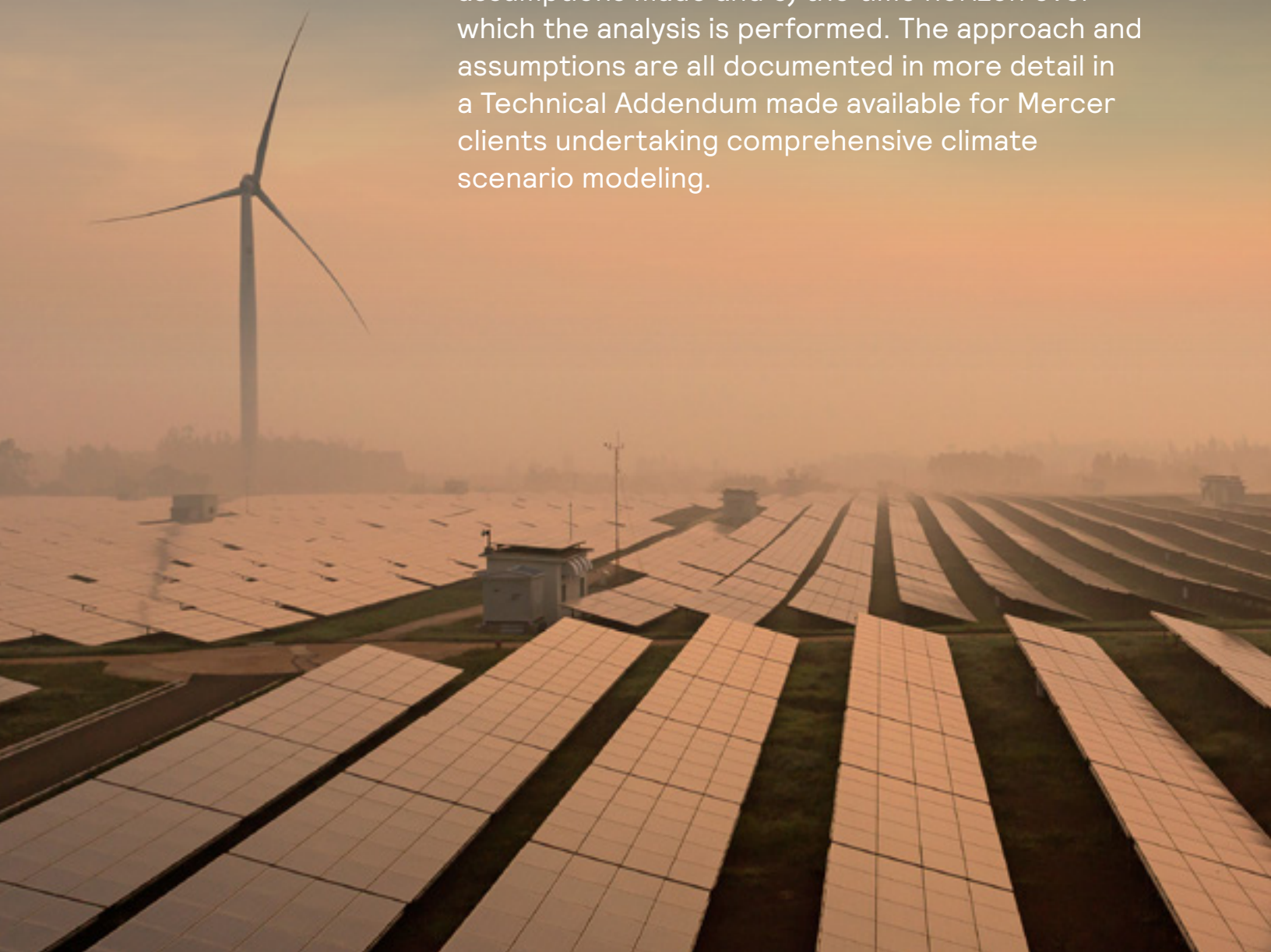
Stress Tests

Scenario Probability Change		Market Pricing Change		Capitalized Pricing Event
• What might the probability be for changes in either transition risk or physical damages risks becoming more likely?	x	• How likely is it that the market has the same view or is under- or overpricing?	=	• This describes the percentage impact on valuation if market pricing changed to a) account for a different view on the more likely climate scenario and b) account for climate change to a different extent.

Source: Mercer

Quantitative Models — A Cautionary Note

Mercer continues to believe that climate scenario modeling for assessing the potential investment impacts of climate change is a valuable exercise, notwithstanding the shortcomings mentioned below. However, quantitative modeling in itself is limited when assessing climate-related risk and opportunity and requires qualitative judgment to also be applied, along with stress testing. As with other forms of investment modeling, the climate scenario modeling featured in this report is subject to uncertainty introduced at several levels, including a) the overall construct of our modeling approach, b) the specific assumptions made and c) the time horizon over which the analysis is performed. The approach and assumptions are all documented in more detail in a Technical Addendum made available for Mercer clients undertaking comprehensive climate scenario modeling.



Forecasting is notoriously difficult: As former US Federal Reserve Chair Alan Greenspan reflected in 2013 when looking back on the financial crisis, "The whole period upset my view of how the world worked — the models failed at a time when we needed them most … and the failure was uniform."

Although we typically focus on what is modeled, it is just as important to recognize what is not modeled. The points below are intended to highlight known shortcomings in climate scenario modeling, both in the IAMs and in economic modeling generally, to encourage additional discussions in decision-making.

In summary, know the limitations regarding the current data and methodology available for climate scenario modeling:

- The magnitude of results — particularly related to physical damages — is likely underestimated.
- When you combine the above with multidecade timeframes, the annual investment impacts are invariably relatively small in absolute terms. Focusing on the relativities rather than the actual magnitude will thus be more-informative.
- The scenarios we have used reflect a single pathway for each factor and temperature outcome, when the range of potential pathways is actually quite broad, especially later in the century.
- Similarly, we have used each scenario to modify the expected (mean) return impact on asset classes and portfolios. For want of available probabilistic data on the range of potential temperature and economic outcomes, the impact of climate on asset class and portfolio risk (for example, in terms of standard deviation or credit value at risk [CVAR] of returns) has not been estimated, though this could be significant.

The additional points below are intended to highlight known shortcomings in climate scenario modeling, both in the IAMs and in economic modeling generally, to encourage additional discussions in decision-making.

Physical Impacts of Climate Change

Top down, economy-wide damage functions, which are most often used to estimate the long-term physical impacts of climate change, arguably grossly underestimate the speed/magnitude of physical damages given the way models tend to treat uncertainty, narrowing down wide dispersions and "tail risks" to a more-central thesis, where scientific consensus can be reached. IPCC reports on the physical damages typically exclude the high-uncertainty "feedback loops" that can create climate tipping points, such as permafrost melting and releasing methane.[55] For the Mercer model, in 2019, a bottom-up approach was taken to supplement existing top-down physical impact estimates. Although a bottom-up approach carries benefits (for example, transparency into the peril/region-specific drivers of damage), it also carries drawbacks (for example, very few peril-specific damage functions exist with global consistency, meaning any bottom-up approach is likely to have gaps; also, more research would be needed into the interactions between perils to avoid double counting).

Financial Stability and Insurance "Breakdown"

Estimating physical damage impacts is very important for insurers, and insurance is a central feature of our global economy. Regulators responsible for financial stability are increasingly raising the alarm that there could be systemic failure of the financial system without addressing climate change, with a 4°C world described by one of the world's leading insurers as "uninsurable,"[56] but this is not yet captured in the IAMs.

Costs of Adaptation and Planned Resilience

To date, the focus has been on mitigation actions, but, increasingly, adaptation activities are becoming a reality. Planning to ensure resilience with manageable adaptation costs is already underway, yet the IAMs generally assume adaptation costs come later and outside the typical investor timeframe.

Economic Damages Simplified Into GDP

IAMs generally capture economic damages by focusing on impacts to GDP. The flaws in GDP as a simplistic measure of economic growth and progress are widely discussed in the financial community, with all economic activity, "positive" and "negative" to society, being captured as one figure and therefore masking impacts experienced in reality. It also ignores human well-being, unpaid contributions to society (for example, caregiving), income/wealth distribution and the negative impact of economic growth on the environment.[57]

And then there are the social factors, which are typically difficult to quantify but could exacerbate currently modeled climate change implications:

The impact on population and workforce health — Regional capacity and ability to adapt to changing weather patterns and healthcare needs are key. Many infectious diseases are highly sensitive to climate conditions. Climate change also extends the transmission seasons and expands the geographical extent of many diseases, like malaria and dengue fever. Climate change could also create greater heat stress, making working conditions unbearable in a number of regions.[58]

Migration — Situations caused or heightened by energy, food or water shortages lead to accompanying social and economic impacts and potential political implications or conflicts. The UN Global Compact for Migration, which was adopted by more than 160 countries in December 2018, specifically references climate change as an underlying risk of forced and unsafe migration.[59]

The Mercer climate scenario modeling analyzes climate change in isolation, but these scenarios are not necessarily independent of other economic scenarios and could minimize or exacerbate them. For example, technology and policy developments aiming to reduce air and plastics pollution and establishing "sustainable finance" guidelines will also drive the low-carbon transition but aren't driven by climate change per se. Litigation risks are another consideration not captured in the modeling. Litigation is primarily being targeted at companies for failures to mitigate, adapt or disclose, but there are examples of litigation against governments[60] and, most recently, pension funds.[61]

We have also focused on estimating mean return impacts, whereas the variance around these mean return impacts is likely wide, with a particularly significant negative tail in the hypothetical distribution around the 3ºC and 4ºC outputs. The scenarios modeled are deterministic, which is necessary given the gaps in scientific research and our current understanding of climate change (not to mention the complexity of conducting investment analysis 80 years into the future). However, the interactions are likely to be much more complex than we can ever model.

The financial and scientific community continues to seek to improve upon the models available, using the most recent data points possible. Improved transparency and disclosure will be critical to this endeavor and reinforces the objective of the global Financial Stability Board in establishing the TCFD.

In the interim, acknowledging what cannot yet be quantified is an important part of the thinking needed on climate change. Investors need to consider and prepare for multiple eventualities, rather than relying on a single scenario as most likely or "correct."

What Are the Portfolio Impact Results?

The modeling results have evolved from the 2015 Report; however, the headline messages remain consistent, reinforce the recommendations made at that time and support greater urgency for action to achieve a well-below 2°C scenario. The relative impacts across asset classes and sectors convey a number of key signals for investors to consider in portfolio construction and asset-allocation decisions. Stress-test modeling is also beneficial to demonstrate the potential magnitude of return impacts in the shorter term if changes in policy, market pricing or physical damages are more sudden than currently anticipated.

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A key conclusion is that investing for a 2°C scenario is both an imperative and an opportunity:

- An imperative, since, for nearly all asset classes, regions and timeframes, a 2°C scenario leads to enhanced projected returns versus 3°C or 4°C and therefore a better outcome for investors
- An opportunity, since, although incumbent industries can suffer losses in a 2°C scenario, there are many notable investment opportunities enabled in a low-carbon transition

[iv] In the Sequel, two sample asset allocations were used to illustrate the key findings: 1) the same diversified growth asset allocation introduced in the 2015 Report and 2) a 2019 portfolio that is equivalent to the 2015 portfolio but with explicit allocations to sustainability-themed investments in multiple asset classes. Current limitations in data and methodology available for modeling physical damages, together with the myriad of factors not yet captured and multidecade timeframes, mean the resulting magnitudes are likely to be significantly underestimated and invariably relatively small in absolute terms. The Sequel outlines more on these additional considerations when assessing quantitative results.

The Sequel's highlights include the following:[iv]

1. **The results emphasize the physical damages risks and why a below 2°C scenario is most beneficial**, and the 4°C and 3°C scenarios are to be avoided, from a long-term investor perspective. In the two sample portfolios, there is a return opportunity to 2030 of between 0.10% p.a. and 0.30% p.a. in a 2°C scenario compared to -0.07% p.a. in a 4°C scenario. To 2100, a 4°C scenario leaves each portfolio down more than 0.10% p.a. compared to a 2°C scenario.

2. **Transition opportunities emerge from a 2°C scenario, with transition now expected to be a benefit from a macroeconomic perspective**,[62] including the potential to capture a "low-carbon transition (LCT) premium."[63] Although a 2°C scenario definitely still presents transition risk (especially for portfolios aligned to a 3°C or 4°C+ world), opportunistic investors can target investment in the many mitigation and adaptation solutions required for a transformative transition. In the two sample portfolios, the sustainability-themed version is nearly 0.20% p.a. better off to 2030.

3. **Expected annual return impacts remain most visible at an industry-sector level, with significant variations by scenario**, particularly for energy, utilities, consumer staples and telecoms. Asset class returns can also vary significantly by scenario, with infrastructure, property and equities being the most notable. Variations in results between asset classes and across regions, cumulative impacts, and the emphasis on sustainable opportunities provide multiple portfolio construction possibilities for investors.

Example industry sectors and asset classes	% p.a. to 2030 in 2°C scenario	% p.a. to 2050 in 2°C scenario	% cumulative impact to 2030 in 2°C scenario	% cumulative impact to 2050 in 2°C scenario
Coal	-7.1	-8.9	-58.9	-100.0*
Oil and gas	-4.5	-8.9	-42.1	-95.1
Renewables	+6.2	+3.3	+105.9	+177.9
Electric utilities	-4.1	-3.3	-39.2	-65.7
Developed market equities	0.0	-0.2	-0.5	-5.6
Emerging market equities	+0.2	-0.1	+1.8	-4.0
All world equities — sustainability themed	+1.6	+0.9	+21.2	+32.0
Infrastructure	+2.0	+1.0	+26.4	+39.4
Infrastructure — sustainability themed	+3.0	+1.6	+42.3	+67.1
All world real estate	0.0	-0.2	-0.1	-4.7

* Effective absolute loss of value is expected to occur in 2041 under a scenario in which global warming is limited to 2°C by 2100.

In a 2°C scenario by 2050, there are minor positives as well for materials, telecoms and consumer staples sectors. In 3°C and 4°C scenarios, all sectors, apart from renewables, have negative return impacts, to 2030, 2050 and 2100, with return impacts varying between 0.1% p.a.and 7.7% p.a.[v]

Real estate is expected to be flat to 2030 under a 2°C scenario, but a 4°C scenario, even in the near term, starts to impact negatively. A 4°C scenario to 2050 sees infrastructure and property down 0.4% p.a. and 0.2% p.a., respectively, developed market equities are down 0.1% p.a. and emerging markets are down 0.3% p.a. In a 4°C scenario, India and China equities are down 0.4% p.a. and 0.3% p.a., respectively. Sovereign debt provides a safe haven and marginally positive results, with fixed income continuing to remain relatively muted overall, with some variations within the asset class.

4. **In reality, sudden changes in return impacts are more likely than neat, annual averages, so stress testing is an important tool in preparing for this eventuality**. Stress testing portfolios for changes in view on scenario probability, market awareness and physical damage impacts can help investors to consider how longer-term return impacts that may appear small on an annual basis could emerge as more-meaningful shorter-term market repricing events.

   Testing an increased probability of a 2°C scenario with increased market awareness can result in sector-level returns where renewables increase by more than 100% and coal decreases by nearly 50%. Positive asset class impacts include infrastructure at almost 23% and sustainable equity at more than 5%. Testing an increased probability of a 2°C scenario or a 4°C scenario with greater market awareness, even for the modeled diversified portfolios, results in +3% to -3% return impacts in less than a year.

