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Climate Change Scenarios – Implications for Strategic Asset Allocation

Public Report

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Project participants:

International Finance Corporation (IFC)
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Norwegian Government Pension Fund, Norway
Ontario Municipal Employees Retirement System (OMERS), Canada
VicSuper Pty Ltd., Australia
PGGM Investments, Netherlands

Mercer team:

Dr. Danyelle Guyatt (Primary Researcher, Project Manager)
Rob Curtis (Lead, Modelling)
Jianchun Wu (Modelling)
Harry Liem (Adviser, Modelling)
Susanna Jacobson (Researcher)
Dr. Jelle Beenen (Adviser)
Divyesh Hindocha (Peer Review, Adviser)
Crispin Lace (Adviser)
Nick Sykes (Adviser)
Rich Nuzum (Adviser)
Jane Ambachtsheer (Project design, Adviser)
Lynn Slipp (Project Management Support)
Laureen Bird (Project Management Support)
Kelly Gauthier (Analyst, Communications)
Matt Damsker (Editor)
Shaun Harding (Legal)
Helga Birgden (Peer Review, Client Management, AsiaPacific)
Craig Metrick (Client Management, US)
Dr. Elisabeth Bourqui (Client Management, Canada)
Rachel Whittaker (Researcher)
Vanessa Hodge (Researcher)
Dr. Xinting Jia (Researcher)
Rebecca Dixon (Researcher)
Deb Clarke (Specialist Input, Equities)
Amarik Ubhi (Specialist Input, Infrastructure)
Paul Cavalier (Specialist Input, Fixed Income)
Sanjay Mistry (Specialist Input, Private Equity)
Paul Richards (Specialist Input, Real Estate)
John Wills (Specialist Input, Real Estate)

The Grantham Research Institute on Climate Change and the Environment, London School of Economics together with Vivid Economics:

Dr. Simon Dietz (Grantham LSE and Vivid Economics)
Dr. Sam Fankhauser (Grantham LSE and Vivid Economics)
Dr. Cameron Hepburn (Grantham LSE and Vivid Economics)
Dr. Alex Bowen (Grantham LSE)
Robin Smale (Vivid Economics)
Helen Jackson (Vivid Economics)
Philip Gradwell (Vivid Economics)
Dr. Robert Ritz (Vivid Economics)

Research group:

Alan Miller (Principal Climate Change Specialist Environment Department, IFC)
Dr. Monica Araya (Senior Associate, E3G, Third Generation Environmentalism, UK)
Ingrid Holmes (Programme Leader Low Carbon Finance, E3G, Third Generation Environmentalism, UK)
Professor Gordon Clark (Halford Mackinder Professor of Geography, Oxford University)
Nick Robins (Head of Climate Change Centre of Excellence, HSBC)
Joaquim de Lima (Global Head of Equity Quantitative Research, HSBC)
Bruce Duguid (Head of Investor Relations, The Carbon Trust)
Garrie Lette (Chief Investment Officer, Catholic Super, Australia)
Stephanie Pfeifer (Executive Director, Institutional Investor's Group on Climate Change)

Other contributors:

Keith Ambachtsheer (Director, Rotman International Centre for Pensions Management, University of Toronto, Canada)
Professor Rob Bauer (Director, European Centre for Corporate Engagement, Maastricht University, the Netherlands)

Quotes from the partners on why they participated in the research

"That climate change poses significant financial and economic risks has only been accentuated by the tens of billions of dollars in losses due to recent climate-related natural disasters such as the floods in Australia and Pakistan and the wildfires in Russia. This study makes a significant contribution to our ability to measure the level of risk that climate change creates for investment portfolios. Managing that risk in a way that maintains the returns expected by beneficiaries is a crucial responsibility for the management of these investment portfolios. This report provides some practical steps that investors can take today to shift their asset allocation to manage climate change risks and finance the much-needed infrastructure for a lower carbon future."

– Rachel Kyte, Vice President, IFC

"This report is unique and groundbreaking in quantifying the increased portfolio risk arising from global efforts to tackle climate change. It demonstrates that unless this risk is tackled intelligently by increasing exposure to climate-sensitive asset classes, then long-term rewards could fall. The findings undermine the notion of a conflict between 'green' investing and acting in beneficiaries long-term financial interests. This will have profound implications for fiduciary duties and places a clear obligation to increase analysis of the consequences of climate change for portfolio management."

– Bruce Duguid, Head of Investor Engagement, The Carbon Trust

Contents

"Why does climate change matter to institutional investors like the Environment Agency pension fund? It matters because we know that we will need to be paying out pensions to our fund members well into the 21st century. We think all pension funds will need to adopt a climate change-proofed financial investment strategy in the future to enable them to fulfill their fiduciary duties. We also want our pensioners to retire into a similar environment that we enjoy today and not one that is affected by the extremes of climate change that could reduce their life expectancy."

– Howard Pearce, Head of Environmental Finance and Pension Fund Management, Environment Agency

"In early 2010, we set a goal to better understand how climate change could be factored into our broad investment actions. For example, should the risk and return impacts of global warming modify our allocation between and within asset classes? The Mercer study has helped clarify our thinking on some of these uncertainties. In our view, the report makes an original contribution by giving financial meaning to recognised climate science (Stern, IPCC) and provides ideas on constructing portfolios acknowledging climate trends. It also raises many more questions and hopefully will stimulate additional in-depth work around investment capital and climate change."

– Doug Pearce, CEO/CIO, British Columbia Investment Management Corporation (bcIMC)

"CalPERS has been a leading advocate for environmental and climate change issues for many years and recognises these to be key risks for long-term investors. This opportunity to collaborate with institutional investors from around the world to look at the impact of climate change scenarios on investments helps us to shape our strategic thinking in this area and better integrate our programs, policies and risk management."

– Joe Dear, CIO, CalPERS

"Climate change is a global risk factor that all long-term investors should take into account when formulating investment strategy. This in-depth analysis will provide valuable input to our long-term strategy reviews."

– Tom A. Fearnley, Investment Director, Norwegian Ministry of Finance, Asset Management Department

"Participating in this project has not only given us better insight of what impact climate change could have on asset classes and the long-term performance of our portfolio; it has also given us enhanced tools for our strategic asset-allocation analysis."

– Johan Magnusson, Managing Director, Första AP-fonden (AP1)

"VicSuper has taken an active position in integrating sustainability into its investment strategy. This has involved investing in low-carbon equity funds such as the Vanguard Carbon Aware International Shares Fund, as well as in venture capital clean technology, which in turn invests in technology and products providing solutions to environmental challenges. Our participation in this *Climate Change Scenarios* report has assisted our thinking in how to integrate climate change risk and opportunity into our investment strategy, and also in ways to access a robust and defensible methodology to assess the possible risk and return implications of climate change. We do this for the benefit of our more than 250,000 members."

– Peter Lunt, Head of Investment Research, VicSuper

"This project has given us insight into the complexity of the effects climate change could have on the risk and return of our portfolio. Climate change proves to be a source of uncertainty. Although there is currently no straightforward answer to managing this uncertainty, we will continue to address this issue in our investment activities."

– Jaap van Dam, Managing Director Strategy, PGGM Investments

Executive summary

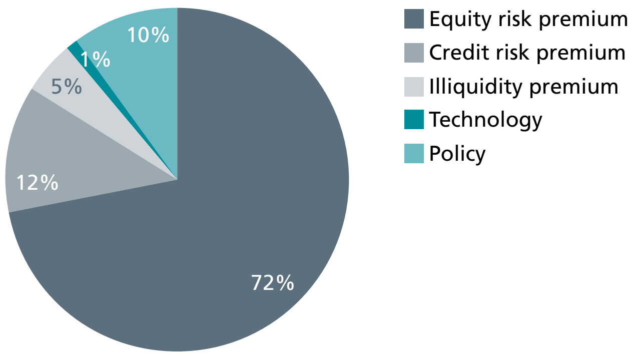
It is widely acknowledged that climate change will have a broad-ranging impact on economies and financial markets over the coming decades. This report analyses the extent of that impact on institutional investment portfolios and identifies a series of pragmatic steps for institutional investors to consider, including allocation to climate-sensitive assets and the adoption of an "early warning" risk management process.

- **Traditional approaches to modelling strategic asset allocation fail to take account of climate change risk:** Strategic asset allocation (SAA) is a key component of the portfolio management process, with some research estimating that more than 90% of the variation in portfolio returns over time is attributable to SAA decisions. While standard approaches to SAA rely heavily on historical quantitative analysis, much of the investment risk around climate change requires the addition of qualitative, forward-looking inputs. Given the unclear climate policy environment and uncertainty around the full economic consequences of climate change, historic precedent is not an effective indicator of future performance.

- **New approaches to Strategic Asset Allocation are therefore required to tackle fundamental shifts in the global economy:** This report uses scenario analysis to anticipate future trends and develops four alternative pathways that might result from climate change. Using the scenarios, the report models climate change risks using the "TIP™ Framework". This framework assesses three variables for climate change risk: the rate of development and opportunities for investment into low carbon technologies (Technology), the extent to which changes to the physical environment will affect investments (Impacts) and the implied cost of carbon and emissions levels resulting from global policy developments (Policy).

- **The "TIP™" framework suggests that climate policy could contribute as much as 10% to overall portfolio risk:** Uncertainty around climate policy is a significant source of portfolio risk for institutional investors to manage over the next 20 years. The economic cost of climate policy for the market to absorb is estimated to amount to as much as approximately $8 trillion cumulatively, by 2030. Additional investment in technology is estimated to increase portfolio risk for a representative portfolio by about 1%, although global investment could accumulate to $4 trillion by 2030, which is expected to be beneficial for many institutional portfolios. The economic model used in this study excludes physical risks of climate change which are not consistently predicted by the range of scientific models, and primarily for this reason concludes that, over the next 20 years, the physical impact of changes to the climate are not likely to affect portfolio risk significantly. However, this does not imply the absence of significant (and growing) risk, as shown by recent climate-related disasters that investors need to monitor closely. See Figure 1 for the contribution to risk for a representative portfolio mix.

Figure 1
Contribution to risk for representative portfolio mix in 'default' case



Source: Mercer

- **To manage climate change risks, institutional investors need to think about diversification across sources of risk rather than across traditional asset classes:** Mitigating climate change risks will require a new approach for investors. The short-term horizon of traditional equity and bond investments means that it will be more difficult for investors to price in long-term risks around climate change compared to some of the more climate sensitive assets. Consequently, the traditional way

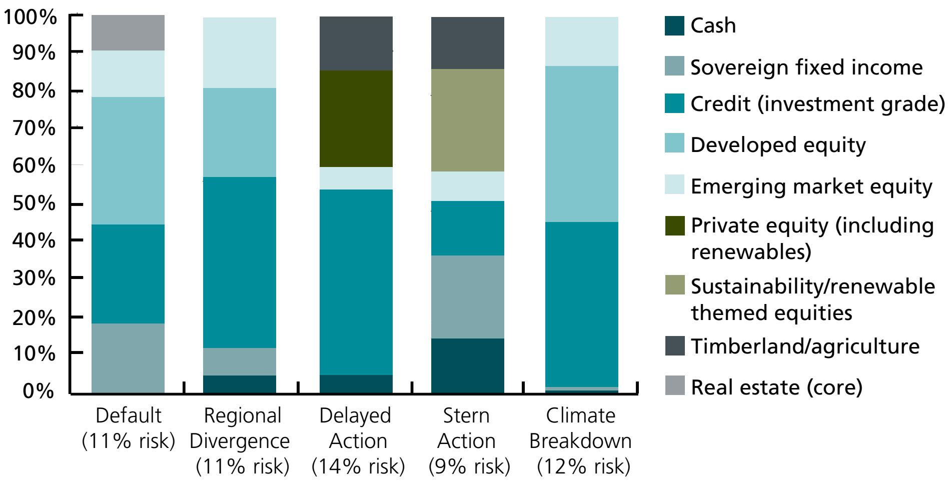
of managing risk through a shift in asset allocation into increased holdings of more conservative, lower risk, lower return asset classes may do little to offset climate risks. Further, in some scenarios such a strategy could result in a decline in returns, adversely affecting long-term portfolio performance and potentially affecting income for beneficiaries.

- **Managing climate change risks could lead to increased allocation to climate sensitive assets:** This report finds that under some scenarios, the best way to manage the portfolio risk associated with climate change, while retaining similar returns, is to increase exposure to those assets that have a higher sensitivity to climate change "TIP™" factors. The analysis suggests that under certain scenarios, a typical portfolio seeking a 7% return could manage the risk of climate change by ensuring around 40% of assets are held in climate-sensitive assets (this includes opportunities across a range of assets including infrastructure, real estate, private equity, agriculture land, timberland and sustainable listed/unlisted assets) – see Figure 2 for an example of asset class portfolio mixes by scenario. Some of these climate sensitive investments might be traditionally deemed as more risky on a standalone basis, but the report shows that selected investments in climate-sensitive assets, with an emphasis on those that can adapt to a low-carbon environment, could actually reduce portfolio risk in some scenarios. This offers the prospect that institutional investors' interests can be aligned to both serve their beneficiaries' financial interests as well as help tackle the wider challenge of climate change by increasing investment in mitigation and adaptation efforts globally. These results imply that typical funds are likely to require a shift in allocation towards more climate sensitive investments, as most will have only limited holdings in these classes. The extent of any shift will also depend on the overall view of the probability of different scenarios taking place.