What's Next for Investors?

The findings strengthen the argument for investor action on climate change and suggest greater attention is required on how investors will actively support the transition to a 2°C scenario — as Future Makers as opposed to Future Takers.

The recommended Investor Actions from the 2015 Report remain valid — to incorporate climate change considerations as part of good governance and investment decision-making — and are consistent with the 2017 TCFD recommendations. We include several investor case studies, which reinforce how scenario analysis helps prioritize the portfolio risks for some and opportunities for others. The case studies also demonstrate the pace of change by peers.

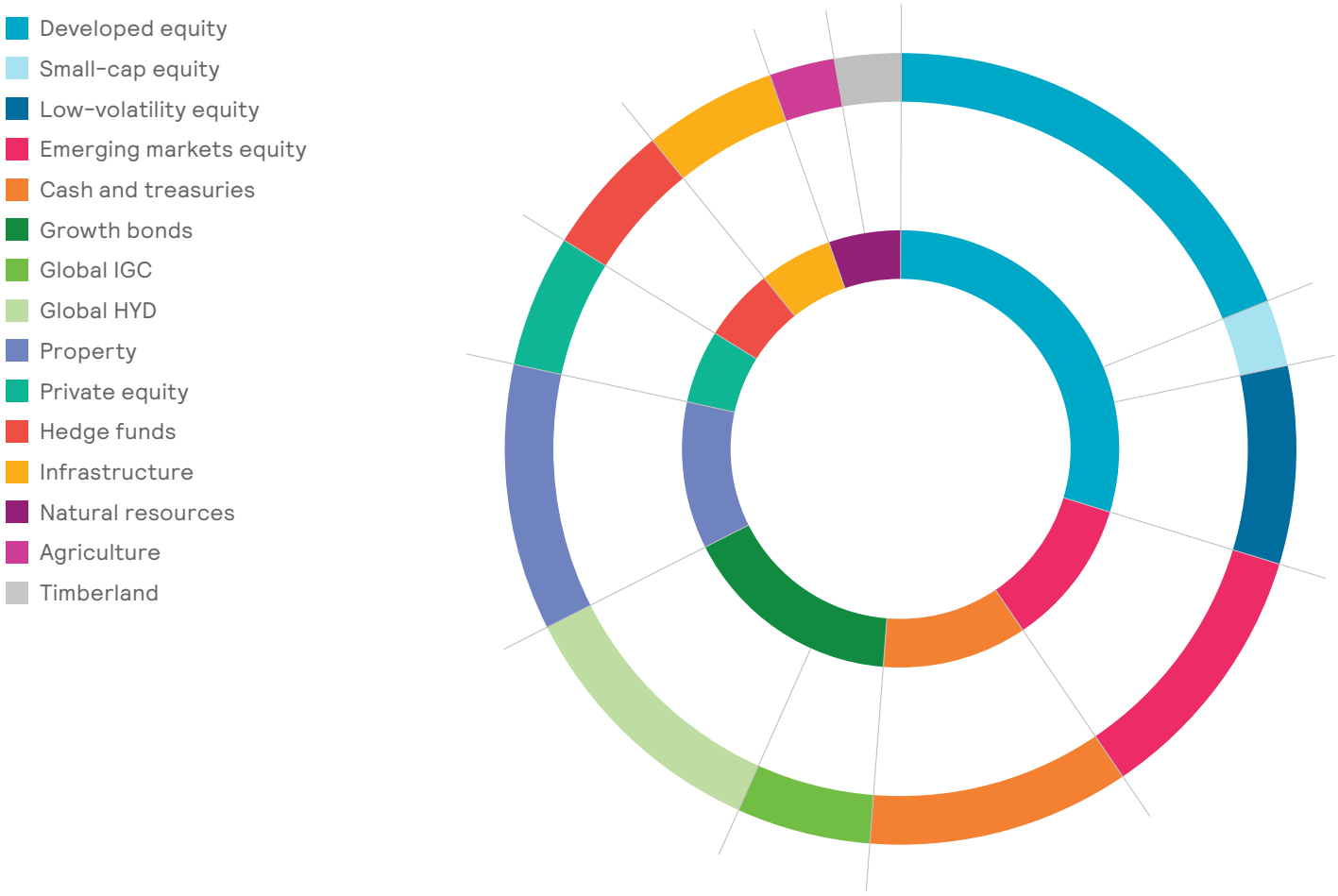
Consistent with Mercer's thinking on the best way to incorporate ESG and climate change considerations into the investment process, we continue to recommend an integrated approach when setting investment beliefs, policies and processes, and when constructing and managing portfolios, as set out in Mercer's *Responsible Investment Pathway.* This enables climate-related risks and opportunities to be included alongside other investment considerations and for processes and portfolios to evolve over time — grounded in agreed-upon beliefs and policies.

[v] The strongly negative impacts reflect sectors that are required to essentially discontinue by 2050. Therefore, return would be driven more by the income received within that time period, and this income is not allowed for in these figures.

Results Case Studies

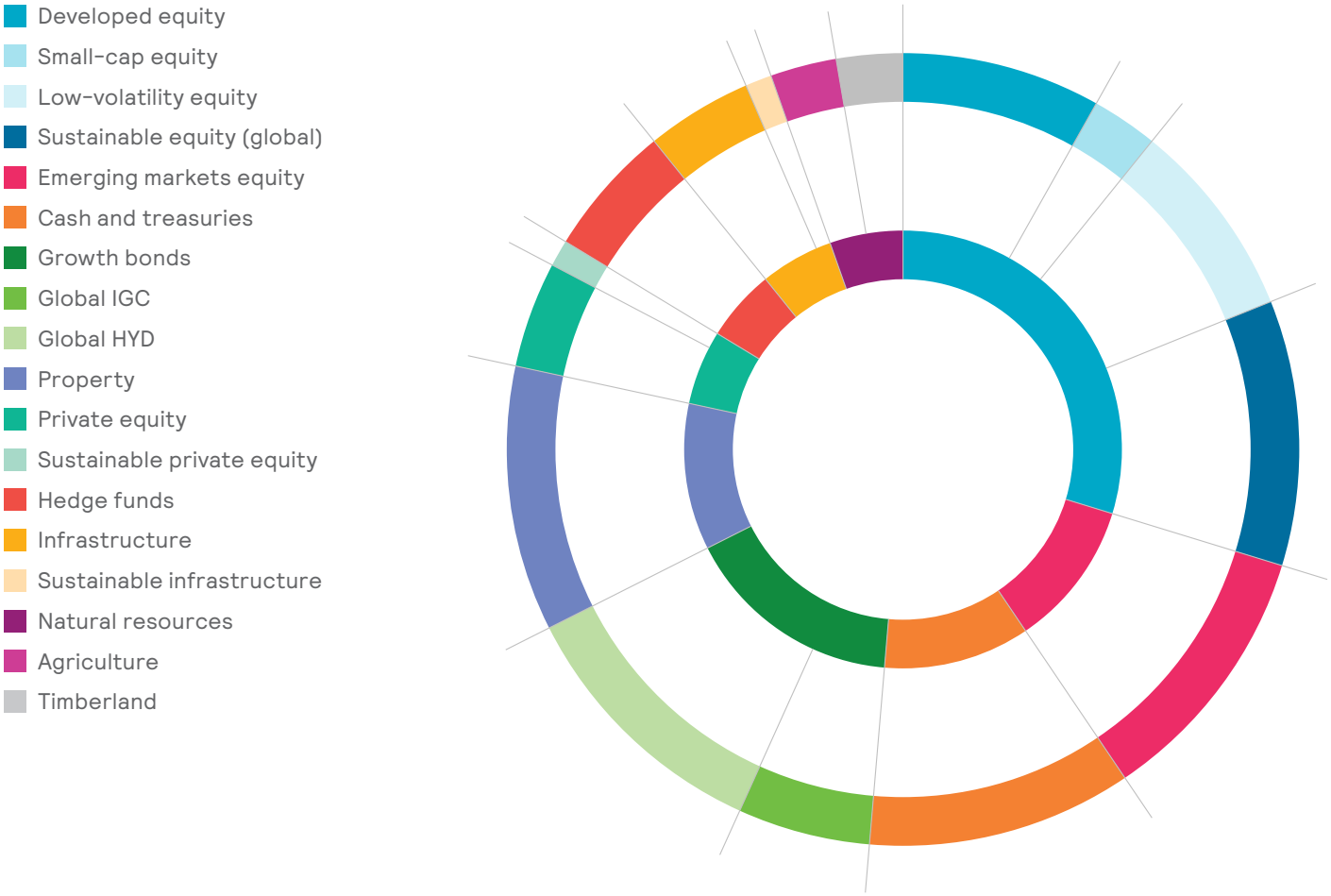
The results in this section show the outcomes of the scenario modeling approaches using two sample asset allocations: 1) the same diversified growth asset allocation introduced in the 2015 Report and 2) a 2019 portfolio that is equivalent to the 2015 portfolio but with explicit allocations to sustainability-themed investments in multiple asset classes.

Figure 9. #1 Portfolio — Growth



Source: Mercer

Figure 10. #2 Portfolio — Sustainable Growth



Source: Mercer

Recognizing the many challenges to long-term investment, we believe it is important that post-2030 climate implications be considered, recognizing the physical damage impacts to come. The stress-testing analysis assesses how longer-term return impacts could manifest as market-pricing events.

Total Portfolio Results

The expected annual climate impact on return for both sample portfolios is shown below over three climate scenarios and three time periods (nine results per portfolio). The aim is to extend investment decision-making to include factors regularly outside the investment time horizon with 2100 and 2050 observations and reflect those against the more-strategic investment horizon to 2030.

Recognizing the many challenges to long-term investment, we believe it is important that post-2030 climate implications be considered, recognizing the physical damage impacts to come. The stress-testing analysis assesses how longer-term return impacts could manifest as market-pricing events.

Figure 11. Annualized Total Portfolio Results

Source: Mercer

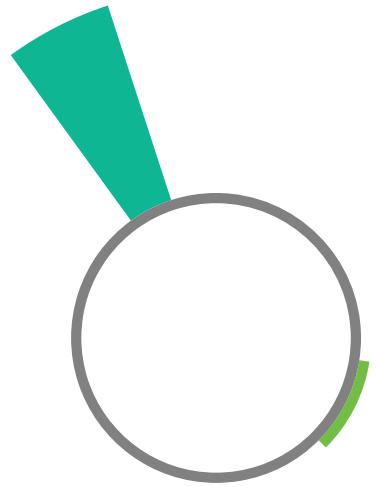
For both portfolios, the 2°C scenario has the best outcome, and the 4°C has the worst outcome across all three timeframes evaluated. The allocation to sustainability-themed asset classes enhances the return outcome of the 2019 portfolio in the 2°C and 3°C scenarios but has no noticeable effect in 4°C. This poor hedging benefit from sustainability allocations in 4°C speaks to the challenge of adapting to significant changes in weather patterns and the lack of adaptation-focused investment opportunities in the market today.[64]

Asset Class Results

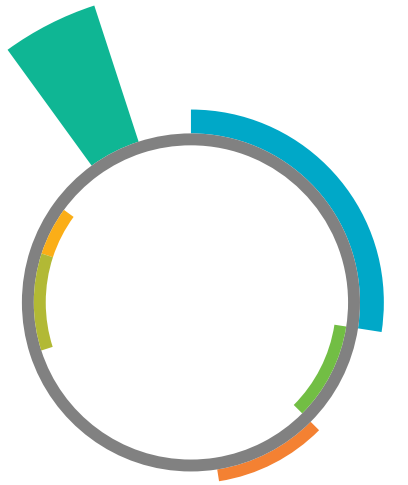
In the "circle charts" in Figures 12 and 13 on the following pages, each circle represents the total asset allocation, with the sizes of each asset class section equivalent to the weighting in the portfolio. If the asset class section is within the circle, it represents a negative impact on return, whereas if the asset class section is sitting outside the circle, it represents a positive impact on expected returns. Note, some of the sub-asset classes (for example, within equities) have been grouped to simplify visual representation.

Figure 12. Asset Class Return Impacts to 2030 and 2050 in the 2°C Scenario

	Growth Portfolio	Sustainable Growth Portfolio
to 2030	2°C	2°C



to 2050	2°C	2°C

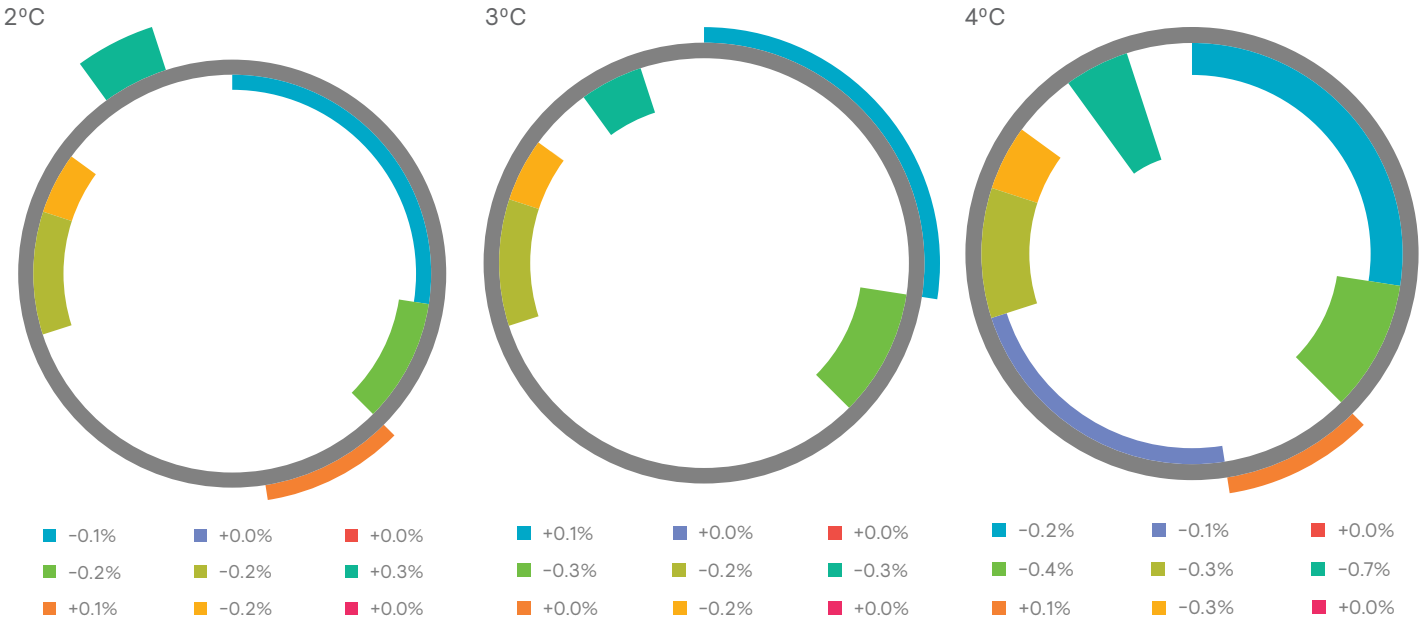


- Developed equity
- Emerging markets equity
- Cash and treasuries
- Growth bonds
- Property
- Private equity
- Hedge funds
- Infrastructure
- Natural resources

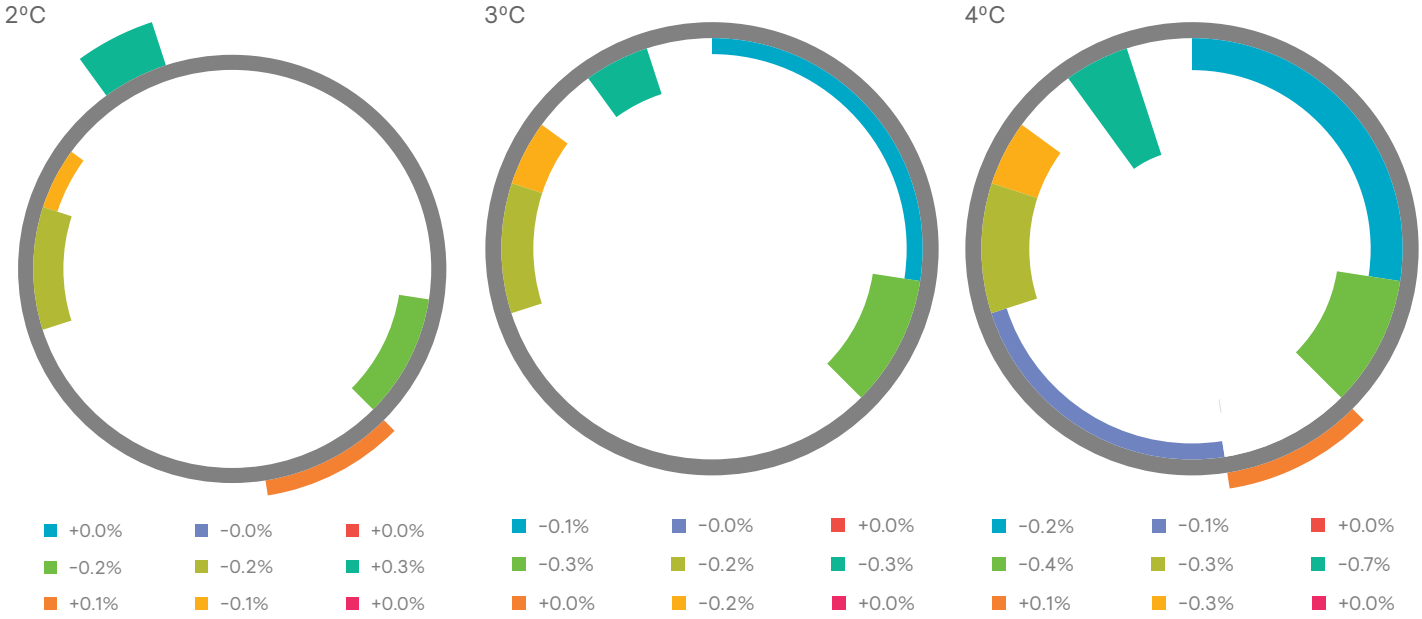
Source: Mercer

Figure 13. Asset Class Return Impacts to 2100 Across All Scenarios

Growth Portfolio



Sustainable Growth Portfolio



Developed equity
Emerging markets equity
Cash and treasuries
Growth bonds
Property
Private equity
Hedge funds
Infrastructure
Natural resources

Source: Mercer

The risk factors as acronyms symbolize the following: S = spending, T2= 2°C transition, T3 = 3°C transition, I = impact of natural catastrophes and R= resource availability. This table is over the 2100 timeframe. Over a shorter timeframe, the S would be more sensitive and the I and the R would be less sensitive. The relative ranges are applied to the asset classes included within this table only and are not designed to be directly compared with relative ranges in other similar tables.

Figure 14. Relative Sensitivities — Asset Classes

Asset class	S	T2	T3	I	R
Developed market global equity					
Emerging market equity					
Developed market sovereign bonds					
Investment-grade credit					
Emerging market debt (sovereign)					
High-yield debt					
Real estate					
Private equity					
Infrastructure					
Timberland					
Agriculture					
Hedge funds					

Most negative			No sensitivity			Most positive		

Source: Mercer

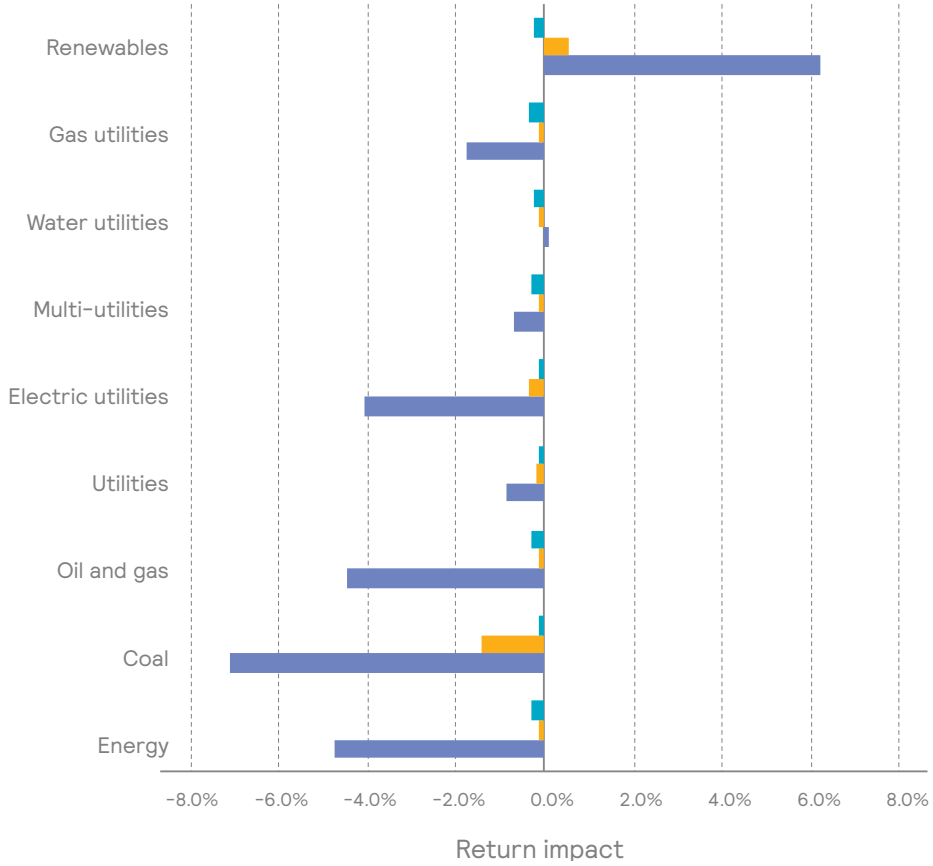
The highlights, in summary, are:

- **Equities:** At an aggregate level, global developed market equities are now expected to be much less negatively impacted by the low-carbon transition than anticipated in 2015. The government stimulus required to achieve a 2°C scenario creates an opportunistic investment environment in the near term balanced out over time by the requirement to service stimulative debt. That said, on a relative basis, sustainability-themed equity is expected to benefit even further from a low-carbon transition, and emerging market equities are still expected to benefit from additional climate-finance support from developed countries, as established in the Paris Agreement and reinforced in subsequent United Nations meetings.
- **Bonds:** Emerging market debt and high-yield debt are most sensitive to the climate change risk factors within global fixed income as an asset class. Although, in contrast to 2015, we now expect the depressive macroeconomic effect of climate change to lead to interest-rate decreases and therefore price and return increases in most debt asset classes irrespective of scenario. We do not expect developed market sovereign bonds to be sensitive to the climate change risk factors at an aggregate level, but there are some sovereigns that we would expect to be more sensitive to the impact of physical damages and resource scarcity, such as Australia and New Zealand.
- **Real assets:** Real estate, infrastructure, agriculture and timberland have the greatest negative sensitivity to the impact of physical damages and resource availability, but infrastructure has a high positive exposure to transition risk, due primarily to expected exposure to renewable assets in most infrastructure allocations. We note that the sensitivity to the climate change risk factors will vary by underlying sector. More-stringent climate change policy (and investment in technology) is likely to reduce the value of some assets that are less-advanced or unable to adapt, whereas others will benefit strongly. Overall, we would expect more-stringent climate change policy to be a net positive for infrastructure, as policy changes should drive an extended period of significant economic transformation and investment globally.
- **Liquid alternatives:** We do not expect hedge funds, in aggregate, to be sensitive to the climate change risk factors, but long/short equity funds, commodities and insurance-linked securities (ILS) will not be immune.

Industry Sector Results

Figures 15 and 16 show the annualized return impact to 2030 and 2050 for each sector across the three climate scenarios. Note, the energy sector is an aggregation of the coal sector and the oil and gas sector. Renewables sit within utilities, which is a change since the 2015 Report reflecting classification developments for renewables.

Figure 15. Sector-Level Return Impacts to 2030

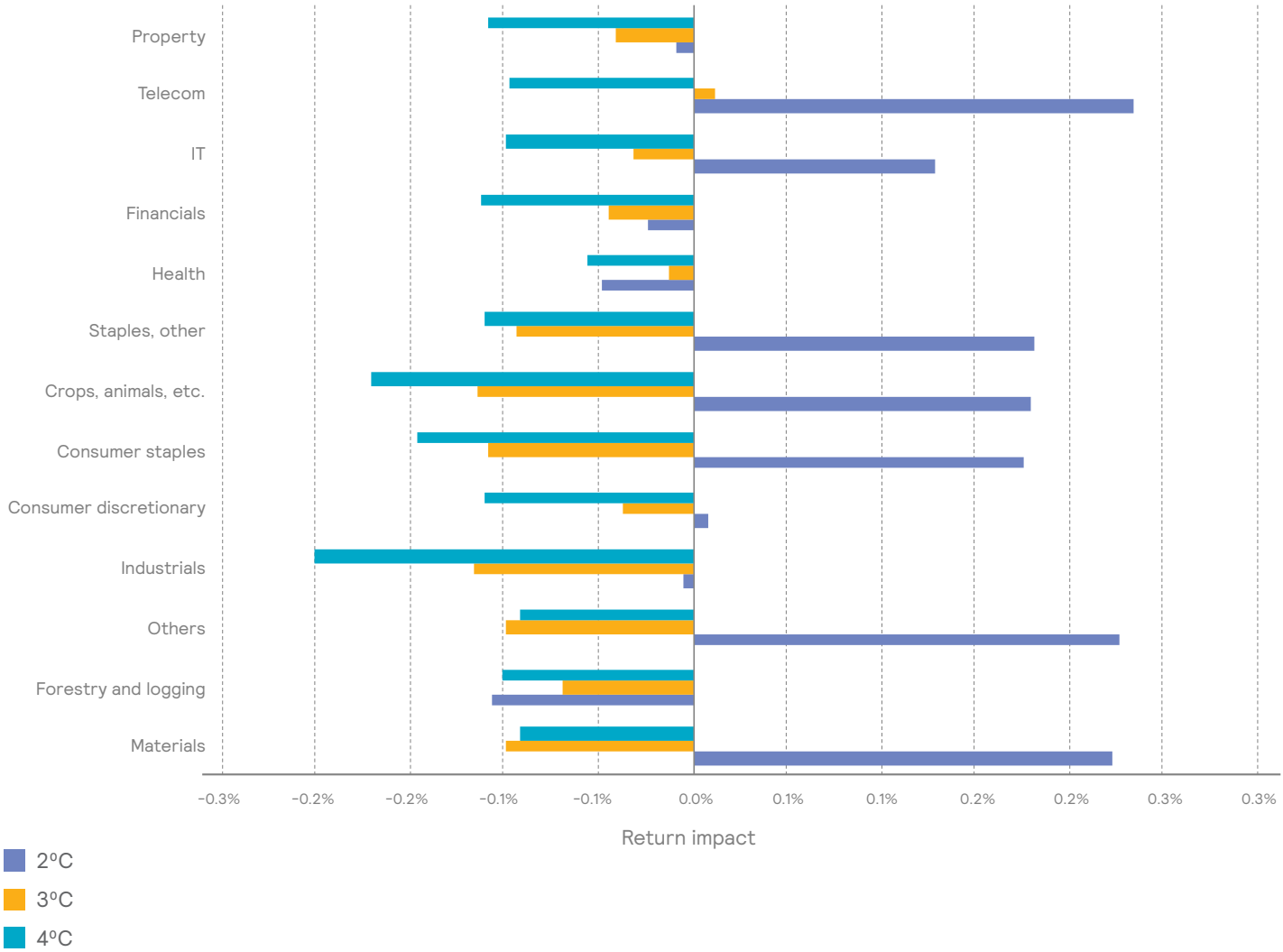


2ºC
3ºC
4ºC

Source: Mercer

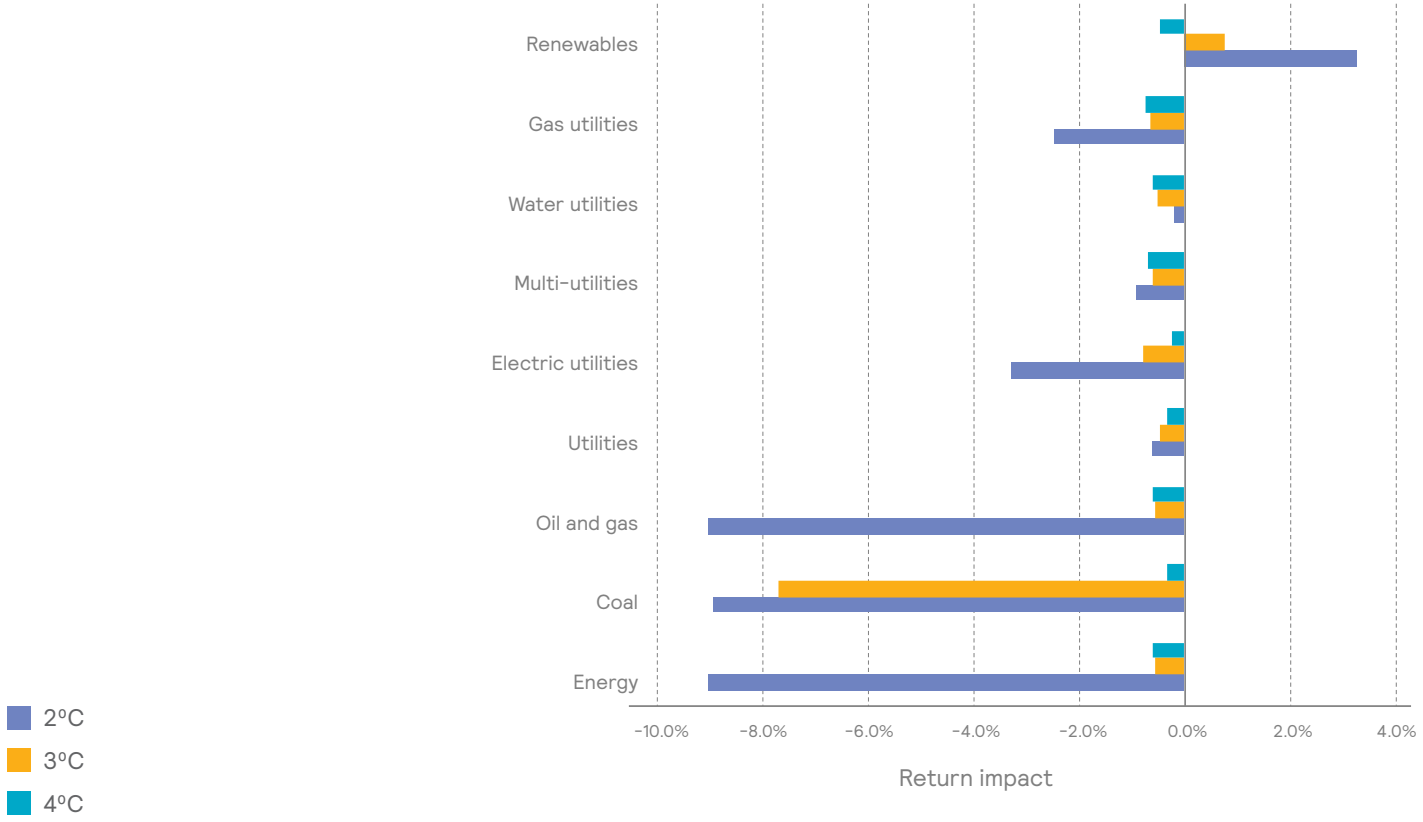
An equivalent chart, with energy and utilities removed, is included below to help illustrate the scale differences of the other sectors more clearly.