- **Investors can take steps now to improve the resilience of their portfolios to climate-related risks:** This report proposes a series of pragmatic steps that investors can take today to begin the process of managing climate change risks. Initial actions could include the following: introduce a climate risk assessment into ongoing strategic reviews; increase asset allocation to climate-sensitive assets as a climate "hedge"; use sustainability themed indices in passive portfolios; encourage fund managers to proactively consider and manage climate risks; and engage with companies to request improved disclosure on climate risks. It also highlights the need for investors to communicate with policymakers the need for a clear, credible and internationally coordinated policy response and for dialogue to emphasise the potential economic and financial cost of delay. While many institutional investors might view engagement with policymakers as a separate function from strategic decision-making processes, the findings of this study suggest that it can play a vital role in overall portfolio risk management.

Figure 2

Example of portfolio mix across the scenarios – portfolio to target 7% return



Source: Mercer

Report **Highlights**

"Technologies change, competitive structures change, government policies change, and the way in which they operate change. If we are going to have markets that work well tomorrow, we must be continually concerned that they are going to adapt to new problems and new strategies."

– North (1999:24)

Climate change is a systemic risk

Climate change was described by Nicholas Stern as "the greatest market failure the world has seen" (Stern Review, 2007). But relatively little research has focused on the investment implications of climate change at the total-portfolio level and how institutional investors might respond. That is the purpose of this project.

Uncertainty is a key stumbling block in climate-change research. Every link in the chain of manmade greenhouse gas emissions, physical changes in the climate system and their socioeconomic impacts is highly uncertain. Therefore, investors cannot simply rely on a best guess as to how the future will unfold when planning their investments. Moreover, because many of these uncertainties emanate from complex systems that are poorly understood and difficult to model, climate change has been called a problem of "deep uncertainty" (Lempert, Groves et al, 2006).

In this context, deep uncertainty implies that probabilities cannot be assigned to future states with high confidence. This calls into question the appropriateness of relying too heavily on quantitative modelling tools, for which investors must specify probability distributions to underpin the parameters of their investment models.

Institutional investors must develop new tools to more effectively model systemic risks such as climate change. These tools require an expansion of the way we think about portfolio risk, looking beyond mere volatility. Describing probable scenarios, identifying the potential sources of risks, and measuring and monitoring them over time are the components of an improved risk management strategy that seeks to protect the long-term assets that institutional investors oversee on behalf of their stakeholders.

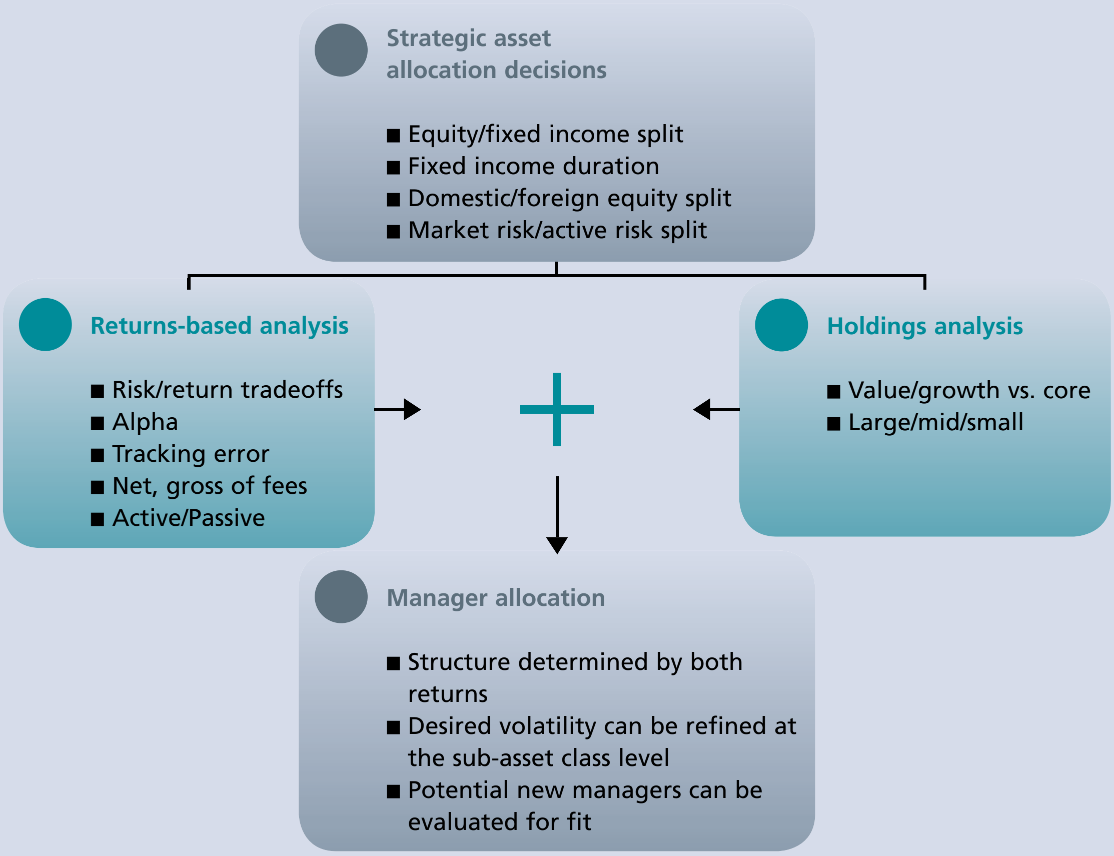
It is in this context that the collaborative group came together to look at the implications of climate change for strategic asset allocation (SAA). Box 1 (on page 5) summarises the role of SAA in the institutional investment management process. Led by Mercer, 14 global institutional investors, the IFC and the Carbon Trust all joined forces to examine what climate change might mean for the underlying drivers of the major asset classes and regions around the world. Grantham LSE/Vivid Economics and a research group composed of specialist practitioners and academics were also involved in parts of the process along the way.

Hightlights Box 1:
Systemic risk and the role of strategic asset allocation

SAA can be broadly defined as the use of optimisation tools by asset owners to determine long-term asset allocation benchmarks to achieve their long-term objectives. The objectives vary depending on the type of asset owner and its obligations to beneficiaries or other stakeholders. For example, the objective may be to generate sufficient returns to hedge liabilities, to protect a reserve pool of assets while minimising risk and maximising return, to minimise variations in contributions for sponsors, or to target a certain funding level.

SAA involves making decisions about allocation to high-level asset classes – that is, equity/fixed split, domestic/international/emerging equity split, duration of fixed income and the split between nominal and inflation-adjusted fixed income, allocation to unlisted assets and sustainability-themed assets. This is distinct from other considerations such as portfolio structuring (including allocation to capital weightings, styles and sectors, and includes active/passive analysis) and manager selection (the evaluation of manager performance in order to select one suitable for a client's requirements).

Below is a visual depiction of the distinction between SAA decisions and other investment decisions.



SAA is a key component of the portfolio management process, with academic research estimating that more than 90% of the variation in portfolio returns over time are attributable to SAA.[1] When considered just in terms of contribution to returns, SAA dominates over market timing and security selection.

This backdrop was relevant for considering the investment implications of climate change, as many investors have, to date, approached climate change primarily from a bottom-up, opportunistic perspective, investing in climate-sensitive securities and assets when opportunities arise. While this is important, it addresses only part of the picture.

Additional consideration should be given to exploring what climate change might mean for the underlying determinants of asset-class risk and return, as well as for overall market risk. Bottom-up analysis may not in itself be sufficient to reveal market shortcomings in the pricing of systemic risks ahead of time, which potentially leaves institutional investors exposed to unexpected adjustment costs from large-scale events, as the global financial crisis has reminded us.

It is therefore prudent for institutional investors to work towards building in, ahead of time (to the extent possible), potentially large-scale systemic risks, such as climate change, into risk management and SAA decision-making processes.[2] This requires the development of a framework to unravel the uncertainties around climate change, combining both top-down and bottom-up tools and processes.

[1] See Brinson et al (1986); Grinblatt and Titman (1989); Brinson et al (1991); Blake et al (1999); and Ibbotson and Kaplan (2000).

[2] See "Beyond the Credit Crisis: The Role of Pension Funds in Moving to a More Sustainable Capital Market" (2009), available at http://www.mercer.com/referencecontent.htm?idContent=1332305.

Traditional asset allocation methodologies do not adequately capture climate change risks

Traditional modelling approaches do not adequately capture the nature of the economic transformation process and the potential source of risks associated with climate change. As such, the tools to integrate climate change into the way we think about SAA risk must be expanded to reflect the following:

1. **Need to embed climate change risk into asset-allocation processes:** Climate change can have a significant impact on the performance of a portfolio mix over the long term, with the primary source of risk resulting from uncertainty about climate policy and its associated adjustment costs. The findings of this study show that for most asset classes, the impact of climate change varies significantly across different scenarios, contributing as much as 10% to portfolio risk for a representative asset mix. This supports the need for a clear climate policy framework as well as ongoing analysis to build these risks into asset-allocation models.

2. **Need to look beyond macroeconomic impacts:** The Grantham LSE/Vivid Economics analysis showed that the potential impact of climate change on GDP, interest rates and inflation across the scenarios magnifies beyond 2050 but will not be the driving force behind investment risks before then. Mercer's analysis indicated that the source of investment risk over the coming 20–30 years will result from increased uncertainty about new technology, physical impacts and climate policy (called the TIP™ factor risk framework).

3. **Need to think about diversification across sources of risk:** To varying degrees, traditional asset allocation techniques optimise portfolio exposure based on assumptions about the risk, return and correlation between asset classes where diversification across assets is sought. An additional tool for this analytic approach is to think of SAA in terms of diversifying across sources of risk, rather than via asset classes per se. This means utilising a factor risk approach to supplement asset-allocation decision making.

4. **Need to be more forward looking:** Climate change requires forward-looking analysis and cannot rely on the traditional technique of modelling historical asset-class relationships. This means utilising tools such as scenario analysis.

5. **Need to go beyond quantitative analysis:** Qualitative factors need to be embedded into the decision-making process. SAA decision-making processes rely heavily on quantitative analysis, whereas much of the investment risk around climate change requires the exercise of judgement about how things might develop in terms of the science of climate change, the policymakers' response and the types of technologies that may or may not prosper.

6. **Need to review assumptions regarding market risk:** Past periods of economic transformation have been associated with a significant change in the realised equity risk premium (ERP)[3] over time, ranging from destructive war-time periods to positive periods of substantial efficiency improvements arising from a growing service sector and innovations in IT. Assumptions regarding the ERP should therefore be reviewed in light of the potential impacts of climate change on the process of economic transformation that may occur in the transition to a low-carbon global economy.

[3] Broadly defined, the ERP represents the compensation for taking on equity risk versus a risk-free rate.

A new framework has been developed to unravel climate change uncertainties

Our goal in this project was to develop a framework to put around climate change that will assist institutional investors in their risk management and SAA processes.

The study's time horizon focused on the potential investment impacts out to 2030. The reason for this is that while strategic investment decisions may be reviewed on an annual basis, they are typically set with a 10+ year horizon in mind. The time path of potential impacts out to 2050 was also considered, to provide investors with a sense of how things might evolve.

The key questions to address are:

1. **What investment risks and climate change issues must institutional investors take into account as part of their strategic decision-making processes?**
2. **What impact could climate change have on different asset classes and regions?**
3. **What actions can institutional investors take?**
4. **What are the messages for climate change policymakers?**

Our framework is built on three elements:

- Developing factors to represent the investment impacts of climate change and linking these factors to the key drivers of different asset returns
- Developing climate-change scenarios and an understanding of how climate change and asset classes may respond in each hypothetical scenario
- Building a simple quantitative framework to test the relationships established in the factor analysis and to decide whether any investor action is appropriate

To better analyse the investment impact of climate change, Mercer developed the TIP™ risk factor framework (Figure 1) to examine which factors drive asset-class returns into the following three areas:

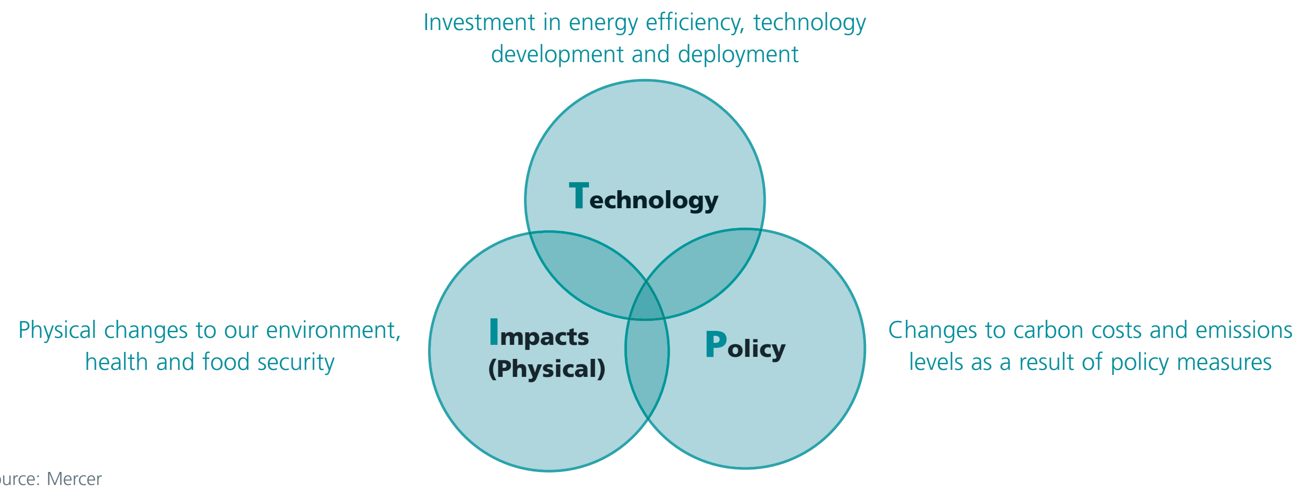
- **Technology** (T) – broadly defined as the rate of progress and investment flows into technology related to low carbon and efficiency, which are expected to provide investment gains
- **Impacts** (I) – the extent to which changes to the physical environment will affect investments (negatively)
- **Policy** (P) – the cost of climate policy in terms of the change in the cost of carbon and emissions levels that result from policy, depending on the extent to which it is coordinated, transparent and timely

These factors are interdependent; hence, the framework cannot be viewed in a linear way. Each factor is a key consideration in future asset performance.