Figure 16. Sector-Level Return Impacts to 2030 (Ex Energy and Utilities)



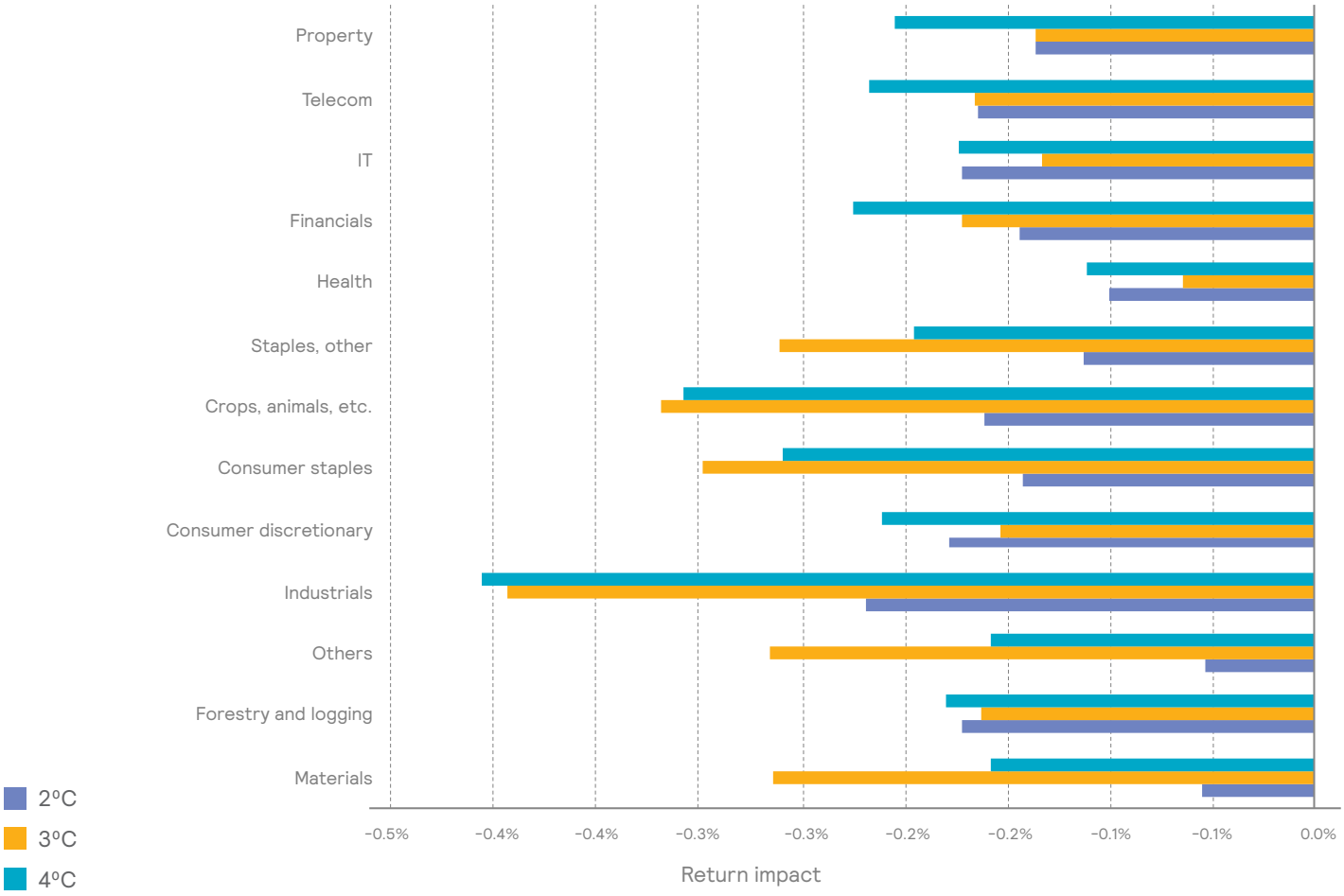
Source: Mercer

Figure 17. Sector-Level Return Impacts to 2050 — Energy and Utilities



Source: Mercer

Figure 18. Sector-Level Return Impacts to 2050 (Ex Energy and Utilities)



Source: Mercer

The risk factors as acronyms symbolize the following: S = spending, T2= 2°C transition, T3 = 3°C transition, I = impact of natural catastrophes and R= resource availability. This table is over the 2100 timeframe. Over a shorter timeframe, the S would be more sensitive and the I and the R would be less sensitive. The relative ranges are applied to the asset classes included within this table only and are not designed to be directly compared with relative ranges in other similar tables.

*The sensitivity to the R factor for water utilities is not directly drawn only from the modeling outputs but reflects the high sensitivity expected to lower water availability.

Figure 19. Relative Sensitivities — Equity Industry Sectors

Equity industry/subsector	S	T2	T3	I	R
Energy					
Oil and gas					
Coal					
Utilities					
Renewables utilities					
Electric utilities					
Gas utilities					
Multi-utilities					
Water utilities*					
Materials					
Forestry and logging					
Industrials					
Consumer discretionary					
Consumer staples					
Crops and animals					
Health					
Financials					
IT					
Telecoms					
Real estate					

Most negative			No sensitivity			Most positive		

Source: Mercer

The highlights are:

Unsurprisingly, transition risk sensitivity is most negative for the energy sector, coal more so than oil and gas, and electric and gas utilities. This sensitivity is greatest in a 2°C scenario. Renewables have the most positive transition sensitivity, even in a 3°C scenario.

Physical risk sensitivity is most negative for utilities and energy, but some sensitivity is relatively widespread across sectors, including industrials, telecoms, financials, and consumer staples and consumer discretionary.

Within each sector, there will be “winners and losers” at a stock level, including those sectors where overall sensitivity is expected to be neutral.

Stress-Testing Results

Stress testing considers how longer-term return impacts could manifest as market-pricing events, reflecting how markets may respond to new climate-related information. The key aim of stress testing, by definition, is to put pressure on the average annual impacts and gain insights from outcomes that may deviate from the relatively orderly pathways our scenarios assume.

Mercer's stress tests consider the impact of a short-term market repricing event, where a catalyst of some sort (for example, new regulatory requirements, change of investor focus or a surprise election result) causes the market to change how it incorporates long-term climate change risk in asset pricing. The model can consider changes in:

- Awareness — the degree to which the market allows for expected impacts
- Scenario probabilities — the likelihood the market applies to a given temperature outcome
- Damage function — the impact of different expectations on the extent and shape of physical damages

Mercer does not believe markets are fully pricing in climate change for a variety of reasons, including:

- **The tragedy of horizons:** Time horizon mismatches across the capital markets value chain present long-term asset owners with both a challenge and an opportunity.
- **Complexity and uncertainty:** Uncertainty regarding the global pathway toward a given temperature outcome also causes confusion about which risks are likely to manifest when.
- **Pricing failures:** Carbon pricing is still too low to reflect the full social cost of emissions and send a meaningful signal to the market; therefore, they remain as "externalities" not captured in valuations.
- **Behavioral economics:** Research in behavioral economics points to the inability of humans to properly account for the effects of future risks, especially those that are large and infrequent. This relates to prospect theory, hyperbolic discounting and other behavioral economics concepts that are well-studied.[65]
- **Peer practices:** To date, a low proportion of institutional investors have adopted climate change risk management strategies. As peer practices are a key input for many investors' decisions, this can have a depressive effect on market behavior until norms shift over time.

Figure 20. First Portfolio Stress Test

Stress Test #1

Tests the potential market reaction to a sudden shift (greater awareness) in the likelihood of a 2ºC scenario outcome by changing:

- The current pathway of 3.3˚C, as per the Climate Action Tracker, to a 100% probability of 2ºC
- The current market awareness of climate-related financial risks from 20% to 80%

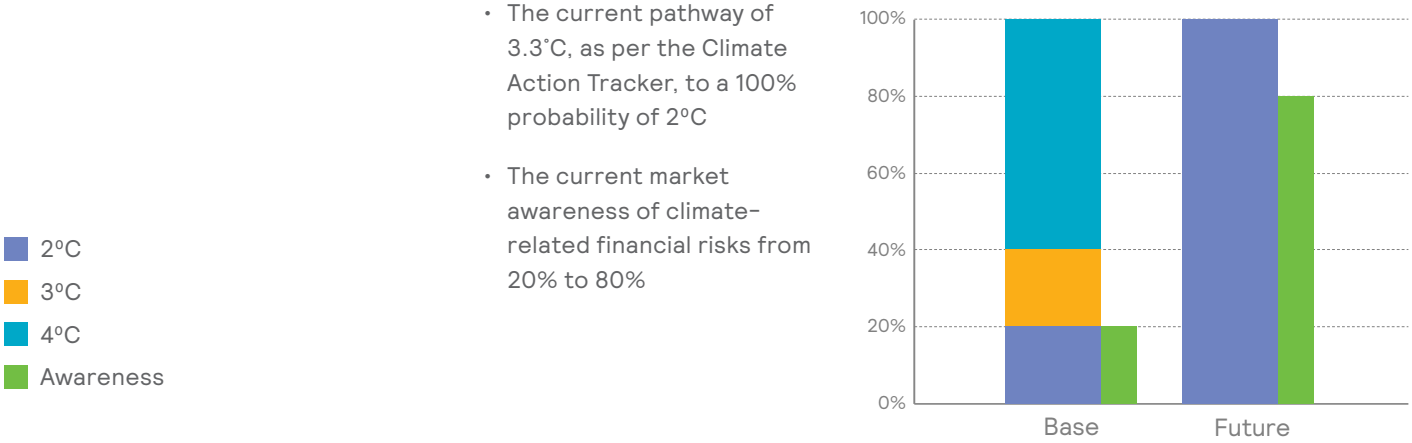
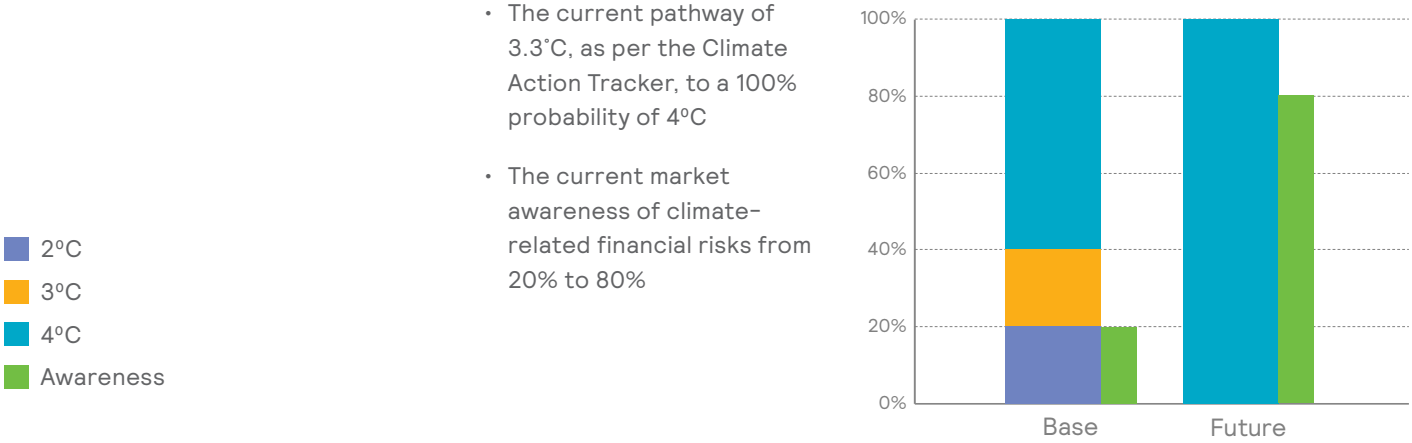


Figure 21. Second Portfolio Stress Test

Stress Test #2

Tests the potential market reaction to a sudden shift (greater awareness) in the likelihood of a 4ºC scenario outcome by changing:

- The current pathway of 3.3˚C, as per the Climate Action Tracker, to a 100% probability of 4ºC
- The current market awareness of climate-related financial risks from 20% to 80%



The return figures in this section are not annualized but instead show a single-point-in-time impact over less than a year, illustrating an alternative view of how return impacts could be experienced in practice. Example return results for these two tests are shown for key sectors in Figures 22 and 23 and for the growth and sustainable growth portfolios in Figures 24–27.

Figure 22. Stress Test #1 Key Sectors

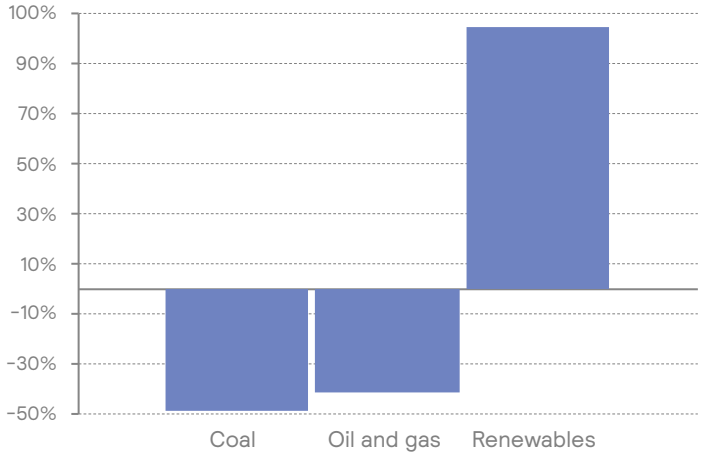
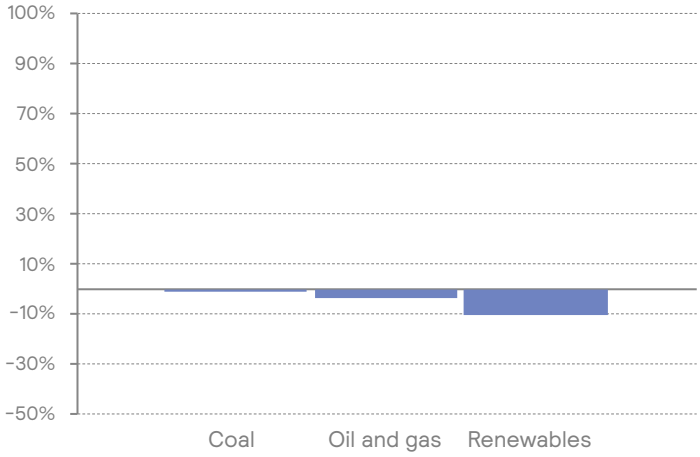


Figure 23. Stress Test #2 Key Sectors



Source: Mercer

Figure 24. Stress Test #1 Growth

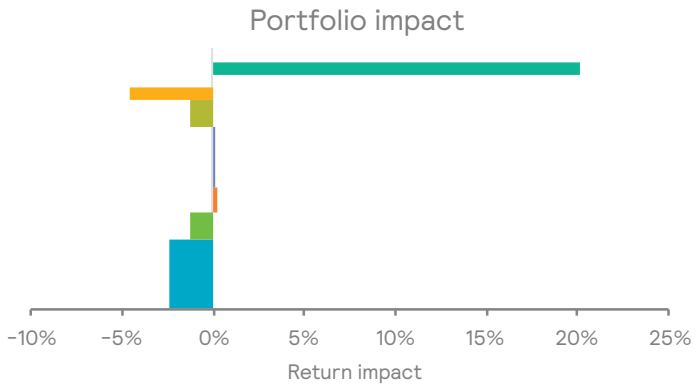


Figure 25. Stress Test #2 Growth

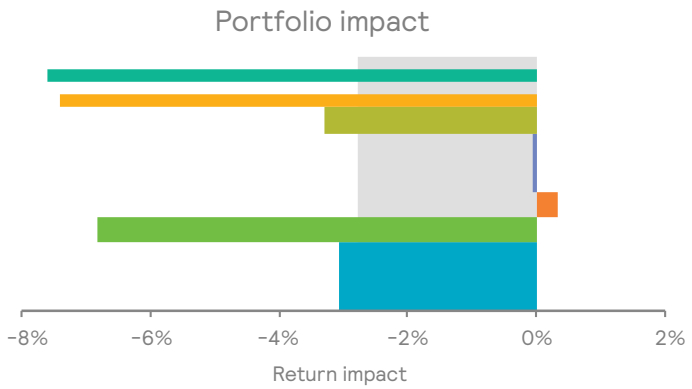


Figure 26. Stress Test #1 Sustainable Growth

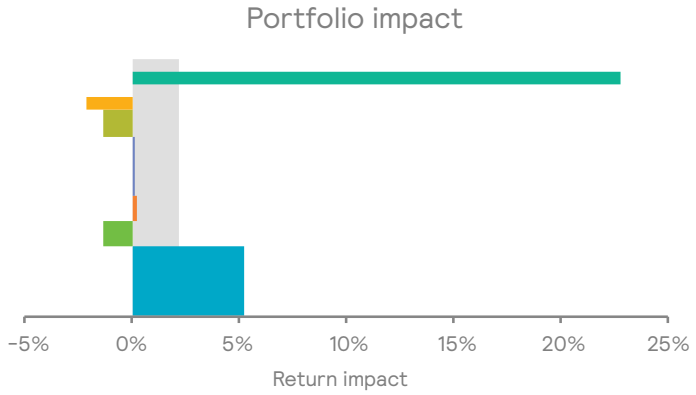
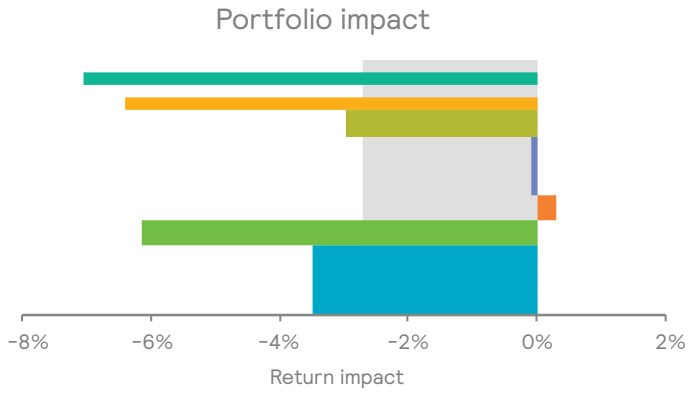


Figure 27. Stress Test #2 Sustainable Growth



- Developed equity
- Emerging markets equity
- Cash and treasuries
- Growth bonds
- Property
- Private equity
- Hedge funds
- Infrastructure
- Natural resources
- Total portfolio

Source: Mercer

Mercer expects stress-test analysis will support discussion among decision makers to agree on next steps. For example, decision makers may hold differing views on the relative likelihood of an increase in market awareness, scenario probability and the timing of impacts. A 2ºC scenario will require a strong and coordinated policy response; some consider this response to be inevitable but with uncertain timing.[66] The next flashpoint for such a response could be as early as 2020, when governments are due to resubmit their nationally determined contributions (NDCs) as part of the Paris Agreement, or perhaps 2023, when the first global stocktaking occurs. Over time, policy inertia could, of course, see a drift to a 4ºC scenario and the greater likelihood of physical damage impacts emerging. This may still result in a sudden and disruptive policy response to mitigate future physical damages even if a 2ºC scenario result becomes unlikely to eventuate.

When using stress tests with clients, we often present the impact of opposite changes; for example, increasing or decreasing awareness. This illustrates that for all asset classes, there are potential positive and negative climate-related scenarios. However, overlaying an opinion on the likelihood of those developments gives greater insight. For example, we view increasing climate awareness in market pricing to be more likely than decreasing awareness. This therefore provides support to the concept of an LCT premium.

Asset Class Feature Focus — Sustainability-Themed Allocations

Since the 2015 Report, "sustainable" variants of global equity, private equity, infrastructure and bonds have been added to the modeling options. This enables investors to compare how different portfolio allocations may respond in each climate change scenario and consider portfolio implementation changes. This section provides additional context and clarification on the term "sustainable" and gives some opportunity-set examples.

In its simplest form, sustainability is literally "the ability to sustain." The most widely accepted definition is that "which meets the needs of current generations without compromising the ability of future generations to meet their own needs," from the 1987 Brundtland report for the UN on sustainable development.[67] Population growth and consumption patterns are placing unsustainable pressures on the world's finite resources. Aging infrastructure, pollution levels and environmental damage to human health are also reducing the value of economic activity and raising the importance of sustainability as a topic.

The 2015 UN Sustainable Development Goals for 2030 include 17 goals and 169 Key Performance Indicators. Climate change is a sustainability issue that connects to many other location-specific challenges that aren't driven by climate change but may be exacerbated by it. Climate change has its own Goal 13 but is also explicitly connected to Goal 7 and implicitly to all other goals.

Figure 28. The Sustainable Development Goals

Source: United Nations Sustainable Development Goals, available at http://www.un.org/sustainabledevelopment/sustainable-development-goals.

At Mercer, we believe an investment approach that includes ESG factors and incorporates consideration of broader systemic issues, such as climate change and sustainable development, along with active ownership (stewardship), is more likely to lead to sustainable investment outcomes and enable stakeholder objectives to be met. In practice, this can mean investors focusing on allocating to Mercer's higher-ESG-rated strategies, using active ownership techniques to support changes in company management practices (for example, voting and engagement) and/or allocating to sustainability-themed strategies.

The Investment Case

The demand being created by the environmental and social challenges we're facing is fundamental to the investment case. As an investment theme, sustainability aims to identify the growth in companies that provide solutions to immediate challenges driven by changes in public sentiment, technology, resource constraints and the evolving policy response.

Following the 2015 Paris Agreement, policy changes expected to ultimately raise carbon prices pose the risk of negative financial outcomes and even the potential for "stranded assets"; that is, the possibility that a proportion of existing fossil fuel reserves will never be utilized due to changes in regulation, demand and technology. Accordingly, investors are increasingly focused on "low-carbon" portfolios specific to climate-related policy risks alongside portfolios more resilient to physical damage impacts and opportunities aligned with anticipated shifts in energy and resource use.

Market participants with a specialist sustainability focus and expertise typically better understand the market and the often-disruptive new dynamics. This is amplified by timeframe biases in the traditional marketplace, which relies on historical models and still assumes sustainability developments are further into the future than is actually the case. We expect these aspects to create a potential information advantage that could generate additional risk-adjusted returns over time.

The sustainability-themed equivalents in the Sequel differ only in terms of their climate change sensitivities, which determine the quantum of the LCT premium we believe exists in the context of a 2°C scenario or a scenario getting meaningfully closer to 2°C than our current trajectory. The underlying asset fundamentals remain the same, and the ongoing risk/return profile of the asset class is not expected to be different. As with all investments, it will still require good asset management skills to identify the "winners."

The LCT premium in lower warming scenarios is not equivalent to other investment-risk factors (for example, inflation, liquidity) that would apply across scenarios. It also cannot be calculated historically, as it is based on forward-looking assumptions. Our assumptions suggest an asymmetric assessment of carbon-risk pricing — either it is priced in or it is mispriced, and fossil-fuel-exposed stocks will underperform over time. This positioning is deliberate, as, on balance, we think it is more likely that carbon risk is underpriced today than either fairly priced or overpriced. However, we recognize there is a lack of consensus on the extent to which markets are pricing long-term risks like climate change in valuations today. We also appreciate that the fixed costs associated with transitioning portfolios need to be factored in and will vary on a case-by-case basis. It can also take time to review the investable products available and execute the portfolio transition.[68]

The risk factors as acronyms symbolize the following: S = spending, T2= 2°C transition, T3 = 3°C transition, I = impact of natural catastrophes and R= resource availability. This table is over the 2100 timeframe. Over a shorter timeframe the S would be more sensitive and the I and the R would be less sensitive. The relative ranges are applied to the asset classes included within this table only, and are not designed to be directly compared with relative ranges in other similar tables.

Figure 29. Relative Sensitivities — Sustainability Themed

Asset classes	S	T2	T3	I	R
Developed market global equity					
Sustainable equity (global)					
Low-carbon equity (global)					
Fossil-fuel-free equity (global)					
Developed market sovereign bonds					
Investment-grade credit					
Global green bonds					
Infrastructure					
Sustainable infrastructure					
Private equity					
Sustainable private equity					

Most negative			No sensitivity			Most positive		

Source: Mercer

The Opportunity Set

Private markets typically provide the best access to environmental themes that are all directly connected to climate change, including: renewable and alternative energy, energy efficiency, water infrastructure and technologies, pollution control, waste management and technologies, environmental support services and sustainable resource management. Listed equities can also provide access to some of these, together with broader sustainability themes, including health and financial services as "social" themes. Access via listed or unlisted options will depend on the usual client considerations, such as timeframes, liquidity, fee budgets, current portfolio diversification and accessibility of the themes.

Asset class	Description
Low-carbon equity	Low-carbon equities, active and passive, are expected to insulate portfolios from stranded asset risk in a low-carbon economic transition, with very-low tracking error versus parent indices. They are focused solely on minimizing policy-related risk, typically by reducing exposure to both high-carbon emitters (for example, utilities) and fossil fuel reserve owners (for example, oil and gas majors).
Fossil-fuel-free equity	Fossil-fuel-free (FFF) equities (defined here as excluding fossil fuel reserve owners), active and passive, are also expected to insulate portfolios from stranded asset risk in a low-carbon economic transition, though this risk-protection benefit is expected to be less-reliable than a low-carbon approach, since an FFF portfolio maintains exposure to high-carbon emitters. Tracking error may also be higher depending on the reweighting mechanisms used.
Sustainable public equity	Sustainable equities, primarily accessible in active strategies, are expected to be well-positioned from a policy point of view but also capture upside from a low-carbon transition through greater exposure to solutions providers.
Sustainable private equity	Sustainable private equity is a mixture of venture, growth and buyout funds focused on investments in companies with significant technology risks and exposure primarily to environmental themes. Funds may be generalist sustainability managers or sector-focused (for example, food and agriculture).
Sustainable infrastructure	Sustainable infrastructure consists of a broad range of projects and solutions, including renewable energy, that would be expected to benefit from clean technological innovation and strong policy action to combat emissions. Similarly, sustainable infrastructure would benefit by avoiding exposure to assets that may become stranded in a low-carbon transition and/or focusing on retrofitting assets to be climate-resilient.
Green bonds	The green bond market is currently dominated by government/supranational issuances, but more corporate issuance is expected going forward. Corporate green bonds will be issued by organizations that have, in general, proactive climate risk management practices overall and thus may be less susceptible to climate-related default risk. However, on balance, fundamental risks like credit quality and interest rates are likely to dominate, making our expectations of green bonds the same as for typical global-investment-grade debt.

Source: Mercer

The table below provides some context on the opportunity set within Mercer's Global Investment Manager Database (GIMD), including the progress on integrating ESG factors and the availability of sustainability-themed strategies. In a number of asset classes, real estate is an example, higher ESG integration can be more "sustainable," but this is not the same as explicitly targeting sustainability themes to drive opportunities. We have labels within GIMD for those explicit strategies, and some guidance on their relative availability compared to mainstream counterparts is summarized below. It is worth highlighting that equities are relative to a very large universe.

Figure 30. Mercer's View on ESG Integration Progress and Availability of Sustainability Strategies by Asset Class

	Manager progress on ESG integration*	Availability of sustainability-themed strategies**
Public equity (active)	Medium/high	Low/medium
Fixed income	Low/medium	Low
Real estate	Medium/high	Low
Private equity and debt	Medium	Low/medium
Infrastructure	High	Medium/high
Natural resources***	Medium	Medium/high
Hedge funds	Low	Low

Note: Low: < 5%; low/medium: 5%-10%; medium: 11%-20%; medium/high: 21%-40%; high: > 40% (as of December 2018),
* Refers to the percent distribution of ESG1- and ESG2-rated strategies in GIMD, where available.
** Refers to the percent distribution of sustainability-themed strategies compared to the asset class universe — noting equities is a large universe, so the low relative number is not actually a low absolute number.
*** Conservative view — research updates in this asset class may result in a more favorable view than is currently held.

Source: Mercer

We are confident there are enough current and new opportunities emerging in sustainability-themed assets globally to increase exposure in portfolios to such assets. "Sustainability Is Gaining Momentum" is one of Mercer's four Themes and Opportunities in 2019 for this very reason. Some examples are highlighted below.

Sustainable Infrastructure

Investment in infrastructure is widely recognized as crucial to promoting economic growth and social stability through the delivery of essential services and assets. As the global population grows and urbanizes, the demand for infrastructure grows with it. The New Climate Economy estimates that from 2015 to 2030, the global requirement for new infrastructure assets will be US$90 trillion, more than the value of the world's existing infrastructure stock.[69] Current infrastructure spending of US$2.5 trillion to US$3.5 trillion per year across both the public and private sectors is only about half the amount needed to meet the estimated US$6 trillion annual infrastructure demand.[70]

To achieve the ambitions of the Paris Agreement and the Sustainable Development Goals, new infrastructure must be sustainable, low-carbon and climate-resilient. Although this could increase upfront capital costs by roughly 5%, sustainable infrastructure can also generate lower operating costs over the life of the investment while also reducing risks and negative externalities and therefore making it more resilient and likely to have a longer life.[71] Since many long-lasting infrastructure assets are being built today, the imperative for incorporating such sustainability considerations into related investment decisions is a current one.

Investor interest in infrastructure is driven by a combination of factors, such as low yields in traditional asset classes, the potential for low correlations to other asset classes, stable cash yield, inflation protection and investment performance throughout the whole economic cycle. Together, these should be positively reinforcing developments. However, many investors still haven't developed a formal approach to sustainable infrastructure.[72]

Low-Carbon Indices

Several significant institutional investors have implemented low-carbon equity index investment strategies, and the general popularity of low-carbon indexing as a climate risk management strategy has grown worldwide. The reasons for the relative success of this strategy are many, though they likely include the following:

- Carbon data, while knowingly flawed in scope and consistency, is nevertheless readily available, widely used and reasonably accurate.
- Low-carbon indices are relatively easy/cost-effective to implement as a replacement for market-cap-weighted index exposures in public equity allocations.
- Low-carbon indices are often designed to minimize tracking error versus market-cap-weighted parent indices, reducing the risk of mismatch and lowering concerns about climate strategy underperformance.