Highlights Figure 1

TIP™=Technology, Impacts and Policy

Factor risk approach to evaluate climate change investment impacts



Source: Mercer

Our goal was not to produce a quantitative analysis that leads to a statistically optimal portfolio for all investors. Indeed, given the uncertainties, we believe that such an aim is unrealistic. Instead, the framework is intended to help investors gain additional insight into the risks within their current investment policies and decide how best to try to manage the added risks arising from climate change.

In considering how climate change might have an impact on a portfolio's asset mix from now until 2030, four scenarios were developed, the key features and outcomes of which are summarised below. The scenarios do not represent a forecast of the future and should not be interpreted in a probabilistic way; rather, they provide a framework for considering the key climate change drivers from an investment perspective over the coming decades. A broad indication as to which scenario is more or less likely to have an impact is indicated in Table 1 (on page 10) to provide some general guidance for interpretation. The likelihood was based on discussions among Mercer, Grantham LSE/ Vivid Economics and the Research Group.

- **Regional Divergence** – Some regions (EU and China/East Asia) demonstrate strong leadership in responding to the need to reduce emissions and act locally, with policy mechanisms ranging from market-based to regulatory solutions. Other regions (Russia) fail to respond and continue their high levels of emissions. Some regions (US, India/South Asia and Japan) fall somewhere in the middle, with local initiatives and measures associated with high policy implementation risk. Overall, this scenario involves a high degree of economic transformation and investment in some regions, but the level of uncertainty increases for investors due to the disparate nature of the policy responses across the different regions, increasing market volatility.

- **Delayed Action** – Business as usual (BAU) continues until the year 2020, when rapid policy measures will be introduced that will lead to significant shifts in behaviour that raise the cost of fossil fuel usage dramatically (such as a global carbon tax) and quickly reduce emissions. There is a high degree of economic transformation led by public sector regulation rather than by private sector innovation; this will necessitate relatively high levels of adjustment costs to comply with the new regulations. After the introduction of regulatory changes, the level of uncertainty regarding climate policy will decline, creating a stronger investment backdrop.

- **Stern Action** – This scenario has been named to reflect the policy response advocated by Nicholas Stern, author of the *Stern Review* (2007). It is the most aggressive scenario in terms of policy response and private-sector innovation. It suggests that there will be swift agreement to a global framework and a very high level of coordination in policy efforts internationally, resulting in a high degree of economic transformation across the global economy, with new investment opportunities as well as risks. The uncertainties are lower than for the other scenarios, as investors are able to predict the pathways of policies with a reasonable degree of confidence, as policies are implemented in a very transparent and orderly manner internationally. This scenario will be associated with a higher economic cost, in order to achieve the level of abatement in emissions; however, the GDP impact is expected to be secondary in driving asset-class returns within our report's time horizon. Less uncertainty for investors about climate policy and new technology investments will be the major drivers of positive transformation.

- **Climate Breakdown** – The status quo prevails in terms of policy, business and consumer behaviour. With continued reliance on fossil fuels, carbon emissions remain high and there is little economic transformation. The investment impacts are hard to predict, although the risk of catastrophic climate-related events increases significantly over time, reaching critical levels towards the end of this century. This scenario brings potentially very high risks for investors over the long term, particularly for regions, assets and sectors that are most sensitive to the physical impacts of climate change.

Highlights Table 1

Key features and potential outcomes of the climate scenarios to 2030

Scenario	Global policy response	Carbon cost (in 2030)	Emissions levels (now to 2030)
Regional Divergence *(Most likely)*	**Divergent and unpredictable** – Framework agreed to succeed Kyoto Protocol – Targets announced of medium ambition	Cost of carbon \$110/tCO_2e in all countries in this study (EU, US, China/East Asia and Japan) except India/South Asia and Russia	50 Gt[4] CO_2e emissions per year in 2030 (equivalent to -20% from BAU)
Delayed Action *(Close second in likelihood)*	**Late and led by hard policy measures** – Strong mitigation, but only after 2020, when sudden drive by major emitting nations results in hasty agreement – Very little support to vulnerable regions on adaptation	Cost of carbon \$15/tCO_2e to 2020, then dramatic rise to \$220/tCO_2e globally (not unanticipated by the market)	40 Gt CO_2e emissions per year in 2030 (equivalent to -40% from BAU)
Stern Action *(Much less likely)*	**Strong, transparent and internationally coordinated action** – Generous support to vulnerable regions for adaptation	Cost of carbon \$110/tCO_2e globally (anticipated by the market)	30 Gt CO_2e emissions per year in 2030 (equivalent to -50% from BAU)
Climate Breakdown *(Least likely)*	**BAU; no mitigation beyond current efforts** – Very little support to vulnerable regions for adaptation	Cost of carbon \$15/tCO_2e limited to the EU Emissions Trading Scheme regional schemes and implicit cost of carbon estimates	63 Gt CO_2e emissions per year in 2030 (equivalent to BAU)

Source: Grantham Research Institute LSE/Vivid Economics

[4] "Gt" refers to gigatonne, which equals 1,000 million tonnes of CO_2e emissions.

Key findings of climate change impacts on investments

1. Climate change increases investment risk: Climate change increases the uncertainty and event risk that could have an impact on the realised returns for risky assets across the scenarios, with higher risk resulting from inefficient policy (see Table 2).

2. Technology investments could accumulate to $5 trillion by 2030: The private-sector response to changing environmental conditions, new technology and policy measures may produce a substantial number of new investment opportunities. According to Grantham LSE/Vivid Economics, by 2050 fossil-fuel use could decline by as much as two-thirds under Stern Action. Figure 2 shows the shift in energy demand and

Highlights Table 2

Impact of scenarios on source of investment risks

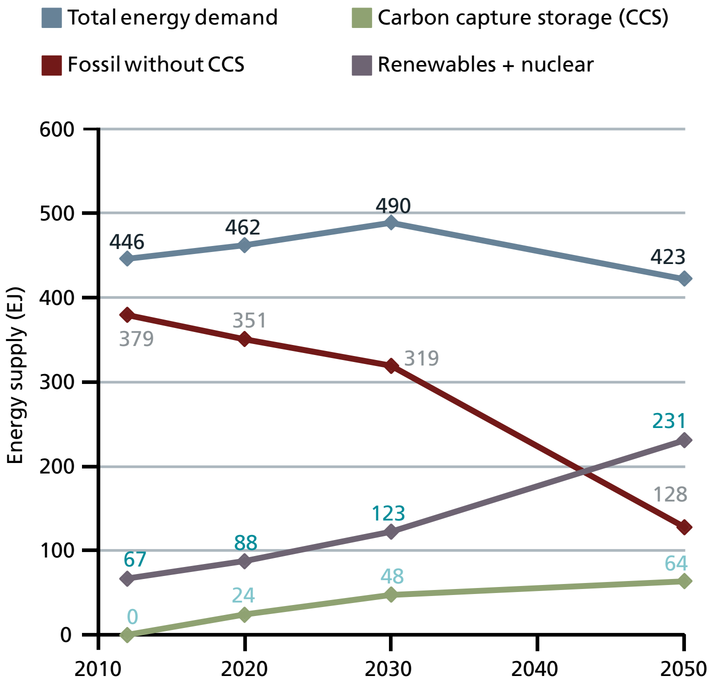
Scenario	Fundamental factors	Market factors	Climate change factors		
	Economic cycle Inflation	*ERP Volatility*	*Technology*	*Impact*	*Policy*
Regional Divergence	Unchanged	Higher volatility	High dispersion of capital inflow into low-carbon investments; leading countries include the EU and China	Higher risk of future impact costs due to slower reduction in emissions	Higher uncertainty and potentially higher reward for some assets due to regional disparity in climate policy
Delayed Action	Higher inflation Higher interest rates	Higher volatility Lower realised ERP	Business as usual (BAU) investment in low carbon until 2020 when policy measures stimulate flows	Higher risk of future impact costs due to delay in policy response	Higher uncertainty around policy until 2020, then dramatic U-turn reduces policy uncertainty
Stern Action	Unchanged	Lower volatility Higher realised ERP	Clarity on climate policy stimulates strong capital flows into low-carbon solutions	Lower risk of future impact costs due to reduction in emissions	Policy clarity at the global level reduces investment uncertainty
Climate Breakdown	Unchanged	Unchanged; risk of higher volatility	Higher risk attached to low-carbon technology investments due to policy inaction	Higher impact risks due to lack of policy action, rising future costs and market pricing in future policy shift	BAU climate policy (unchanged from today's measures)

Source: Mercer

supply under Stern Action. About two-thirds of the shift is attributable to lower overall energy demand, primarily due to improvements in energy efficiency, while the remaining third results from supply-side changes. Mercer estimates, based on International Energy Agency data, suggest that additional cumulative investment in efficiency improvements, renewable energy, biofuels, and nuclear and carbon capture and storage (CCS) could expand in the range of $3 trillion to $5 trillion by 2030 across the mitigation scenarios examined in this study. This presents meaningful investment opportunities that are still in their infant stages.

Highlights Figure 2

Renewables and nuclear overtake fossil fuels, in Stern Action scenario, by 2050



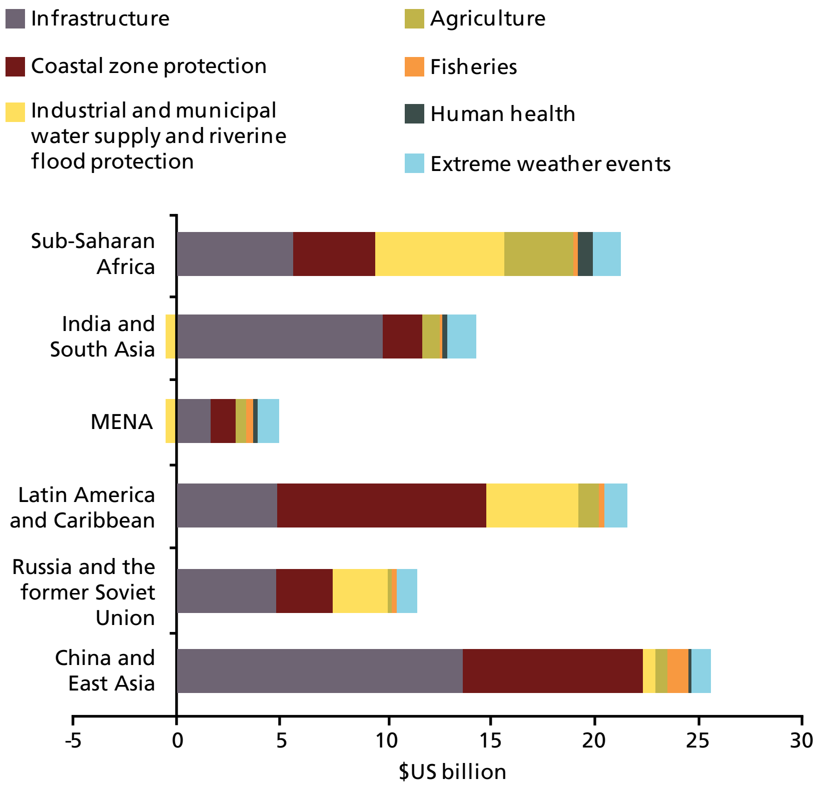
Source: Grantham LSE/Vivid Economics, based on Edenhofer et al (2009)

3. **Impact costs could accumulate to $4 trillion by 2030:** Grantham LSE/Vivid Economics have estimated that the cumulative economic cost of changes to the physical environment, health and food security across the climate scenarios could be in the range of $2 trillion to $4 trillion by 2030, with costs rising the greater the delay and the less well-coordinated the policy response. Most adaptation costs come from infrastructure (for example, transport and coastal zone protection, such as flood defence) sectors; though in Africa, water supply and agriculture comprise more than half of all costs (see Figure 3).