The above factors combine to make low-carbon indices readily implementable in a passive-equity context, with some investors describing the low-carbon tilt as a "free hedge" against climate change transition risk.

Green Bonds

Many of the same factors are at play in the green bond market. Green bonds offer demonstrably similar performance characteristics as standard bonds, with similar credit quality and duration. Indeed, many "environmentally neutral" fixed income investors already own green bonds simply by virtue of their risk/return characteristics. Although it is difficult, given present performance data and the loose linkage between use of proceeds (which determines a bond's "greenness") and issuer credit quality, to demonstrate that green bonds offer investors a "greenium"[73] or provide climate-risk-protection benefits, they do at least offer investors the opportunity to more-readily track their environmental impact in public markets. While outstanding green or climate-aligned bonds remain a relatively small portion of the global bond universe, issuance continues to increase year over year, lessening liquidity concerns, which have surrounded early investments in this space.

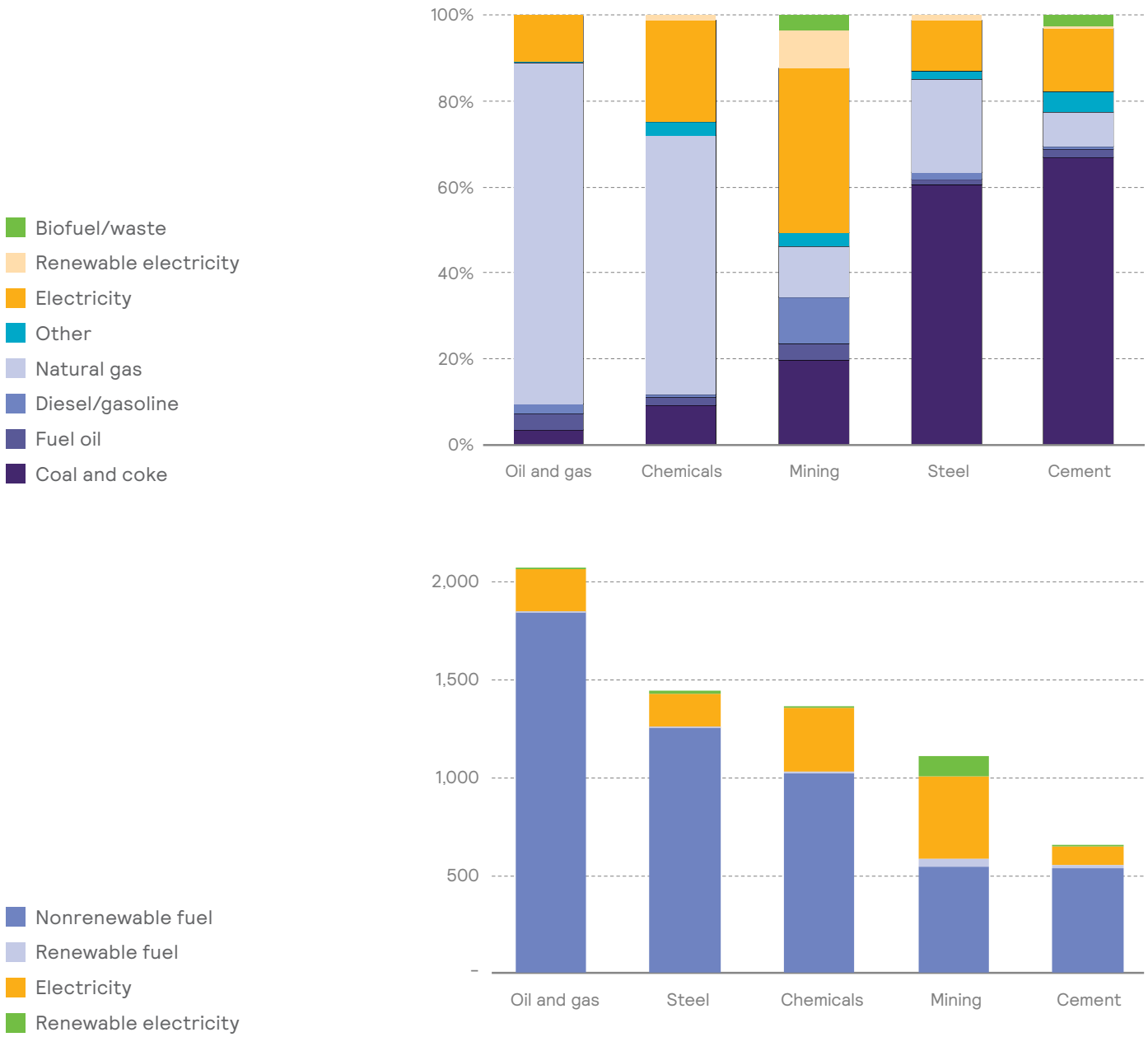
Industry Sectors Feature Focus — Industrials and Renewable Energy

One of the key findings from the 2015 Report and the Sequel is that climate change risks are most significant at an industry and sector level, and asset owners are encouraged to look further than asset-class exposure alone. The 2015 Report highlighted the energy sector. If the well-below 2°C ambition is going to be achieved, transformative change is required across industry sectors, not just the energy sector. CDP (a not-for-profit charity that runs the global disclosure system for investors, companies, cities, states and regions to manage their environmental impacts) was commissioned to consider the current status of renewable energy take-up by heavy users of energy within industrials and where the risks and opportunities lie. This includes analysis on renewable energy production and the utilities sector and the impact of investor engagement on the switch to renewable energy sources.

Uptake of Renewable Energy in Industrials Sectors

Some sectors are currently better-positioned to incorporate renewable energy into their operations than others. In terms of consumption, as shown in Figure 31 on the following page, the mining sector leads the way, performing significantly better than the other subsectors in terms of both absolute and relative share of renewable energy consumption, with 12% of energy consumed coming from renewable sources in 2016. The cement sector follows mining, with 3% of total energy consumption coming from renewables. Chemicals and steel are both positioned third, with renewables comprising just 1% of their total energy consumption. Finally, oil and gas lags at the bottom of the pack, with no material uptake of renewables.

Figure 31. Energy Consumption Breakdown Across Sectors in 2016 (Share and Absolute)



Source: CDP

The following demonstrates where the opportunities lie for future improvements given the significant energy burden for these sectors:

Mining

- Energy expenditure accounts for up to 30% of mining cash costs and up to 75% of operational emissions.
- Operating with the lowest energy intensity offers cost-saving potential, especially against the backdrop of falling ore grades and deeper ore bodies requiring more energy.
- The production of metals such as aluminum is extremely electricity-intensive and therefore, traditionally, metal production sites have been located in close proximity to low-cost hydropower plants (IRENA, 2018).
- Hydro therefore makes up a significant share of the renewable electricity consumed by mining and metals companies.
- Integrating renewable fuels tends to be a more difficult task. Although hydrogen shows promise in some cases, the electrification of traditionally fuel-based equipment, such as haul trucks, may provide a more-cost-effective solution (IEA, 2017).

Cement

- Electricity accounts for around 15% of total energy consumed, depending on plant type, with most of the remaining energy burden coming from thermal energy required to heat the kiln.
- The use of biofuels to heat the kiln therefore presents the most tangible opportunity to increase the uptake of renewable energy in the sector.
- Although this is already being done in many operations, it is limited in scale, and competition for biofuels is likely to present barriers in the future.
- Another opportunity is the use of electric furnaces rather than traditional rotary kilns for the calcination process.
- Although such furnaces are commercially available, they are not manufactured in the dimensions necessary to produce clinker (IEA, 2017).

Steel

- Although the most common form of steel-making uses a basic oxygen furnace that is not electrified, newer plants are increasingly using electric arc furnaces that can be powered by renewables.
- Other opportunities include the electrolysis of iron ore, known as electrowinning, or the use of hydrogen as a reducing agent.
- According to empirical evidence, electrowinning is the most energy- and resource-efficient production route, with 2.6 MWh of energy required per metric ton of crude steel produced, comparative to the current global average of 5.83 MWh/t (Weigel et al, 2016).
- Using hydrogen as a reducing agent, however, is closer to commercialization.

Chemicals

- Ammonia, methanol and high-value chemicals (HVCs) account for almost three-quarters of total final energy use, including feedstocks, in the chemicals and petrochemicals subsector.
- As 95% of the emissions generated from petrochemical production are associated with feedstocks and processes, the scope to reduce emissions through renewable electricity is limited (IEA, 2017).
- Renewables-based electrolysis of water to produce ammonia or methanol is the low-hanging fruit for the chemicals sector in terms of decarbonization potential and cost.
- For high-value chemicals, cellulosic ethanol conversion, based on forestry and agriculture sector residues, provides some promise.
- The deployment of biomass-based methods for producing HVCs may, however, be limited by competition for biofuels.

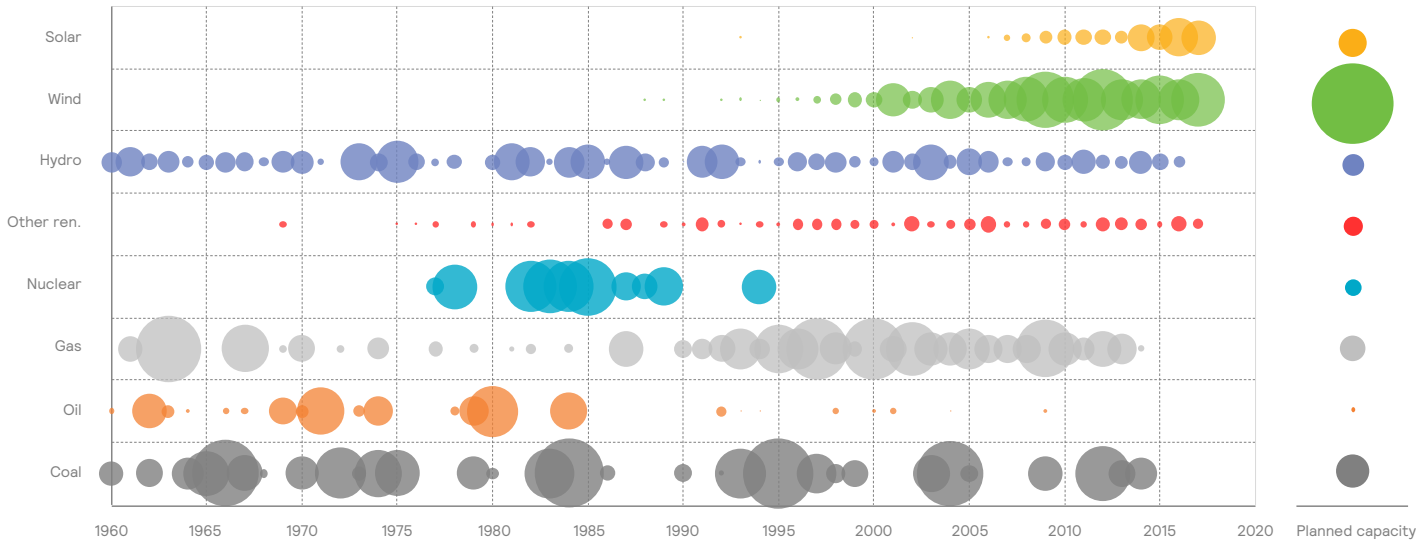
Source: CDP

However, such opportunities to decarbonize do not come without upfront investment and therefore cost. A recent report from McKinsey estimates sector costs out to 2050 and highlights steps that both companies and policymakers can take, noting that "advance planning and timely action could drive technological maturation, lower the cost of industrial decarbonization and ensure the industry energy transition advances in parallel with required changes in energy supply."[74]

Production of Renewable Energy Across Utilities

In 2016, renewable electricity generation grew by 6% globally and represented around 24% of global power output. The largest share of renewable power came from hydro, which accounted for around 70%, followed by wind (16%), bioenergy (9%) and solar photovoltaic (PV) (5%).[75] Solar overtook wind for the first time in terms of capacity additions, with almost 50% higher growth than 2015. This was largely driven by China, which doubled its capacity relative to 2015. Onshore wind capacity, however, represented a 15% reduction since 2015. Hydropower additions are estimated to have decreased for the third consecutive year since 2013, with fewer projects becoming operational in China. According to the International Energy Agency (IEA)'s 2°C Scenario, by 2060, the decarbonization of the power sector will largely be driven by variable renewable energy, led by wind, which will account for 20% of electricity generation, followed by solar, which will account for 17%.[76]

Figure 32. Energy Capacity Additions Per Technology (1960 to Beyond 2020)*



* Size of bubble represents capacity of plant.
Source: CDP Using Bloomberg New Energy Finance (BNEF) data

Renewable take-up still has strong potential to grow from here, with planned renewable capacity additions continuing to accelerate beyond 2020. This acceleration is led by wind, which accounts for 62% of total future additions.

Investor Engagement on Renewables

We expect global investors to play a significant role in engaging with both companies and policymakers to monitor whether industrials are on track for the transition to the low-carbon economy. Collaborative investor efforts, such as the Transition Pathway Initiative (TPI), an asset-owner-led initiative, are already highlighting trends across industrials, with recent reports focused on the cement and steel producers. Similar to the CDP analysis, the TPI found that there is clear room for transition across the steel industry, with only very few (five out of 22) companies having a long-term, quantified target to reduce their greenhouse gas emissions.[77]

Increasing renewables take-up in heavy industries is an important part of the climate change response but will also likely require a portfolio of measures, including increasing asset recycling (for steel), alternative materials, CCS and better energy efficiency, as per a recent report on the cement sector from the Energy Transition Commission and Chatham House.[78]

See the following section for a more comprehensive outline on investor action, including engagement.

What Actions Can Investors Take?

The portfolio impact findings strengthen the argument for investor action on climate change. The recommended investor actions from the 2015 Report remain valid, and incorporating climate change considerations within investment program governance and in portfolios via ESG integration, stewardship and allocations to sustainability themes is consistent with the 2017 TCFD recommendations. Investor case studies, which reinforce how scenario analysis helps to prioritize the portfolio risks for some and opportunities for others, also demonstrate the pace of change by peers.

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Consistent with Mercer's thinking on the best way to incorporate ESG and climate change considerations into the investment process, we continue to recommend an integrated approach when setting investment beliefs, policy and process, and constructing and managing portfolios.

Mercer encourages investors to bring climate change into their governance by introducing statements about climate change risk and opportunity in investment belief documentation and policy statements. This enables climate risks and opportunities to be included alongside other investment considerations and for processes and portfolios to evolve over time — grounded in agreed-upon beliefs and policies. This governance framework should consider the four key implementation strategies — integration, stewardship, investment and screening.

1	2	3	4
Belief	Policy	Process	Portfolio

Source: Mercer

Integration

Include ESG factors in investment decisions, with an explicit approach to climate change transition and physical risks, which are portfolio-wide.

AIM:
Financial objectives
+ risk management improvement

Stewardship

Exercise active ownership/stewardship through voting and engagement with underlying companies and by engaging with policymakers.

AIM:
Financial objectives
+ financial system improvement

Investment

Allocate to sustainability themes or impact investments for new opportunities — for example, renewable energy, water and social housing.