Perhaps the most important issue that is not reflected in these estimates is the impact of climate change in the longer run. Since many of the greenhouse gases emitted today (particularly CO_2) might still reside in the atmosphere until 2100 and beyond, emissions reductions are required in the short term in order to avoid them. As a result, consistent with the Stern Review (2007), the cost of climate change will rise rapidly after 2050.

It is also important to bear in mind that the direct, economically realised costs of climate change may reflect only a fraction of total costs incurred, particularly in developing countries. Property insurance, for example, is much more extensive in the industrialised world than it is in developing countries, such that many losses in the latter may be uncompensated but nevertheless real. By way of illustration, costs incurred from the Pakistani flood damage in 2010 were calculated to be up to $43 billion. Climate damage is therefore an important risk for institutional investors to manage, both in terms of asset sensitivity and in terms of influencing policy outcomes to mitigate, and adapt to, these risks.

Highlights Figure 3
Adaptation costs in 2030 for Climate Breakdown scenario



Source: Grantham Research Institute/Vivid Economics calculations, based on World Bank (2009a)

4. Policy measures could increase the cost of carbon emissions by as much as $8 trillion cumulatively, by 2030: The future cost of carbon emissions increases the longer the policy delay and the less well-anticipated and coordinated the policy action is. Grantham LSE/Vivid Economics has estimated that the cost of carbon could be \$110/tCO_2e to \$220/tCO_2e by 2030 across the mitigation scenarios, compared to the current EU Emissions Trading Scheme (ETS) price equivalent of approximately \$15/tCO_2e. These costs may be explicit in the market or implicit costs that affect operating costs outside of emission trading schemes.[5]

[5] For a discussion of the implicit price of carbon and estimates, see Vivid Economics, *The Implicit Price of Carbon in the Electricity Sector of Six Major Economies*, October 2010, available at http://www.interactivemediarelease.com/ogilvy/ClimateInstitute.

Highlights Figure 4

Climate change risks – **TIP™** framework formulation

Technology: $ size of additional low carbon investment flows by 2030	**Impacts:** $ cost of physical climate change impacts by 2030	**Policy:** $ change in cost of emissions to 2030 as a result of climate policy
Cumulative additional investment in efficiency improvements, renewable energy, biofuels, nuclear and CCS to 2030 (Source: derived by Mercer from IEA WEO 2009)	Cumulative economic cost of changes to the physical environment, health and food security to 2030 (Source: estimates by Grantham LSE/ Vivid Economics)	Change in cost of emissions = [2030 Emissions x $ / tCO_2e] – [2010 Emissions x $ / tCO_2e] (Source: CAIT and Grantham LSE/Vivid Economics)
IEA estimates modified according to different degree of mitigation across scenarios. Climate Breakdown is baseline investment flows that would happen without additional mitigation	Calculations by Grantham LSE/Vivid Economics, using Hope's PAGE2002 model estimates and data on adaptation costs from the World Bank/United Nations Framework Convention on Climate Change (UNFCCC)	Carbon price derived by Grantham LSE/Vivid Economics from the WITCH model; emissions derived by Grantham LSE/Vivid Economics based on Bowen & Ranger, 2009 and IEA 2009
Result: The value of additional investments in these assets will grow by between $180 bn to $260 bn pa to 2030 for all mitigation scenarios, with Stern Action at the upper end	Result: The costs range in the order of $70 bn to $180 bn pa globally in terms of adaptation and residual damage costs, with Climate Breakdown the highest cost	Result: The increase in the cost of emissions from 2010 to 2030 ranges between $130 bn and $400 bn pa globally, with Delayed Action the most costly due to late and unanticipated policy

Source: Mercer. The factors have been discounted to the net present value using a 3% discount rate. This was chosen based on a composite of global 10-year bond yields as at October 2010.

5. **Infrastructure, private equity, real estate and some commodities are highly sensitive to climate change:** The results of the asset-class impacts are summarised in Table 3, where the overall sensitivity of each asset-class to the climate-change TIP™ risk factors is presented in the highlighted section at the top of the table, with the direction of the impact (positive, negative or neutral) denoted by the colour.

6. **Sustainable assets could act as a hedge:** As Figure 5 highlights, sustainable assets perform comparatively well across the mitigation scenarios compared to core assets.[6] The exception to this is Climate Breakdown, which is not surprising, as this assumes no further progress on policy from where we are today. Exposure to sustainable-themed equities, efficiency/renewables in listed and unlisted assets, timberland and agricultural land could therefore improve the resilience of a portfolio mix across the climate scenarios.

Highlights Table 3

TIP™ factor risk sensitivity and direction of impact for asset classes

Sensitivity of the impact: where L = Low; M = Moderate; H = High; VH = Very high sensitivity to the combined climate change factors.

Direction of the impact: where ■ = Positive; ■ = Neutral; and ■ = Negative. Agriculture = agricultural land; RE = real estate; Infra = infrastructure; EME = emerging-market equity; EMD = emerging-market debt; LBO = leveraged buyout; VC = venture capital.

	Listed equities				Fixed income			Commodities		RE	Private equity			Infra	
	Global equity	EME	Sustainable equity	Efficiency/renewables	Global fixed	EMD	Inv grade credit	Agricultural land	Timberland	Unlisted	LBO	VC	Efficiency/renewables	Core, unlisted	Efficiency/renewables
Sensitivity	L	M	H	VH	L	M	L	H	H	H	M	H	VH	H	VH
Regional Divergence	Neutral	Neutral	Positive	Positive	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Positive	Neutral	Positive
Delayed Action	Negative	Negative	Positive	Positive	Neutral	Negative	Negative	Neutral	Positive	Negative	Negative	Negative	Positive	Negative	Positive
Stern Action	Positive	Positive	Positive	Positive	Neutral	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
Climate Breakdown	Neutral	Negative	Negative	Negative	Neutral	Negative	Neutral	Negative	Negative	Negative	Neutral	Neutral	Negative	Negative	Negative

Source: Mercer. Sustainable equity = broad multi-themed listed equity companies that generate a substantial proportion (typically more than 25%) of their earnings through sustainable activities. Efficiency/renewables assets = both listed/unlisted sustainability themed assets whose core activities are theme specific and more concentrated in terms of exposure than are broad sustainability equity. This includes (but is not limited to) energy efficiency, low energy transport, renewable energy, bioenergy, carbon capture and storage, smart grid, water supply, usage and management, waste management, hydro energy and geothermal, to name a few.

[6] "Sustainable assets" refer to investments that generate a substantial proportion (typically, more than 25%) of their earnings through sustainable activities. At its broadest level, sustainable investment seeks to support sustainable economic development, enhance quality of life and safeguard the environment. This includes sustainable themes such as energy efficiency, low energy transport, renewable energy, bioenergy, carbon capture and storage, smart grid, water supply, usage and management, waste management, hydro energy, geothermal and biofuel, to name a few.

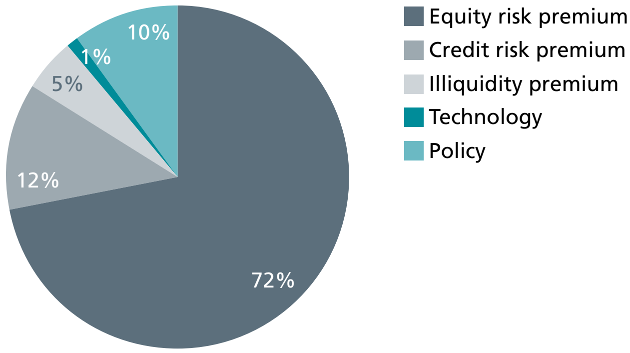
7. Climate policy is a significant contributor to portfolio risk: Understanding the exposure of a portfolio to the underlying return drivers is a key component of strategic decision making, which is what Figure 6 attempts to measure through incorporating TIP™ factor risks alongside more traditional risk factors for a representative portfolio. The existence of risk exposure does not necessarily imply lower returns, as exposure can be associated with superior returns under different market conditions. The aim is to unravel the sources of portfolio risk and diversify across the return drivers, as opposed to simply diversifying between asset classes.

Using Mercer's proprietary Growth Portfolio Toolkit (GPT), the example is calculated on a hypothetical but representative portfolio of a typical asset mix, with allocation of 34% developed large-cap equities, 13% emerging-market equities, 18% global government bonds, 26% investment-grade credit and 9% property.[7] As can be seen, most of the risk comes through the ERP, as the portfolio has a high exposure to equities. This can be improved by allocation to a wider range of assets, as we will see later in this report.

The results show that the climate policy (P) factor of the TIP™ framework contributes 10% to portfolio risk in this example, with technology (T) contributing just over 1% risk. Impact risk (I) does not appear as a contributor to risk. This can be explained by the small allocation to climate-sensitive assets included in this example that have a higher sensitivity to impact risks (real estate, infrastructure and commodities), along with the evidence pointing to a lower variability in the impact risk factor to 2030 (with risks increasing considerably beyond 2050).[8]

Highlights Figure 5

Contribution to risk for representative portfolio mix



Source: Mercer

8. Allocation to sustainable equities, efficiency/ renewable assets, timberland and agriculture land could improve portfolio resilience: Below is an illustrative example of the potential impact of these asset-class sensitivities on a portfolio mix, based on optimisation to a nominal return of 7%[9] that allows for allocation to a wider set of assets. As can be seen, in the Delayed Action and Stern Action scenarios a sizeable allocation to some of the climate-sensitive assets (up to 40% of the total portfolio) is suggested. Opportunistic investments in the Regional Divergence scenario will also be beneficial in the leading regions. Importantly, the risk associated with each scenario varies, too, reflecting the higher level of uncertainty associated with the Delayed Action scenario (14% risk) compared to the Stern Action scenario (9% risk). Climate Breakdown is quite similar to the default case, as it is essentially BAU out to 2030, although future risks will increase dramatically in Climate Breakdown beyond 2050 – hence, a longer horizon would produce more notable differences.

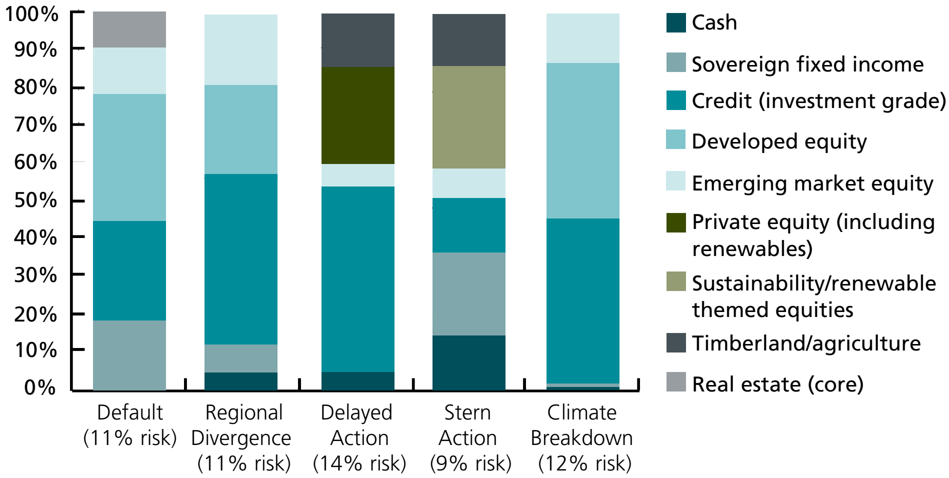
[7] The approach underpinning the growth portfolio toolkit and factor risk approach to asset allocation are explained in the Methodology section (on page 93). Also see Hawker G. "Diversification: A Look at Risk Factors" (2010), available at http://www.mercer.com/referencecontent.htm?idContent=1378620. For further explanation of the impact risks, please refer to "Mapping Evidence to Scenarios" on page 75.

[8] For further explanation of the impact risks, please refer to "Mapping Evidence to Scenarios" on page 75.

[9] The chart shows the optimal portfolio to target nominal return of 7% in each scenario compared to the neutral scenario that does not take climate-risk impacts into account. Risk refers to the standard deviation in returns. The results should not be used to imply that the most appropriate portfolio to meet these objectives is exactly as shown. This will depend on factors such as an institution's existing asset mix, cash rate for the country in which the investor is based, funding position, degree of risk appetite, investment restrictions and any changes to the assumptions made for risk/return and correlations that may be considered appropriate and potentially have a significant impact on results. For example, while infrastructure is not included within the allocations shown in the chart, an allocation to infrastructure may be appropriate based on the rationale provided in this report and the specific opportunities available for investment.

Highlights Figure 6

Portfolio to target 7% (nominal) return



Source: Mercer

9. **The EU and China are set to lead the low-carbon transformation:** The regions that are best placed to lead the climate change transformation are those that pre-emptively find alternative sources of energy, improve efficiency, reduce carbon emissions and invest in new technology. Indicators of current and future investment flows and policy measures out to 2030 suggest that the "leaders" are likely to be the EU and China/East Asia (see Table 4, with sensitivity at the top and direction denoted by the colour). The potential for low-carbon transformation in the US is also significant in the best-case scenario of Stern Action, but a political impasse on climate change suggests it may lag in the other mitigation scenarios, with "improver" countries, including Japan and India/South Asia, coming through.

While the "do nothing" (Climate Breakdown) scenario may appear to have lower risk than the Delayed Action scenario across the regions, that is because this study focuses on the investment impacts over the next 20 years when the policy costs will need to be absorbed. Grantham LSE/Vivid Economics point out that the physical impact costs, as well as the policy adjustment costs, will rise substantially in the Climate Breakdown scenario beyond 2050 in the absence of any action.

Highlights Table 4

TIP™ factor risk sensitivity and direction of impact for regions

[green] = Positive; [orange] = Neutral; and [red] = Negative in terms of the direction of the impact for investments for each region.

TIP sensitivity	EU	US	Japan	China/East Asia	Russia	India/South Asia
Sensitivity	Moderate	High	Moderate	High	Moderate	Moderate
Regional Divergence	Positive	Neutral	Neutral	Positive	Negative	Neutral
Delayed Action	Negative	Negative	Negative	Negative	Negative	Negative
Stern Action	Positive	Positive	Positive	Positive	Neutral	Positive
Climate Breakdown	Neutral	Neutral	Neutral	Negative	Neutral	Negative

Source: Mercer assessment as per aggregate estimates, using T, I and P data available at the regional level. Direction of impact derived through a qualitative process.

10. **Health impacts and population migration risks are underestimated:** These risks can potentially have an impact on long-term liabilities and affect assumptions around mortality rates. At present, the evidence available is not sufficiently strong to draw meaningful conclusions. The health effects will be both positive and negative, and the timing in which they will become pronounced is uncertain. The research on population migration impacts is sporadic and qualitative, and further research will be required to evaluate the potential impact on pension fund liabilities. Grantham LSE/Vivid Economics highlight that the existing studies omit potentially important sources of mortality, including malnutrition and deaths from extreme events. So they are likely to underestimate the increases in illness and death between now and 2050.

Actions for institutional investors to consider

Institutional investors can respond to the findings of this study in a number of ways. The most important step will be to consider climate change in strategic discussions of long-term investment risks and opportunities. The framework is not intended to provide a simplistic "tick box" solution for investors to apply in a mechanistic way but to help provide a better understanding of the driving forces behind climate change, the sensitivity of asset classes and regions to these drivers, and the uncertainties that remain, opening the way to further debate and discussion among investment decision makers.

Given the high level of uncertainty associated with climate change, we caution against optimising portfolio holdings to any one scenario presented in this report. Actions to consider:

1. **Understand the risks associated with climate change and embed these into asset-allocation policies.** Monitor the evidence related to climate change in terms of technology, impacts and policy, and discuss what features of the climate scenarios are emerging and what this means for your investments. This could be built into your annual strategic review and risk management assessments.

2. **Evolve and transform portfolio mix.** Rather than optimising to any one scenario as presented in this report, investors could consider a gradual rebalancing of a portfolio towards climate-sensitive assets that are also tilted towards the sustainability theme across infrastructure, private equity, real estate, timberland and agricultural land. This could help to diversify across the sources of investment risk (including climate change) and improve portfolio resilience across the mitigation scenarios.

3. **Allocate to sustainable assets.** An additional response might be an allocation to sustainable investments across both listed and unlisted assets. This could be viewed as a hedge against some of the risks around climate change, particularly climate policy. The risks and opportunities within each asset class, as highlighted in this report, could be used as an initial guide for the selection of the type of investments that might feature in a well-diversified portfolio.

4. **Consider a wider pool of passive options.** Where portfolios are passively managed, consider investing in a wider pool of products against different (environmental) indices to better capture the potential upside and/or help mitigate the risks of climate change. Passive equity investors should consider the index constituents and the weighting attached to sustainability issues when considering benchmarks for their investments. They can also exercise their ownership rights through voting and engagement on climate-change issues, either directly, through third-party agencies or via the provider of the passive index product, where appropriate. Under both the Delayed Action and Stern Action scenarios, for example, an allocation to sustainable equities appeared as part of the portfolio mix.

5. **Engage with active fund managers.** This will help to ensure that your portfolio is better positioned for responding to the uncertainties in a way that helps reduce the risk of being too late, reactive and costly. Ask your fund managers to specify key criteria and pressure points that they will measure and integrate into their investment processes. This might include an ongoing assessment of climate policy developments, cost-of-carbon scenario analysis, the impact of technology flows on risks and opportunities, and an evaluation of any possible risks from climate damage, including on assumptions regarding expected returns such as the ERP.

6. **Engage with companies.** Institutional investors should engage with companies in which they are invested on climate risk management issues to proactively manage the risks. This will include requests for improved disclosure of emissions levels, environmental impact assessments, as well as full disclosure and reporting of sustainability management policies and practices. This can be undertaken collaboratively through initiatives such as the Carbon Disclosure Project, the Water Disclosure Project, the UN Principles for Responsible Investment, or through investor groups such as the Institutional Investors Group on Climate Change (in Europe), the Investor Network on Climate Risk (in the US) and the Investor Group on Climate Change (Australia/New Zealand), to name a few. It could also be undertaken through third-party engagement agencies, via fund managers that are delegated with the management responsibility or, where the assets are managed internally, through asset owners, who can engage directly with investee companies on these issues.

7. **Engage with policymakers.** This study showed that climate policy uncertainty is a notable source of risk for investors over the coming 20 years, contributing as much as 10% to risk for a representative portfolio. Stretching further into the future, the longer the policy delay, the higher the impact costs will be for investors. It is therefore crucial for institutional investors to engage with policymakers on the specific details of policy plans and measures as part of their risk management process, to help protect and enhance the long-term value of the assets they oversee. This should go beyond high-level motherhood statements and should be appropriately resourced and focused on targeting specific policy measures at the local and global levels, to actively manage the policy risk that climate change produces.

8. **Support ongoing research.** Consider areas for further research and look for collaborative opportunities to support these endeavors with academics, policymakers and relevant experts. Some ideas include the following:

- **Continue to evaluate the impact of climate change on strategic decision making.** This study developed a framework with which to examine climate change and its potential impact on long-term risks/returns across asset classes and regions. However, institutional investors need to apply the results to their portfolios to evaluate the risks they face and internalise the framework into their decision-making processes. This will also involve supporting the development of new tools and approaches as the climate change data and evidence changes over time.

- **Spend time exploring the best way to build exposure.** The implementation of the findings of this study at the asset-class and regional levels needs to be carefully considered in terms of the right vehicle to use and the preferable approach to take. It is essential for institutional investors to spend time considering ways to allocate to the opportunities across the asset classes in a cost-effective and prudent manner. This means exploring the costs and benefits of investing in funds, fund of funds, co-investments or public-private sector partnerships, and/or making direct investments in projects.

- **Monitor the scientific evidence on the physical impacts of climate change.** The range of uncertainty in projecting long-term climate impacts is wide ranging due to many unknowns in the causal chain of climate impacts. For example, if tensions over water resources increase due to droughts, the result could be social pressures leading to changes in governments, migration and conflict. Costs could easily be much greater than the range estimated in this report. Investors therefore need to monitor new scientific evidence and social pressures related to climate change.

- **Research the impact on pensions of population migration.** This study highlighted the lack of research on the potential impact of climate change on population migration, including what regions will be most affected, how governments are likely to respond and what implications may arise for pension funds around the world. Research of this kind, with the participation of the actuarial community, would enable better analysis of the impact of climate change on liabilities than is currently available.

Messages for policymakers

The key messages for policymakers from this study are:

1. **Policy is crucial for mobilising capital.** The policy environment is one of the key factors that investors will consider when deliberating about climate change, as it will be an important signal for future investment in technology-related opportunities and also potential risks associated with changes to the physical environment. Indeed, the risk that investors will attach to such investments under a clear and well-coordinated policy framework is considerably lower than a late or disparate policy approach.

2. **Make policies clear, credible and coordinated.** Policy design needs to be clear, credible and well-coordinated internationally to attract institutional assets and to help reduce risk premiums assigned to riskier investments. A high level of policy uncertainty will increase volatility and lead investors to demand a higher risk premium on their investments than would otherwise be the case.

3. **Delay now, pay (more) later.** Our Delayed Action scenario predicts that most core assets will suffer as a result of unforeseen and dramatic policy action. If this situation emerges, investors will demand a higher cost of capital in the future as risk aversion rises. The investment impact of this scenario is negative for all countries/regions – as the future cost of carbon rises, the longer the delay will be, meaning there will be no long-term winners from a delayed response (although some countries may pose a greater investment risk than others). Many investors may be reluctant to invest in low-carbon opportunities until the policy framework is in place, potentially increasing the required rate of return on such investments in the intervening period.

Overview of **investment impacts**

This section presents the highlights of the investment impacts, with further details provided on each asset class and region in Sections 2 and 3, respectively. This will be presented in seven parts:

1. Source of investment risk across the climate scenarios
2. Sensitivity of assets to investment risk
3. Impact on the equity risk premium (ERP)
4. Estimates of TIP™ risk factors
5. Sensitivity of assets to the TIP™ risk factors
6. Sensitivity of regions to the TIP™ risk factors
7. Quantitative analysis

Source of investment risk across the climate scenarios

Table 1 presents Mercer's interpretation of how the different sources of investment risk vary for each climate scenario. This was derived through a qualitative process that followed a series of discussions between the Mercer project team and in-house asset-class experts, the Research Group and the rest of the project group participants (see Methodology, on page 93, for further details).

The greatest sources of investment risk across the climate scenarios are expected to come through changes to climate change risks and (to a lesser extent) market risks, rather than through fundamental risks. A few additional observations:

- Fundamental risk factors – the fundamental risks are not expected to change for most of the climate scenarios. This is largely based on the Grantham LSE/Vivid Economics finding that the macroeconomic impacts become more pronounced beyond the time horizon of this study – that is, beyond 2050. The exception to this is the Delayed Action scenario, in which inflation and interest rates increase due to an (unanticipated) carbon price shock.

- Market risk factors – the ERP and volatility are expected to change in the more extreme mitigation scenarios, in which policy changes and the degree of transformation in technology increase. This expectation is based on comparable periods in history that have produced a significant difference between historical risk premiums over time due to transformative events (see discussion below for further details).

- Climate change risk factors – changes in technology and climate policy are the driving forces behind the differences across the climate scenarios. Where policy measures are anticipated by the market (Stern Action), the result is generally more favourable for the assets most sensitive to climate change. A more detailed discussion of the sources of risk around climate change is provided below.

Table 1
Impact of scenarios on sources of investment risk

Scenario	Fundamental factors	Market factors	Climate change factors		
	Economic cycle Inflation	*ERP Volatility*	*Technology*	*Impact*	*Policy*
Regional Divergence	Unchanged	Higher volatility	High dispersion of capital inflow into low-carbon investments; leading countries include the EU and China	Higher risk of future impact costs due to slower reduction in emissions	Higher uncertainty and potentially higher reward for some assets due to regional disparity in climate policy
Delayed Action	Higher inflation Higher interest rates	Higher volatility Lower realised ERP	Business as usual (BAU) investment in low carbon until 2020 when policy measures stimulate flows	Higher risk of future impact costs due to delay in policy response	Higher uncertainty around policy until 2020, then dramatic U-turn reduces policy uncertainty
Stern Action	Unchanged	Lower volatility Higher realised ERP	Clarity on climate policy stimulates strong capital flows into low-carbon solutions	Lower risk of future impact costs due to reduction in emissions	Policy clarity at the global level reduces investment uncertainty
Climate Breakdown	Unchanged	Unchanged; risk of higher volatility	Higher risk attached to low-carbon technology investments due to policy inaction	Higher impact risks due to lack of policy action, rising future costs and market pricing in future policy shift	BAU climate policy (unchanged from today's measures)

Source: Mercer

Sensitivity of assets to investment risks

The sensitivity of each asset class to the different sources of investment risk is presented in Table 2, where the asset classes are located according to whether they have a high or very high sensitivity to each source of risk. Some of these risks can be quantified, such as the ERP and volatility. However, some risks cannot be quantified but are still important to consider as part of the risks associated with an investment strategy.[10] A few highlights from Table 2:

- Listed equities, government bonds and investment grade credit all have high sensitivity to fundamental risk factors but not to climate change factors.
- In contrast, real estate, infrastructure, private equity, sustainable equities, efficiency/renewables and commodities are highly sensitive to climate change factors.

To put it simply, this means that portfolios that are dominated by listed equities and bonds may not be as sensitive to climate change, which may be a positive outcome under a "no mitigation" scenario such as Climate Breakdown (which is also the least likely scenario). For all the other scenarios where some degree of mitigation will occur, there will be portfolios with a low allocation to assets that are sensitive to climate change may be less resilient in terms of both the risks and the opportunities.