AIM:
Financial objectives
+ positive social and environmental impact

Screening

Screen out sectors or companies deemed to be irresponsible or not acceptable to profit from.

AIM:
Alignment with values/reputation/risk management or longer-term financial expectations

Source: Mercer

Scenario analysis can be incorporated as part of the investment process in strategy-setting, informing subsequent portfolio construction and implementation. It highlights where the largest risks and opportunities exist, allowing investors to take appropriate actions (in line with individual portfolio risk and return objectives).

Mercer's recommended approach is aligned with the 2017 asset-owner recommendations from the TCFD.[79]

Governance

Strategy

Risk management

Metrics and targets

Source: TCFD, available at http://www.fsb-tcfd.org.

TCFD Recommendations for Asset Owners

Governance: Ensure board and management teams are both educated and engaged on climate change and that agreed-upon beliefs are confirmed in policy documentation and integrated within investment processes.

Strategy: Include climate scenario analysis in portfolio strategy-setting processes (consistent with Mercer's approach set out in this report).

Risk management: Informed by the scenario analysis findings, take action to reduce risk and allocate to opportunities in the low-carbon transition area; for example, altering the allocation to different asset classes and/or the exposures within asset classes. Review and improve the ESG integration and stewardship approach of appointed managers, and increase direct company and regulatory engagement activities as an asset owner.

Metrics and targets: Complement top-down portfolio analysis with bottom-up analysis of underlying companies and assets using metrics such as carbon-emissions intensity (carbon footprinting), forward-looking strategy metrics and green-versus-brown revenue flows.

The Actions Table from the 2015 Report remains relevant today and is consistent with the TCFD framework, noting that specific portfolio considerations and priorities will vary. The Mercer actions to date and the investor case studies in the following supplement give examples and reinforce how scenario analysis helps to both prioritize portfolio risks and opportunities and demonstrate the pace of change.

A separate *Scenario Signposts Reference Guide* has also been created for clients to help investors monitor developments on a regular basis, including suggested considerations and a list of sources to reference. Scenario analysis and stress testing enable investors to incorporate climate-related considerations into the strategy-setting process, which is typically undertaken every three years. In the interim, investors will benefit from monitoring the latest scenario signals on the pace of the low-carbon transition and developments in physical damage impacts.

Where to From Here? Calling all Future Makers

As evidenced by the long-term impact of our 4°C scenario, this would be a very costly pathway for the world to follow. We have also highlighted that these assumptions likely underestimate the potential economic (not to mention social) consequences of high levels of warming. On the other hand, a 2°C (or lower) pathway provides the opportunity to drive economic innovation and protect long-term GDP and investment returns, with associated social benefits. Fiduciaries — motivated by the economic and social interest of their beneficiaries and clients — have the opportunity, and arguably the obligation, to use their portfolios and their influence to help guide us toward this more economically secure outcome.

Since the 2015 Report, there has been a meaningful shift in investor action on climate change, often fueled by a heightened understanding of what a 2ºC —or warmer — scenario could mean for investors over both the short and long term:

- More than 50 investor initiatives have now been established seeking to compel and support investor activity on climate change — whether focused on integration, stewardship, sustainability-themed investment or screening/divestment.[80]
- Mercer is increasingly helping to place billions rather than millions in sustainability-themed assets (through searches for advisory clients and our own delegated solutions).[81]
- There is a regular stream of announcements about investors launching new climate strategies, allocating to low-carbon or low-impact investments, avoiding coal and other high-carbon investments, and ramping up climate-related engagement activities.[82]
- Leadership on climate change is most often displayed by the largest investors, although there is momentum among midsize asset owners, too. For example, Mercer's *2017 European Asset Allocation Survey* found that only 5% of investors had considered climate change as part of their asset-allocation process, whereas this rose to 17% in 2018.[83]

A key characteristic of investor action on climate change is the critical role that collaboration plays, and Mercer has been a global leader in this practice over the past eight years. Since 2015, we have convened an informal network of asset owners that have undertaken Mercer's climate-scenario analysis — the Future Makers Working Group.

Future Makers, a term coined in the 2015 Report, seek to influence a 2ºC-scenario outcome consistent with the best interests of their portfolios over the long term. Future Makers believe that they, individually and collectively, can and should influence the future. Future Makers thus advocate for 2ºC-aligned business plans from companies exposed to transition risk (for example, via the Climate Action 100+[84]) and press governments to take urgent action in implementing the Paris Agreement (for example, via the 2018 Global Investor Statement to Governments on Climate Change[85]), including a "ratcheting-up" of climate commitments.

We have included a number of case studies in the following supplement, which illustrate some of the actions these investors have taken, clearly demonstrating the changes that are underway and the variety of approaches that exist to identify, manage and monitor climate change risk. We expect to see a growing number of Future Makers articulating this belief and acting accordingly, and we look forward to the opportunity to support them as they do so.

Supplement 1: Investor Case Studies

A common experience across the clients we have worked with has been the importance of improving climate-related governance and the critical role scenario analysis has played in supporting this. In the case studies below, written by each organization, the focus is primarily on portfolio-risk-management actions or allocations to new opportunities, supported in some way by the scenario analysis, not an exhaustive list of all activities each organization has undertaken.

Europe

Environment Agency Pension Fund

UK — Pension Assets — > US$4.8 billion

The Environment Agency Pension Fund has been considering the investment implications of climate change for more than a decade. In October 2015, we committed to ensuring that the Fund's investment portfolio and processes are compatible with keeping the global mean surface temperature increase to below 2°C relative to preindustrial levels. Our current approach is set out in the Fund's comprehensive Policy to Address the Impacts of Climate Change, which was updated in October 2017.

We focus on three important goals: invest, decarbonize and engage. Climate change scenario analysis has supported the Fund's investment strategy decision-making, and we aim by 2020 to invest 15% of the Fund in low-carbon, energy-efficient and other climate-mitigation activities, supporting our wider aim to invest at least 25% of the Fund in clean technology and other sustainable opportunities and funds across all asset classes. We trust this will make our portfolio more climate resilient.

We actively collaborate with other asset owners, investment managers, companies, academia and policy makers, recognizing the importance of active stewardship in tackling systemic risk. Priorities include the Transition Pathway Initiative (TPI), which we cofounded with the National Investing Bodies of the Church of England and the Grantham Research Institute at the London School of Economics, as well as our partnership with nine other UK local government pension schemes as part of the Brunel Pension Partnership.

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Europe

The Crop Trust

Europe — Endowment Assets — > US$280 million

The Crop Trust's mission is to ensure the conservation and availability of crop diversity for food security worldwide. We do this by supporting genebanks using income generated by our endowment fund. Clearly, climate change threatens crop diversity — it affects the habitats of some important plants related to our food crops, and extreme weather can affect the way genebanks operate. But it also has financial implications for our endowment assets and therefore our ability to fund future projects.

The Crop Trust's endowment fund is therefore aligned with our belief in the importance of both climate change adaptation and mitigation. We ensure high levels of ESG integration across the portfolio, but our main climate-related focus has been on making sustainability-themed investments in both public equities and private markets, across private equity and infrastructure in particular. Climate scenario modeling has helped support the investment decisions we've made and will continue to help ensure the sustainability and resilience of our endowment fund, maximizing our ability to deliver on our mission now and in the future.

The Church of England National Investing Bodies

Europe — Endowment and Pension Fund Investments — US$16.5 billion

The Church of England National Investing Bodies adopted a comprehensive new policy on climate change in 2015. We no longer invest directly in companies deriving more than 10% of their revenues from the extraction of thermal coal or the production of oil from oil sands and have built up a portfolio of low-carbon assets in excess of US$390 million. These include sustainably certified forestry, thematic listed equities and private markets funds, and renewable energy infrastructure. The three bodies have played a leading role in global investor engagement on climate-related disclosure, seeing shareholder resolutions we co-filed at BP, Shell, ExxonMobil, Anglo American, Glencore and Rio Tinto all pass in the 2015–2017 AGM seasons. Looking ahead, we are focused on promoting climate governance, disclosure and well-below-two-degrees alignment through the US$32 trillion engagement initiative, Climate Action 100+. We will track companies' progress through the Transition Pathway Initiative, which we cofounded alongside the Environment Agency Pension Fund and the Grantham Research Institute at the London School of Economics.

North America

OPTrust

Canada — Pension Fund — > US$15 billion

Climate change is one of the most significant risks we face today. Its effects are complex and wide-ranging and will play out over decades. OPTrust has long recognized that bold steps and new ways of thinking are required to help investors understand the impacts that climate change presents. The pension fund looks at its investments from both a top-down and bottom-up perspective to evaluate its exposure to the risks and opportunities related to the transition to a low-carbon economy. A critical part of OPTrust's investment mandate is to focus on exploring and developing climate change scenarios integrated with its risk-based portfolio construction framework and analyze the impact on the total fund portfolio. The innovative research we undertook on climate change has furthered our industry's understanding of the need for investors to better manage the risks that climate change presents, encouraging increased carbon disclosure from portfolio companies. Evaluating the resilience of OPTrust's total portfolio to four potential climate change scenarios led to our Climate Change Action Plan.

Pacific

QIC

Australia — Pension and Savings Assets — > US$63 billion

We first began reviewing climate change considerations in 2015, and this highlighted the exposure of real asset portfolios in particular to the physical impacts of climate change. Since this time, we've come to recognize that building resilience means understanding potential impacts that could result in a loss of service as well as physical damage to an asset. We've taken a bottom-up approach that started with a high-level climate risk assessment of all assets in Australia that QIC invests in. Through the use of scenario analysis, this facilitated an informed prioritization of projected exposure to natural hazard and physical climate risk. Given the physical impacts of climate risk are highly location-specific, a second phase of work is underway to develop a process to produce detailed quantification of physical climate impacts and adaptation measures that can be applied across our real asset portfolios.

Pacific

The Guardians of New Zealand Super Fund

New Zealand — Pension Assets — > US$27 billion

NZ Super's journey toward a climate change strategy has been a 10-year process, with the first climate change scenario analysis undertaken in 2015. As a result of the scenario analysis, the Guardians have implemented a four-part strategy of carbon reduction, analysis, engagement and searching for new investment opportunities.

The strategy applies across the Fund's entire portfolio. The strategy includes a Guardians-Board-approved commitment to significantly reduce the Fund's exposure to both fossil fuel reserves (40%) and carbon emissions (20%) by 2020. This will be achieved through ongoing engagement with companies, building carbon measures into the Guardians' investment model, targeted divestment of high-risk companies and reduction of other relevant portfolio exposures.

Specific initiatives include:

- Shift to low-carbon benchmark (reference portfolio)
- Active program working with unlisted private market holdings on climate change risk management
- Publishing carbon footprint and setting targets — The US$9.6 billion global passive equity portfolio, 40% of the overall Fund, is now low-carbon. The total Fund's carbon emissions intensity is 19.6% lower, and its exposure to carbon reserves is 21.5% lower than if the changes hadn't been made (June 2018) and goes a long way toward meeting the 2020 target. The Guardians will publicly report on the Fund's carbon footprint annually.
- Engagement and voting program
- Future search for other climate solutions

VicSuper

Australia — Pension Assets — > US$14 billion

VicSuper has, for a number of years, viewed climate change as one of the single-greatest priorities facing our global community. More than 15 years ago, we helped found the Investor Group on Climate Change. Subsequently, we were one of the first super funds in Australia to measure the greenhouse gas emissions intensity of our equities investments and invest in a "Carbon Aware" mandate. Undertaking stress testing of our portfolio in 2017 against a range of climate change scenarios enabled us to take the next step in managing the financial risk due to climate change. Based on the analysis, VicSuper has developed a new Climate Change and Investments Strategy. This has been the foundation for a number of actions taken to support the transition to a low-carbon economy, including:

- A significant update of our responsible investment and climate change beliefs
- Greater engagement with investment managers on climate change
- Producing our first climate change report in line with the TCFD recommendations
- Investing US$700 million in an international equity customized carbon strategy that aims to deliver a 70% reduction in greenhouse gas emissions intensity against its benchmark
- Making additional new investments in renewable energy

The transformative economic transition required to achieve 2ºC and, ideally, 1.5ºC cannot be underestimated. However, the associated physical damages expected under even 0.5ºC of additional warming is a clear motivation for that transformation.

Appendix 1: Sample Asset Allocations

The two asset allocations used to illustrate the results section are documented below.

Figure 33. Sample Portfolio Asset Allocations

Asset category	Growth portfolio weight %	Sustainable growth portfolio weight %
Developed market equity	17.5	7.5
Emerging market equity	10.0	10.0
Low-volatility equity	7.5	7.5
Small-cap equity	2.5	2.5
Sustainable equity		10.0
Private equity	5.0	4.0
Sustainable private equity		1.0
Real estate	10.0	10.0
Infrastructure	5.0	4.0
Sustainable infrastructure		1.0
Timberland	2.5	2.5
Agriculture	2.5	2.5
Hedge funds	5.0	5.0
Private debt	5.0	5.0
Developed market debt (sovereign)	10.0	10.0
Emerging market debt (sovereign)	2.5	2.5
Multi-asset credit	10.0	10.0
Investment-grade credit	5.0	5.0
Total	**100.0%**	**100.0%**

Source: Mercer

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Appendix 2: Methodology

Climate Models and Scenarios

The 2015 Report includes further explanation on the various integrated assessment models (IAMs) that calculate the environmental impacts of climate change and the associated economic damages. These provide a foundation for our assessment of the investment impacts.

There are different models focused on transition risk or physical risk, and they each have different levels of granularity and methodologies. There are shortfalls in the models that generate criticisms, as outlined in the Cautionary Note included earlier; however, they remain the most concrete foundation we have to provide detailed quantitative impact estimates.

The Sequel — Model Inputs

For the 2015 Report, we used the WITCH model, which remains a well-respected model, together with the IEA 2°C Scenario metrics. However, for the Sequel, we have worked with Cambridge Econometrics and their E3ME model. This analyzes the impact of energy-environment-economy policies and was originally developed through the European Commission's research framework programs 20 years ago, with various updates and developments since. E3ME is a macroeconomic model that is linked to a climate model called GENIE, an IAM.[86]

E3ME is recognized globally as one of the leading models for comprehensive economic modeling of policy and technology scenarios. Cambridge Econometrics was recommended by other respected industry colleagues who had worked with them directly or were familiar with their work; for example, New Climate Economy and World Resources Institute. They were also, importantly, able to work with us to deliver very granular data in the format we required for our modeling approach.

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Appendix 1: Climate Models — pages 83–90

"Quantitative projections of climate change impacts depend upon the use of highly aggregated, large-scale integrated assessment models (IAMs). IAMs are integrated in the sense that they use climate science and economic data together. IAMs are diverse in structure but can be described as stylized representations of the relevant interactions of natural and human systems. These models take a set of input assumptions (for example, population growth, baseline GDP growth, technological change) and produce long-term projections of various outputs (for example, mitigation costs, physical damages)."