Table 2
Assets with high or very high sensitivity to investment risks

Fundamental factors	Market factors	Climate change factors
Economic cycle *Inflation*	*ERP* *Volatility*	*Technology* *Impact* *Policy*
Listed equities Emerging equities Government bonds Emerging debt Investment-grade credit Commodities	Listed equities Private equity Infrastructure Real estate	Real estate Infrastructure Private equity Sustainable equities Efficiency/renewables Commodities

Source: Mercer

[10] See "Diversification: A Look at Factor Risks", available at http://www.mercer.com.br/referencecontent.htm?idContent=1399985.

Impact on equity risk premium

Broadly defined, the ERP represents the compensation for taking on equity risk versus a risk-free rate. The notion of the ERP is widely used in finance models and also features as an input into the way Mercer develops some of its asset-class assumptions. Hence, it is important to consider whether the climate-change scenarios might impact the ERP and, if so, in what way and by how much. The following ERP discussion focuses on realised returns for an existing portfolio of assets at a future point in time, which is most commonly referred to as the Historical Equity Premium. This is because the study is evaluating the outcome/consequence of different climate scenarios for an existing portfolio of assets, starting from today and looking at the outcomes at a future end date (in this case 2030).

As Damodaran (2008) summarises,[11] the ERP assumption reflects a fundamental judgement about how much risk we see in the market and what price we attach to that risk. Some of the key determinants of the ERP and a possible link to climate change factors are:

- **Overall risk aversion** – This may increase in scenarios where climate change increases the overall level of uncertainty, as well as in situations where there is a period of transformation in the economy that is costly and unanticipated.

- **The degree of uncertainty** – The sources of uncertainty associated with each climate scenario relate to the degree of technology development and deployment, climate policy transparency and coordination, and physical impact risks.

- **The level and reliability of available information** – Poor transparency on climate-change-related risks combined with increased uncertainty about how to interpret new information could make investors less certain about the future and lead to higher risk premiums.

- **Catastrophic/event risk** – Past examples of catastrophic risks that can cause dramatic drops in wealth include the Great Depression of 1929–1930 in the US and the collapse of Japanese equities in the 1980s. It is not inconceivable that climate change increases the prospect of potentially large and persistent event risks related to water or resource scarcity (creating geopolitical tensions) and large-scale weather-related events. While such climate-related events cannot be predicted, the scientific evidence suggests that the incidence and magnitude of such events are likely to increase, owing to climate change, in which case the ERP will need to reflect that risk.

Damodaran considers three approaches to estimating risk premiums, including the survey approach, the historical premium approach and the implied premium approach. For climate change it is not possible to infer the premium on the basis of historical or implied market data, as the market is not yet pricing in climate risk in a meaningful way, and additionally, it would not allow us to capture how the ERP might change under alternative climate scenarios. Hence, we have formulated a possible directional impact on ERP assumptions based on a qualitative in-house assessment within Mercer and consultation with the project group on how the ERP might change under the climate scenarios.[12]

In addition to this analysis we have also drawn from lessons in the past – in particular, the findings of Dimson et al (2003)[13] on how the historical ERP changed from the first half of the 20th century compared to the second half. In brief, the authors found that the ERP versus Treasury bills was 4.1% in the first half of the 20th century and 7.7% in the second half. In other words, there was a 3.6% difference in the ERP between the first and second halves of the century. This was based on 16 countries and 102 years of data.

There are obviously a range of possible explanations for this divergence, but the authors deduced that periods of turmoil and economic/political uncertainty – such as the first half of the century, with two world wars and the Great Depression – were associated with lower realised return on riskier assets. In contrast, periods of progress and technological advancement – such as in the second half of the century, with the IT revolution and increased levels of productivity – are associated with higher realised return on riskier assets.

[11] Damodaran A. (2008). *Equity Risk Premiums (ERP): Determinants, Estimation and Implications – The 2010 Edition*, available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1556382, accessed 11 January 2011.

[12] The results represent the broad consensus that emerged across the project partner members.

[13] Dimson E, Marsh P and Staunton S. "Global Evidence on the Equity Risk Premium", *Journal of Applied Corporate Finance*, Vol. 15, No. 4, Summer, 2003, pp. 8–19.

This divergence is important for interpreting the impact of the climate-change scenarios on the possible ERP outcomes.

- The period of uncertainty and turmoil of the first half of the century has similarities to the Delayed Action scenario, which may also bring a period of destruction that is not fully anticipated by the market and, hence, costly for some investments. We therefore expect that this will lead to lower realised returns in 2030.
- In contrast, the second half of the century is more akin to the Stern Action scenario, where a period of transformation involves significant new advances in technology, with supportive and transparent policy creating efficiency gains and a positive environment for some investments, with lower volatility expected.

Pulling all of these inputs together, during periods of higher uncertainty around climate change, lower realised returns on riskier assets are more likely to emerge than under more optimistic scenarios of positive economic transformation. The macroeconomic impacts have also informed these conclusions, where higher interest rates and inflation associated with the Delayed Action scenario also support a potential decline in the ERP in that scenario. The final column in Table 3 is constructed on that basis and refers to the realised return in 2030 on an existing portfolio of assets.

Table 3

Determinants of the ERP across the climate scenarios

Scenario	Degree of risk aversion	Degree of investment uncertainty	Reliability of available information	Event risk	Change of realised ERP in 2030
Regional Divergence	Unchanged overall but varies by region	Varied by regions with leaders and laggards creating higher uncertainty overall	Deteriorates in laggard regions, leading regions improves	Increases	Higher volatility
Delayed Action	Increases	Higher uncertainty before policy changes which are not anticipated; uncertainty declines following policy measures	Deteriorates then improves post policy shift	Increases	Lower realised ERP (driven by lower returns and higher volatility)
Stern Action	Unchanged	Lower uncertainty around climate policy due to transparency that is coordinated and anticipated	Improved as businesses are required to report audited emissions data	Lower	Lower volatility
Climate Breakdown	Broadly unchanged to 2030, increasing by 2050	Low uncertainty until 2050, but then increasing, possibly abruptly	Unchanged	Increases but from 2050 onwards intensifies	Unchanged with the risk of dramatic shift further into future

Source: Mercer

Estimates of the TIP™ factor risks

To better analyse the investment impact of climate change, Mercer developed the TIP™ risk factor framework to examine which factors drive asset-class returns across the following three areas:

- **Technology** (T) – broadly defined as the rate of progress and investment flows into technology related to low carbon and efficiency, which are expected to provide investment gains

- **Impacts** (I) – the extent to which changes to the physical environment will affect investments (negatively)

- **Policy** (P) – the cost of policy in terms of the change in the cost of carbon and emissions levels that result from policy, depending on the extent to which it is coordinated, transparent and timely

The results of the TIP™ factor risk estimation are summarised in Table 4 (on page 29), expressed both as the future value of each factor in 2030 as well as the annual change to 2030 for each of the T, I and P factors in $US trillion. The total value for each region is also presented in the table. The regional values do not compute to 100% of the global value, as the analysis represents only the major countries that have comparable data.

For impact costs under the Climate Breakdown scenario, many of the developing economies are the worst hit, which explains the gap in the computations at the regional level for that factor, as they are not all included in Table 4. Nevertheless, the regions included represent the largest in terms of low-carbon investment flows and carbon emissions levels.

As the results illustrate, we expect that there may be significant variability in the TIP™ factors across the scenarios, with a particularly wide dispersion coming through the policy and technology factors.

Table 4
Value of the **TIP™** factors across the climate scenarios

Scenario	Cumulative value of Technology to 2030 (US$ trillion) *% total by region*	Cumulative value of Impacts to 2030 (US$ trillion) *% total by region*	Change in value of Policy to 2030 (US$ trillion) *% total by region*	Change on per annum basis to 2030 (US$)		
				Technology *$US bn*	Impacts *$US bn*	Policy *$US bn*
Regional Divergence	**$3.9**	**$3.0**	**$4.8**	$194	$149	$240
– EU	25%	9%	8%			
– US	17%	32%	23%			
– Japan	3%	4%	5%			
– China/E Asia	35%	21%	25%			
– Russia	1%	7%	24%			
– India/S Asia	6%	19%	15%			
Delayed Action	**$3.7**	**$2.3**	**$8.1**	$183	$112	$405
– EU	19%	9%	14%			
– US	27%	32%	19%			
– Japan	5%	4%	4%			
– China/E Asia	29%	20%	42%			
– Russia	4%	7%	8%			
– India/S Asia	10%	19%	13%			
Stern Action	**$5.2**	**$1.5**	**$2.6**	$259	$76	$130
– EU	19%	8%	11%			
– US	26%	32%	23%			
– Japan	4%	4%	5%			
– China/E Asia	26%	20%	35%			
– Russia	4%	6%	10%			
– India/S Asia	9%	19%	16%			
Climate Breakdown	N/A as the technology factor is calculated as incremental investment flows in addition to investments that would take place under BAU	**$3.7**	**$240 bn**	Baseline	$186	$12
– EU		4%	13%			
– US		14%	21%			
– Japan		2%	4%			
– China/E Asia		8%	43%			
– Russia		3%	7%			
– India/S Asia		10%	12%			

Source: Mercer calculations based on International Energy Agency (IEA) World Energy Outlook 2009 data and Grantham LSE/Vivid Economics reports

Net present value discounted at a rate of 3%. The country and regions included in this analysis are a partial representation of the global economy – hence the reason the totals by region do not compute to 100% for each TIP™ factor. However, in all scenarios the countries included in this study represent around 90% of the total TIP™ risks, as they include the largest markets in terms of investment and emissions levels. Other countries were omitted due to a lack of comparable data to estimate the TIP™ values, but future updates will aim to incorporate markets such as Latin America (Latam), South Korea, Africa, and the Middle East and North Africa (MENA) as data become available.

Technology – size of future investment flows

- The dollar value of this factor can be interpreted as a measure of the future private-sector low-carbon investment flows under different climate scenarios, where a higher technology value indicates a higher level of investment. It is important for investors to have a sense of the low-carbon investment flows across the climate scenarios as an indicator of the potential depth of the pool of investment opportunities.

- The variability in this factor across the scenarios is high, falling in the range of 13%–60% pa higher than a BAU level of investment.

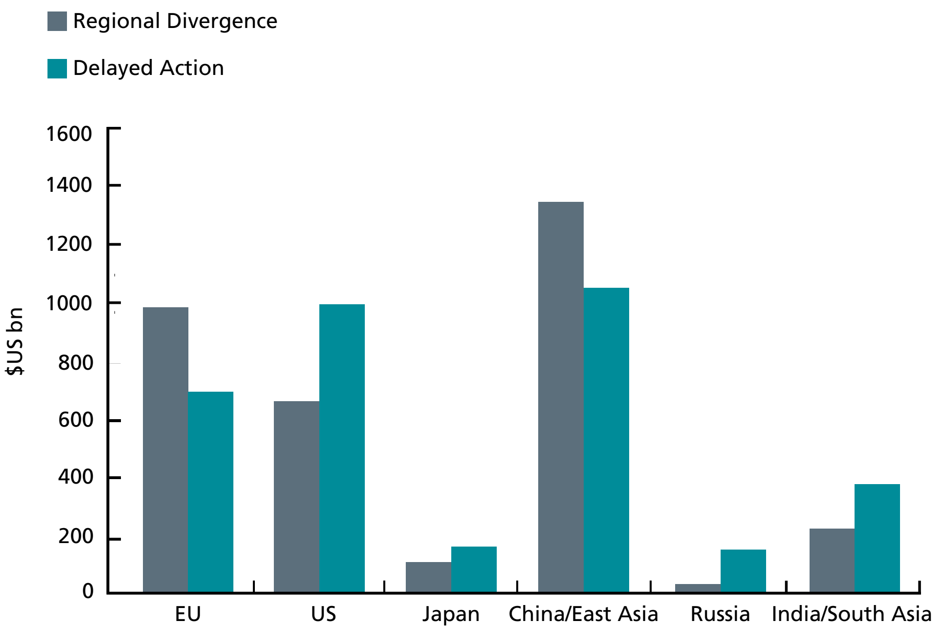
- Additional cumulative investment in efficiency improvements, renewable energy, biofuels, and nuclear and carbon capture and storage could expand in the range of $3 tr to more than $5 tr by 2030 across the mitigation scenarios examined in this study.

- This equates to an increase of $180 bn to $260 bn pa from current levels, with the highest end of the spectrum representing the Stern Action scenario. This would be additional investment on top of recent flows, which have fluctuated between $40 bn and $170 bn pa over the past five years.[14]

- On a regional basis, the biggest differences between the countries are for the Regional Divergence and Delayed Action scenarios. As Figure 1 highlights, the "leaders" in technology under the Regional Divergence scenario are expected to be China/East Asia and the EU. The US, "mature but contracting" in this scenario, nevertheless represents a substantial market in terms of depth. Under Delayed Action, the investment flows are expected to be slightly lower overall due to the delay in getting started, with the US playing catch-up along with some of the "improving" regions, such as Japan and India/South Asia.

Figure 1

Cumulative Investment in Technology to 2030 by region



Source: Mercer computations based on IEA WEO (2009), as defined in the Methodology (see page 93)

[14] UNEP, SEFI and Bloomberg New Energy Finance (2010).

Impacts – cost of physical climate change impacts

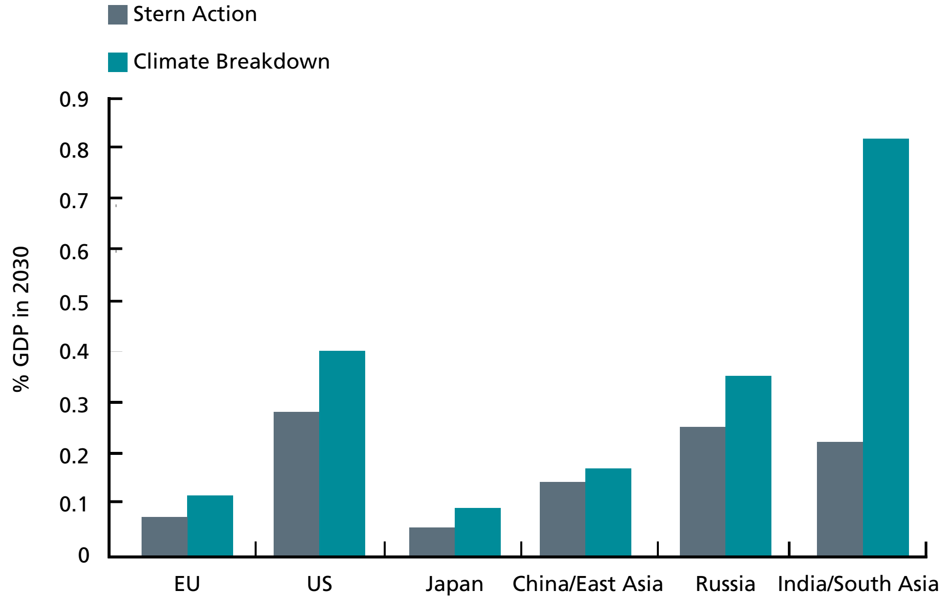
- Some investments may be directly affected by rising risks of climate-change-related events with an impact on the value of their assets. As such, the economic cost of the physical changes is an important variable for investors to monitor over time as part of their overall risk management process.

- The cumulative economic cost of changes to the physical environment, health and food security is estimated to be in the range of $1.5 tr to $3.7 tr to 2030 across the climate scenarios – and as costs rise, the greater the delay and the less well-coordinated the policy response will be. This represents $70 bn to $180 bn pa to 2030.

- The current international policy discussion to commit $100 bn pa, with priority on adaptation and residual damage costs, falls short of covering the impact costs under all the scenarios except for the most optimistic one – Stern Action. This confirms the earlier observation in this report that the current response from policymakers puts us closer to the Regional Divergence or Delayed Action scenarios. The greater the policy commitment and the earlier and more coordinated the action (as for Stern Action), the lower the resulting impact costs will be. Under a Delayed Action scenario, despite the high level of effort and expense associated with climate policy, the impact costs are almost as high as those for the Climate Breakdown scenario. This is because the policy action is late and also unanticipated (hence, more costly).

- On a regional basis, the impact costs increase under scenarios where progress on policy and technology is slow, late or inefficient. Figure 2 plots the percentage of GDP for the two most extreme scenarios in terms of climate impacts – Stern Action and Climate Breakdown. The impact costs rise considerably in India/South Asia under a BAU scenario, where physical impact risks in the time horizon of this study are the highest of the countries analysed.

Figure 2
Adaptation and residual damage costs by region



Source: Grantham LSE/Vivid Economics and Mercer Impact factor calculations, as defined in Methodology (see page 93)

Policy – change in cost of emissions

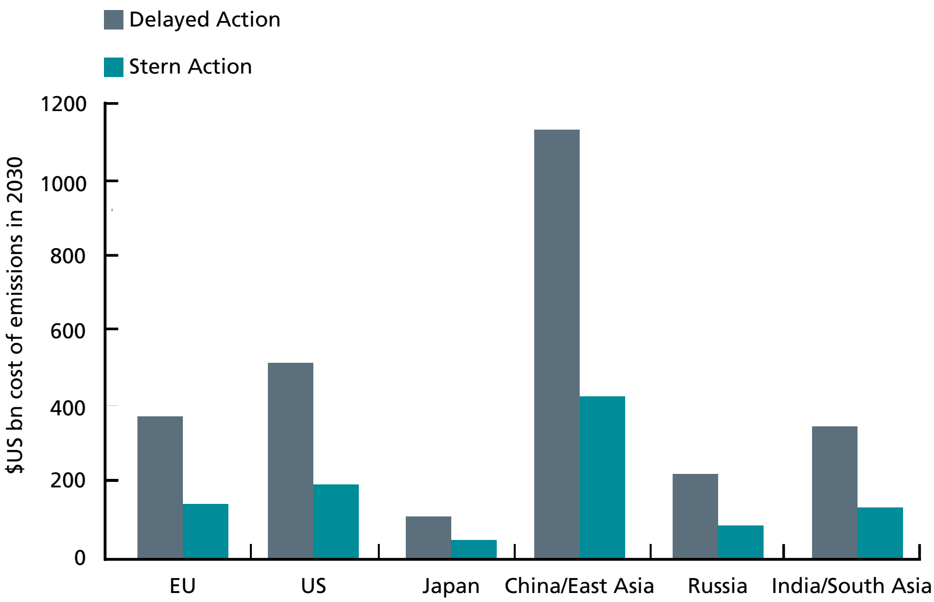
- The degree to which climate-related policy action takes place and is anticipated by investors will be the key factor to consider when evaluating the investment impacts of climate policy. In a situation where credible policy and a higher carbon cost are fully anticipated, the impact may be positive for the highly sensitive assets, as emissions and uncertainty around policy both will be reduced (and vice versa).

- The cost of climate policy is a function of how quickly the policy action is taken, the level of emissions associated with each scenario and the cost of carbon. The cost of carbon emissions increases the longer the policy is delayed, and the less well-anticipated and coordinated the policy action is. Grantham LSE/Vivid Economics estimated that the cost of carbon for mitigation scenarios could be \$110/tC0_2e–\$220/tC0_2e by 2030, compared with the current EU ETS price equivalent of around \$15/tC0_2e. These costs may be explicit in the market or implicit due to policy measures that affect operating costs outside of emission trading schemes.

- Based on the projected trajectory of emissions across the scenarios, the change in the (implicit or explicit) cost of carbon could increase by \$2 trillion to \$8 trillion from 2010 to 2030 across the mitigation scenarios depending on the policy approach taken, where the upper end represents the Delayed Action scenario. Policy delay therefore represents a substantial additional carbon cost for the market to absorb.

- On a regional basis, the greatest differences emerge in the Delayed Action and Stern Action scenarios, where policy delay hits China particularly hard given its rising emission levels and the resultant higher cost of carbon. The higher cost in Delayed Action versus Stern Action suggests that policy risk is a key factor for investors to take into account across all regions.

Figure 3
Policy cost comparison



Source: Mercer Policy factor calculations

Sensitivity of assets to the TIP™ risk factors

The "sensitivity of assets" refers to the degree to which the underlying risk/return drivers of assets are sensitive to the climate-change TIP™ factors. The process of deriving these TIP™ factor sensitivities was largely a qualitative exercise, developed jointly between climate specialists and asset-class specialists both within Mercer and across the project participants. Table 5 summarises the results, the key conclusions of which are highlighted as follows:

- The assets whose underlying risk/return drivers are most sensitive to climate change include infrastructure, private equity, real estate, sustainability-themed listed equity, efficiency/renewables, timberland, agricultural land and carbon. As a consequence, these assets will likely capture the greatest opportunities under the mitigation scenarios and also pose the greatest risk under the Climate Breakdown scenario.
- Equities and fixed income have a lower sensitivity to climate change across the scenarios. This is because the differences are expected to be greater at the sector and regional levels rather than at the asset-class level. It is also due to a combination of being more sensitive to other sources of risk (fundamental factors) and the shorter time horizon in terms of asset pricing compared with some of the more climate-sensitive assets.
- The exception to this would be investments in sustainability-themed listed equities and efficiency/renewables, where the sensitivity to climate change is obviously much higher and pre-emptive. Consequently, these assets could help investors capture more of the upside and protect against unforeseen risks than a traditional equity and bond portfolio would do. They would also expose investors to the downside risk of a "no-mitigation" scenario such as Climate Breakdown, although that is also the least likely scenario.

Table 5

Sensitivity of asset classes to climate change risks

Sensitivity of the impact: where L = Low; M = Moderate; H = High; VH = Very high sensitivity to the combined climate change factors.

Direction of the impact: where [green] = Positive; [orange] = Neutral; and [red] = Negative. Agriculture = agricultural land; RE = real estate; Infra = infrastructure; EME = emerging-market equity; EMD = emerging-market debt; LBO = leveraged buyout; VC = venture capital.

	Listed equities				Fixed income			Commodities		RE	Private equity			Infra	
	Global equity	EME	Sustainable equity	Efficiency/renewables	Global fixed	EMD	Inv grade credit	Agricultural land	Timberland	Unlisted	LBO	VC	Efficiency/renewables	Core, unlisted	Efficiency/renewables
Sensitivity	L	M	H	VH	L	M	L	H	H	H	M	H	VH	H	VH
Regional Divergence	Neutral	Neutral	Positive	Positive	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Positive	Neutral	Positive
Delayed Action	Negative	Negative	Positive	Positive	Neutral	Negative	Negative	Neutral	Positive	Negative	Negative	Negative	Positive	Negative	Positive
Stern Action	Positive	Positive	Positive	Positive	Neutral	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
Climate Breakdown	Neutral	Negative	Negative	Negative	Neutral	Negative	Neutral	Negative	Negative	Negative	Neutral	Neutral	Negative	Negative	Negative

Source: Mercer. Sustainable equity = broad multi-themed listed equity companies that generate a substantial proportion (typically more than 25%) of their earnings through sustainable activities. Efficiency/renewables assets = both listed/unlisted sustainability-themed assets whose core activities are theme specific and more concentrated in terms of exposure than are broad sustainability equity. This includes (but is not limited to) energy efficiency, low energy transport, renewable energy, bioenergy, carbon capture and storage, smart grid, water supply, usage; and management, waste management, hydro energy, and geothermal, to name a few.

Sensitivity of regions to the TIP™ risk factors

Asset-allocation decisions are typically conducted at the top-down level across regions, at most differentiating between local, emerging and developed markets. However, the potential risks and opportunities at a more disaggregated level may be informative for some asset classes where regional disaggregation can be implemented (for example, equities, sovereign fixed income, private equity, infrastructure and real estate).

For long-term institutional investors, the wider socioeconomic trends that are driving the shift away from high-carbon activities are important factors to take into account in considering the sensitivities of regions to the TIP™ risk factors, some of which include:

- Increased energy security in a world of depleting resources and growing population that is spurring sharp increases in energy demand[15]

- Increased energy efficiency across industries, leading to improved international competitiveness in the long term

- New market opportunities in the development and trade of technologies and low-carbon solutions opening up new markets and industries for regions that develop capabilities in this area

- Future cost of carbon exposure being expected to rise over time internationally – the uncertainty relates more to the pace and level of change; hence, it may become more costly for high-emitting countries to redress their carbon liabilities over time

The regions examined in this report are limited to those for which comparable data sources were available within the TIP™ factor risk framework. Table 6 summarises the outcome in terms of the relative importance of the climate factor risks for each region.[16]

Table 6

Sensitivity of regions to climate change risks

■ = Positive; ■ = Neutral; and ■ = Negative in terms of the direction of the impact for investments for each region.

TIP™ sensitivity	EU	US	Japan	China/East Asia	Russia	India/South Asia
Sensitivity	Moderate	High	Moderate	High	Moderate	Moderate
Regional Divergence	Positive	Neutral	Neutral	Positive	Negative	Neutral
Delayed Action	Negative	Negative	Negative	Negative	Negative	Negative
Stern Action	Positive	Positive	Positive	Positive	Neutral	Positive
Climate Breakdown	Neutral	Neutral	Neutral	Negative	Neutral	Negative

Source: Mercer assessment as per aggregate estimates, using T, I and P data available at the regional level. Direction of impact derived through a qualitative process.

[15] Lloyds 360° Risk Insight White Paper, "Sustainable Energy Security, Strategic Risks and Opportunities for Business" (Chatham House, 2010).

[16] The calculation and sources of data for all estimates at the regional level are further explained in the Country and Regional Impacts section (page 69) and the Methodology section (page 93) of this report.

The analysis concludes that countries that act pre-emptively in finding alternative sources of energy, improving efficiency, reducing carbon emissions and investing in new technology may benefit from the transformation that will take place in the form of higher investments with less uncertainty than laggard countries and hence, potentially will be more attractive for long-term investors. Countries that avoid or delay the transformation process may face a more uncertain future with regard to higher carbon mitigation costs and therefore potentially pose a higher risk for long-term investors. Moreover, a delay in policy action may cost all regions, as it pushes up the adjustment costs that will be required to reduce emissions in the future – hence, there are no winners from delay. Overall, this increases the risks for global investors.