(page 83)

The Key Strengths of the E3ME Model

The key strengths of E3ME for modeling investment scenarios include:

- Complete representation of the economy, energy systems and the environment, and the interlinkages between each of these components
- Quantification of GDP, gross value added (GVA) and interest-rate impacts, among other factors (the raw data was received for each risk factor under each scenario for multiple economic variables at annual time steps to 2100)
- A high level of granularity, including coverage of 59 nation-states/regions and up to 70 distinct economic sectors as well as annual results
- Explicit representation of the drivers of technology take-up and the interactions between energy policy and technology
- Integrated fossil fuel supply curves to model stranded fossil fuel reserves
- Econometric rather than optimization methodology, aiming to capture behavioral factors on an empirical basis and not assume optimal behavior, as per traditional economic theory

E3ME contains information for 59 countries/regions and 70 industry sectors. We distilled these into 16 major investment countries/regions and 20 major industry (sub)sectors, as follows:

16 Regions/Countries	20 Industry (Sub)Sectors
Global (GDP weighted)	**Energy**
MSCI ACWI	Oil and gas
MSCI World	Coal
MSCI EM	**Utilities**
MSCI Europe	Renewables utilities
MSCI AC Asia Pacific	Electric utilities
MSCI North America	Gas utilities
US	Multi-utilities
UK	Water utilities
Canada	**Materials**
Australia	Forestry and logging
China	**Industrials**
India	**Consumer discretionary**
Netherlands	**Consumer staples**
Sweden	Crops and animals
Japan	**Health**
	Financials
	IT
	Telecoms
	Real estate

Data from E3ME was provided for five major economic variables across each of these regions and sectors, at annual time steps for 82 years, for three scenarios and a base case with detail for each of the four identified risk factors. Altogether, Cambridge Econometrics provided us with more than two million individual economic data points.

Cambridge Econometrics was able to adapt its transition model to "feed in" the physical damages inputs so that we received a single data feed across risk factors without having to match the results of two disparate models.

For physical damages in the 2015 Report, we primarily relied upon the FUND model, with some additional literature to support adjustments for missing perils. The FUND model is unique among IAMs, as it models damages as functions of physical processes, it produces sector-specific damage functions and it also offers a broader assessment of "socially contingent" and nonmarket damages than most other models. These are all very useful characteristics to inform sector- and asset-class-specific physical impact assumptions.

However, FUND, like all IAMs, has some gaps in its damage estimation, and its agricultural damage function in particular has been subject to meaningful scrutiny and debate. After conducting a detailed review of FUND in consultation with Cambridge Econometrics, we ultimately determined not to use this model for the Sequel due to concerns regarding the robustness of some FUND damage functions, not just agriculture.

As an alternative, we decided to develop our own "Mercer damage function." To do this, we first conducted a survey of available literature on physical damage functions for specific climate-affected catastrophe perils/natural resources and selected best-in-class research to inform the calculation of key physical damages. These peril/resource-specific damage functions were then combined to create an ensemble damage function for modeling purposes. The catastrophe perils and natural resources ultimately addressed by this "bottom-up" approach are:

- Agriculture damage function[87] (wheat, maize, soy, rice)
- Coastal flood damage function[88]
- Wildfire damage function[89]

Although these are generally considered some of the most impactful/impacted catastrophic perils/natural resources, we were not able to readily identify damage functions with sufficient global scope and regional granularity for other catastrophic perils/natural resource types. This approach to damage function development has benefits (more-robust estimation of the distribution and magnitude of specific damages) and drawbacks (an incomplete picture).

The three papers referenced above provide economic damages globally, but we still needed to determine how best to split out damages by regions and industry sectors. For catastrophic perils — coastal flood and wildfire — Mercer first split the losses regionally based on historical loss patterns for each peril. To determine the sectoral distribution, we first needed to determine the split between insurance and other sectors, based on historical insured loss for the peril type by region and the size of the insurance sector by region. Net uninsured damages were then split by the capital intensity of industry sectors other than insurance. We did not model "demand surge" and/or any adaption measures that could lead to growth or enhanced protection in some markets (for example, flood defense).

For agriculture, the effects of the sourced damage functions for wheat, maize, rice and soy are treated via E3ME's Input/Output model. The change in crop production is modeled as a change (usually a reduction) in output, which leads to increased prices, since demand does not change. Although the price increases do offset some of the output losses felt in agricultural sectors, overall related output decreases. The effect of these price changes is felt on consumer spending (a larger share of household income is spent on food versus other consumer goods) and on industry sectors reliant on agriculture as an input.

The results of this bottom-up approach, which knowingly only includes some of the potential impacts from climate change, predicts loss of GDP at 2100 under a 4°C scenario of 17%. Comparing the Mercer damage function to other damage functions from literature reveals some key differences:

- Covington and Thamotheram (2015) illustrated three potential damage functions, which they labeled as "N damages, W damages and DS damages."[90] N and W produce much lower damages at 4°C than the Mercer function, whereas DS produces a much higher damage

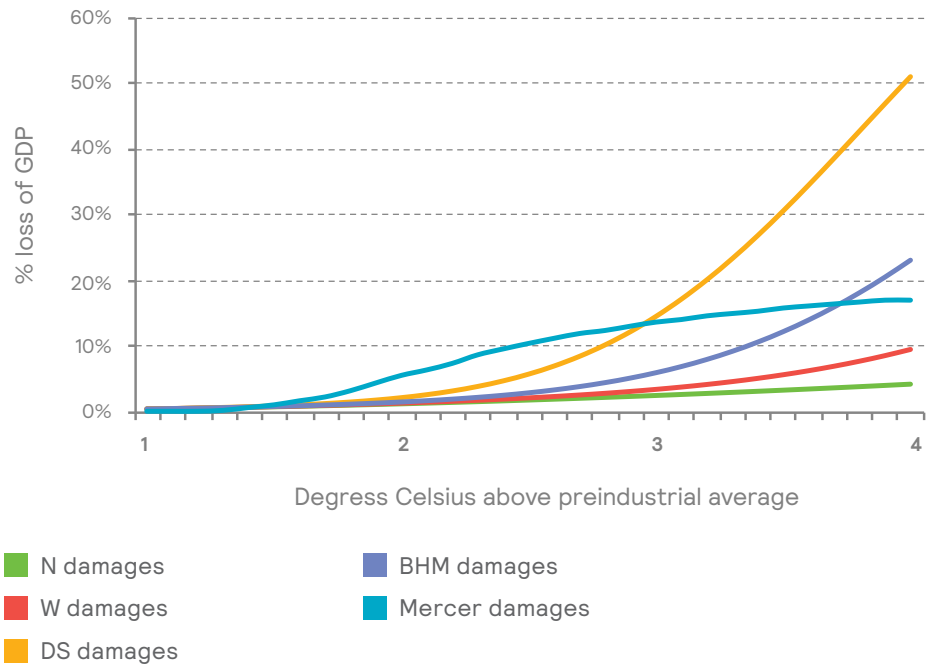
ratio. These are top-down, more-theoretical approaches, that also include climate tipping points (for example, melting permafrost and ice, etc.), hence the exponential shape.

- Burke, Hsiang and Miguel (2015) proposed total damages of 23% in relation to GDP per capita.[91] This was in relation to the impact of temperature increases only on productivity and did not include increased physical damages from catastrophes.

- The Mercer damage function produces the highest damage ratio at 2ºC of warming. It is linear in shape, primarily reflecting the coastal flood damage study used, which accounts for the majority of the Mercer damages. The coastal flood damage values were selected from an ensemble of 720 different scenarios. The Mercer damage function also does not take account of climate tipping points, which could drive nonlinearity in terms of the severity of coastal flooding or wildfire and/or the incidence and intensity of extreme events. Therefore, we see a more linear relationship between temperature change and damages. We also did not take account of adaption measures that could curtail the scale of damages as temperature increases (see Figure 34 for an illustration of the net effects of these assumptions).

Figure 34. Comparison of Various Climate Change Physical Damage Functions

N damages	W damages	DS damages	BHM damages	Mercer damages
4%	9%	51%	23%	17%



Source: Mercer

Note: Mercer's Climate Risk Analyzer tool has the ability to use other damage functions in place of the Sequel damages, which we believe is best used as part of the stress-test modeling.

The Sequel — Mercer Process

Cambridge Econometrics was able to integrate the physical damage functions into the E3ME transition model to allow for seamless treatment of transition and physical damages within the same modeling framework. They delivered the annual economic impact results for GDP and GVA, which adjusts GDP to more closely align with corporate growth, and inflation into a Mercer-defined template by risk factor and scenario across sectors and regions.

Mercer then:

- Created the data template for Cambridge Econometrics to deliver results across multiple economic indicators by risk factor for asset classes and sectors for the three climate scenarios
- Led on the physical damages research with input from the Cambridge Econometrics team
- Reviewed the results and identified anomalies given the significant number of data points, the physical damages adaptation into E3ME and the Mercer-specified format
- Adopted GDP impacts to represent scenario scripts for each of the three scenarios
- Developed sensitivity factors for each asset class and sector for each of the climate risk factors (with differing sensitivity assumptions for the transition risk factor under the 2ºC and the 3ºC scenarios)
- Undertook a thorough calibration/reasonableness review between the target return results from the E3ME model and the resulting scenario pathway and risk-factor sensitivity results to understand the results drivers and identify any inconsistencies
- Assigned an economic indicator weighting to different asset classes given our view on the relative investment impact
- Designed an approach specific to fixed income to capture impacts on yields, including treasury rates and credit spreads for different FI categories
- Created the Climate Risk Analyzer tool that takes the final scenario pathways and risk-factor sensitivities and generates the portfolio and asset class impacts on return

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Scenarios — pages 33–40

Scenarios Detail — pages 91–100

Even under a 2ºC transformation scenario:

"Large-scale adaptation of vulnerable infrastructures — for example, water, energy, and waste management — would be required, and would drastically reduce the risks posed. The human impact of extreme heat events stands to be high even with concerted adaptation with increased heat-related mortality and drought-related water and food shortages causing malnutrition." (page 99)

A 4ºC fragmentation scenario:

"Effects would not be distributed evenly … Increases of 6°C or more in average monthly summer temperatures would be expected in the Mediterranean, North Africa, the Middle East, and parts of the US."

"Agriculture, water resources, human health, biodiversity, and ecosystem services are likely to be severely impacted. This could lead to large-scale displacement of populations and consequences for human security and economic and trade systems." (page 100)

Scenarios

The following table summarizes the key milestones and assumptions for the transition and physical damages in each of the three scenarios modeled in the Sequel — 2ºC, 3ºC and 4ºC. It also compares these to the current situation.

It is also important to remember that if we don't move to a 2ºC scenario trajectory quickly, we can't just move over to a 2ºC scenario some years down the line and hope we will catch up. A whole new scenario would need to be calculated at that time and would likely require an even-steeper transition and greater reliance on net emissions approaches (afforestation, CSS) to remove prior emissions from the atmosphere.

In October 2018, the IPCC released a new report on 1.5ºC, highlighting the difference between that and 2ºC to illustrate the additional impact that 0.5ºC is expected to have and to reinforce why the Paris Agreement ambition is for "well below" 2ºC and how close we are to that window of opportunity closing:

- 1.5ºC requires a 45% CO_2 emissions reduction from 2010 levels to 2030 and net zero achieved at 2050.
- 2ºC requires a 25% CO_2 emissions reduction from 2010 levels to 2030 and net zero by 2070–2080.

This indicates how much steeper the 1.5ºC transition needs to be compared to 2ºC and the significant difference when compared to the current Paris Agreement commitments, assuming they are implemented, which result in a 3ºC trajectory. The transformative economic transition required to achieve 2ºC and, ideally, 1.5ºC cannot be underestimated. However, the associated physical damages expected under even 0.5ºC of additional warming is a clear motivation for that transformation.

When we next come to update the Mercer model, we look forward to working in an ever-improving context that drives the focus on comparing 1.5ºC and 2ºC, where 3ºC becomes the "worst case" from a climate perspective and 4ºC is no longer a consideration. The indicators in the table following should be motivation to make that a reality.

The Sequel Scenarios in Summary

(carbon emissions — $GtCO_2$ — fossil fuel and industrial only)

	Transition milestones and commentary	Physical damage milestones and commentary
Current	• 2017 emissions reached 37 $GtCO_2$.[92] • Fossil fuels are 80% of the energy mix. • 80% of emissions are not covered by carbon pricing. • 59% of 2017 energy supply investment went to fossil fuels. • 3.3 million electric vehicles were on the road in 2017.[93]	• Temperature has increased 1.1°C relative to preindustrial levels. • CO_2 concentration is over 400 ppm (last occurred three million years ago).[94] • Sea-level rise is at 22 cm.[95] • Half of the Great Barrier Reef has bleached to death since 2016,[96] which has significant biodiversity and flood protection implications.[97]
2°C	Aggressive* climate action: • Emissions peak in 2020. • Emissions fall to 16 $GtCO_2$ by 2050 (57% decrease versus 2017). • Net-zero emissions are reached by 2080–2100. By 2050 (relative to 2015): • Total energy demand is down by 12%. • Coal is aggressively phased out. • The energy sector is electrified. • Power generation increases by 60% (with 55% of generation from renewables and 8% nuclear). • Oil and gas supply is down by 10% (oil demand down by 33%; gas supply up by 20%). • New vehicle sales are 50% electric vehicles (EV) and 25% liquefied petroleum gas (LPG).	• There is a 50% chance of keeping temperature increase below 2°C. • By 2050, temperature rises 1.7°C. Physical damage examples at 2°C of warming include[98]: • Average sea level rises around 50 cm. • Annual maximum daily temperature is 2.6°C higher; the number of hot days increases by 25%. • Frequency of rainfall extremes over land increases by 36%. • Average drought length increases by four months. • Suitability of drylands for malaria transmission goes up 27%. • Average crop yields for maize and wheat decrease by 9% and 4%, respectively.

** "Drastic" action would be required to stay below 1.5 °C of warming relative to preindustrial levels.*

	Transition milestones and commentary	Physical damage milestones and commentary
3°C	Some climate action but not transformative, and we fail to achieve a 2°C outcome: • Global emissions are essentially flat to 2050 and rise slighter after. • Emissions reach 41 $GtCO_2$ in 2050. By 2050 (relative to 2015): • Total energy demand is up 18%. • Fossil fuels represent 80% of primary energy. • Coal use is down but only by 7%. • Power generation increases by 85% (with 27% of generation from renewables and 3% nuclear). • New vehicle sales are 37% EV and 35% LPG.	• In 2050: Temperature increases by 1.9°C. • By 2100: Temperature increases by 3.2°C. By 2100, example physical damages are largely considered irreversible (permanent loss of arctic sea ice) and include: • Sea levels rise approximately 58 cm on average.[99] • Average drought length increases by four months. • There is 30% less water availability. • Heat waves and forest fires are greater than recent years. • Risk to marine fisheries and negative aggregate impact on agriculture and food production increases chance of famine.
4°C	Business as usual pathway: • Global annual emissions increase by 49% by 2050 relative to 2015. • Emissions reach 91 $GtCO_2$ by 2100. By 2050 (relative to 2015): • Total primary energy is up by 28%. • Fossil fuels represent 84% of primary energy at 2050. • Power generation is 25% renewable (plus 5% nuclear).	• In 2050: Temperature increases by 2.0°C. • By 2100: Temperature increases by 3.9°C (heading higher). By 2100, example physical damages are largely considered irreversible (permanent loss of arctic sea ice) and include: • Sea level rise of approximately 70 cm on average. • There is 50% less water availability. • The strongest Northern Atlantic cyclones increase by 80%. • Heat wave and forest fire risk is very high and compromise normal outdoor activities. • Risk to marine fisheries and ecosystems and medium-to-high risk of decline in fish stocks, plus negative aggregate impact on agriculture and food production, increases chance of famine and reductions in food supplies and employment.

Source: Mercer

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Please see the Endnotes for further references made throughout the report.

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