While the "do nothing" (Climate Breakdown) scenario appears to be less negative across the regions than the Delayed Action scenario, as explained previously, that is due to the horizon of this study focusing on the impacts over the next 20 years. Grantham LSE/ Vivid Economics point out that impact costs may push up the cost of Climate Breakdown considerably beyond 2050.

It is important to interpret these results with some caution, as there is substantial variation in the type of policy measures that different countries have introduced that may be masked by the overall assessment presented here. The analysis is also based on a limited number of countries due to constraints with comparable data, although those included are the largest nations in terms of low-carbon technology flows and carbon emission levels. Nevertheless, investors need to assess the climate risks of investments by region on a case-by-case basis and continually monitor the policy developments at the regional level.

Quantitative analysis results

We have made some additional quantitative assumptions relating to asset-class exposure to each of the TIP™ factors based on our qualitative analysis. In doing so, we were cognisant that there will always be some subjectivity and uncertainty when determining appropriate assumptions. Appropriate assumptions can also vary significantly depending on the investor and the purpose for which the assumptions are to be used.

The aim of our quantitative analysis is not to suppose that it can calculate the most optimal portfolio for the next 20 years based on the climate-change analysis. We acknowledge that mean-variance optimisation analysis can be extremely sensitive to assumptions and is not sufficiently comprehensive to assess all characteristics of different investments. Instead, the analysis is intended to act as a sense check to our qualitative assessment.

We have used Mercer's GPT[17] risk factor framework to develop and test the internal consistency of the assumptions across the asset classes.

Source of risks

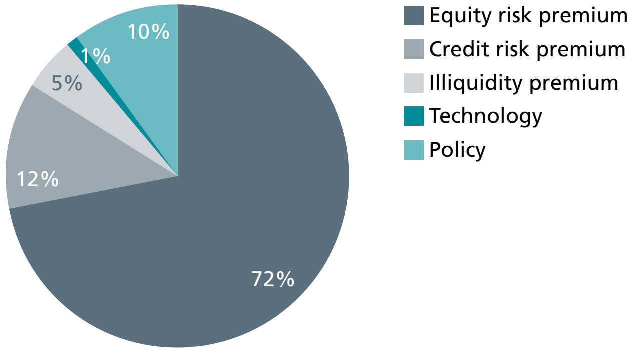
Understanding the exposure of a portfolio to the underlying return drivers is a key component of strategic decision making, which is what Figure 4 attempts to measure through incorporating TIP™ factor risks alongside traditional risk factors. The existence of risk exposure does not necessarily imply lower returns, as exposure can be associated with superior returns under different market conditions. The aim is to unravel the source of portfolio risks and diversify across the return drivers as opposed to simply diversifying between asset classes.

The example in Figure 4 is calculated on a hypothetical but representative portfolio of a typical asset mix, with allocation of 34% developed large-cap equities, 13% emerging-market equities, 18% global government bonds, 26% investment-grade credit and 9% property.

As can be seen, most of the risk comes through the ERP, as the portfolio has a high exposure to equities.

Figure 4

Contribution to risk for representative portfolio mix in 'default' case



Source: Mercer

In this example, the policy (P) factor of the TIP™ framework contributes 10% to portfolio risk, while technology (T) contributes 1.4% risk. The T factor is comparatively low, as the assets with higher sensitivity to technology factors, such as private equity and sustainability-themed assets, are not included in the example. While the technology risk exposure is expected to be beneficial for portfolio returns, it cannot be obtained without taking on policy risk, which is a necessary cost attached to the technology exposure. Furthermore, policy risk has some correlation to overall market risk, as it introduces additional market uncertainty and, hence, is a potential source of volatility. Policy risk therefore is embedded within all asset classes and not only those that are highly sensitive to climate change. This explains why the policy risk exposure is relatively high in the example provided.

Impact (I) risk does not appear as a contributor to risk. This can be explained by the small allocation to tangible assets (infrastructure, commodities, real estate) included in this example that have a higher sensitivity to impact risks, along with the evidence pointing to a lower variability in the impact risk factor compared to the low-carbon technology transformation and change in carbon costs associated with climate policy out to 2030. Investors should, however, be aware that the evidence suggests that further into the future (beyond 2050), the source of portfolio risk attributable to the impacts factor will increase considerably.[18]

[17] Further information on Mercer's approach to factor risk and asset allocation is explained in the Methodology section (page 93) of this report. Also see Hawker G. "Diversification: A Look at Risk Factors", available at http://www.mercer.com/referencecontent.htm?idContent=1378620.

[18] For further explanation of the impact risks, refer to the Mapping Evidence to the Scenarios section (page 75) of this report.

Illustration of potential portfolio impact

The following analysis is based on a traditional and widely used mean-variance analysis approach. While such modelling has a number of drawbacks and, hence, critics (for example, it can be highly sensitive to changes in assumptions – it assumes a normal distribution range of returns and that asset-class relationships are constant over time and, hence, like any model, it cannot capture all characteristics of investments), it can be used to provide some additional insight into appropriate portfolio structure. A few specific approaches have been used for this analysis:

- The assumptions have been modified to reflect the TIP™ factor risks and the sensitivity of each asset class to these sources of risk, in addition to the more traditional drivers of asset-class risk/returns.
- The GPT factor risk framework has been used to test and examine the underlying assumptions to ensure that the modifications are internally consistent and pass the "common sense" test.
- Different climate scenarios have been examined to provide a sense of how portfolios respond to different conditions, highlighting the areas of potential weakness as well as opportunity.
- Additional types of "sustainability" investments within the asset classes have been included in the modelling analysis to examine the extent to which an allocation to such investments might improve the resilience of a portfolio mix to climate change.

Despite these modifications, we recognise the drawbacks of mean-variance analysis and have exercised some caution in structuring our assumptions and conclusions on how sustainability themed asset classes may benefit investors. Our "default" assumption for this modelling is that climate change does not affect the expected return of investments but it does add some additional uncertainty. Because of this, it assumes that sustainable equities and efficiency/renewables (unlisted) may provide the same return but with higher risk compared with their broader market equivalent assets. It is for this reason that these asset classes do not feature in the calculated optimal portfolios (a portfolio that minimises risk for a given level of return, or vice versa) under the "default" or default assumptions.

The changes in performance of the assets are calculated versus this "default" assumption starting point, which assumes that the climate change factors contribute to overall portfolio risk without the benefit of providing additional return.

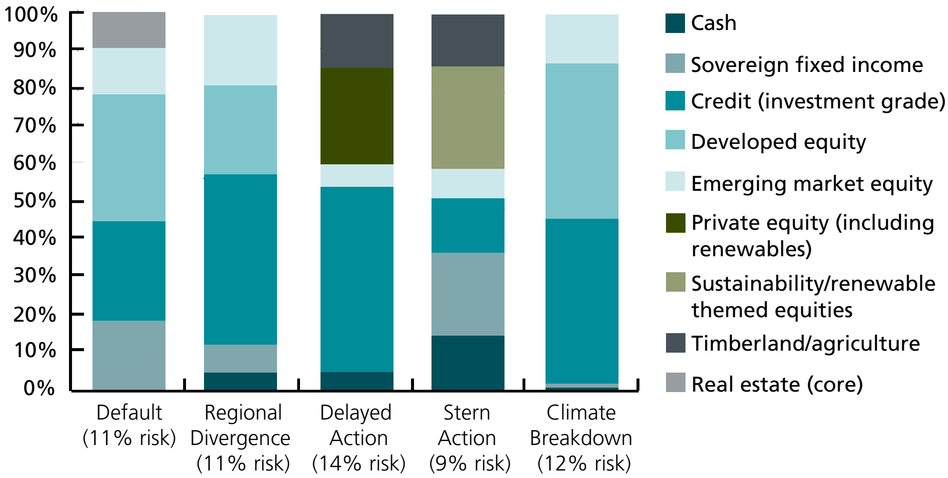
We have summarised part of our analysis in Figure 5 (on page 38). The chart shows the portfolios, as calculated by the model, that target a nominal return of 7% in each scenario, with lowest standard deviation. The results should not be used to imply that the most appropriate portfolio to meet this objective in each scenario is exactly as shown. For example, other sets of assumptions are reasonable and the most appropriate assumptions are likely to change over time. In addition, the characteristics of sustainability-themed investments will often be unique to each product and manager and, hence, cannot be represented by generic asset assumptions in a simplistic way. A different set of assumptions may need to be used for assets depending on the degree to which they are single or multi-themed, multi-country, or in the listed or unlisted space.

Despite these caveats, we believe that the analysis helps to demonstrate that an increase in investor focus on climate-sensitive assets is likely to be rewarded by a reduction in risk or improvement in return in some of the climate-change scenarios analysed. The precise areas of focus in each scenario will depend on more robust supplementary analysis specific to an investor's risk/return profile, product characteristics, timing and the assets in investors' current portfolios.

In addition to showing the composition of the "optimal" portfolio under each scenario, the chart also includes the level of risk for each scenario. The risk measure shown is the standard deviation of the returns. The key differences in the amount of investment risk that is necessary to meet the return target arise in the Delayed Action and Stern Action scenarios. Under Delayed Action, more risk is required because asset returns are expected to be lower. In contrast, under Stern Action, less risk is needed because higher returns are expected from each asset class.

Figure 5

Example of portfolio mix across the scenarios – portfolio to target 7% return



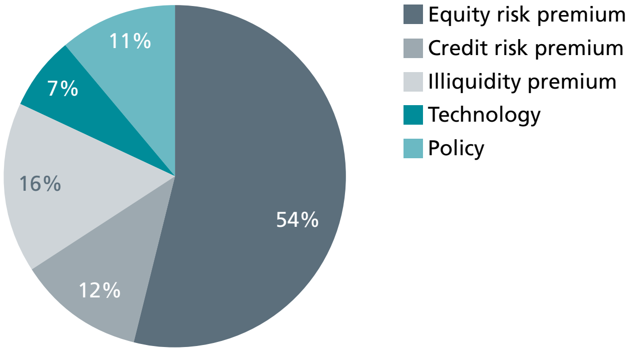
Source: Mercer

Looking at the analysis in more detail, the greatest portfolio impacts occur for the Delayed Action and Stern Action scenarios, with little change under Climate Breakdown due to the constraint on the investment horizon to 2030. For much longer time horizons the investment risks associated with Climate Breakdown would increase substantially, driven by higher "impact" factor risks. We believe that the analysis is explained by the following factors:

- **Regional Divergence** implies that the backdrop for climate-sensitive investments will vary by region. Hence, while we expect the returns of these investments to increase on average, we also expect the uncertainty and variation in returns to increase. It is for this reason that the quantitative analysis does not show assets such as timberland, agriculture land, efficiency/renewables, real estate, sustainable equity or infrastructure as part of the "optimal" results in this scenario – because of the higher uncertainty and sensitivity of these assets to the TIP™ factors. However, as our qualitative analysis highlights, there will be opportunities in these assets in some regions (particularly in the EU and in emerging-markets areas such as China/East Asia) that would be beneficial in this scenario.
- **Delayed Action** is negative for most asset classes – albeit, we would expect some improved performance from climate-sensitive assets over time to alter the optimal portfolio. This is illustrated by a projected increase in efficiency/renewables unlisted assets in Figure 5 (which could be obtained via private equity or infrastructure), timberland and agricultural land. Figure 6 (on page 39) translates these new allocations into a risk factor framework and, as can be seen, the new asset mix would improve the diversification to different risk factors, with a much lower exposure to the ERP and a higher exposure to illiquidity, technology and policy. Such a portfolio is better diversified and therefore likely to be more robust should climate policy be delayed.

Figure 6

Delayed Action – impact of new portfolio mix on contribution to risk



Source: Mercer

- **Stern Action** is a positive scenario for all investments, with a much lower level of risk for the same level of return compared to the Delayed Action scenario (9% versus 14% risk for the latter). The results point to an allocation to timberland and agriculture land, as well as a substantial allocation to listed sustainable assets. The high allocation to sustainability-themed assets reflects the fact that under this scenario, liquid assets with a shorter-term horizon (such as equities and bonds) will also benefit from the climate-change policy response, as will some illiquid climate-sensitive assets like real estate, infrastructure and private equity. This is because, in contrast to the Delayed Action scenario, the Stern Action scenario assumes that the policy response will be fully anticipated by the market. This encourages significant transformation not only in earlier stage (off-market) investments but also across the listed equity and debt markets.

- **Climate Breakdown** suggests no significant change in the portfolio mix within the time horizon of this study. Some opportunities may exist within asset classes, such as equity, private equity and infrastructure investments in adaptation measures (rather than mitigation and technology) such as flood defence, water management, desalination, emergency services and disaster relief. Within agriculture there could also be a rise in crop yields as temperatures rise in regions such as North America, northern Europe and Russia, although as Grantham/LSE Vivid Economics pointed out, the timing and magnitude of such effects are uncertain.

- The important caveat to these results is the uncertainty around when the market will begin to price in the increasing risk of physical damage to the environment due to the lack of policy action and/or future carbon costs as they grow. In addition, there is much uncertainty in the climate science literature about the regional impacts and likely timing of the changes that could take place. These uncertainties could increasingly weigh on climate-sensitive assets and regions in the future. This could affect risk premiums on tangible assets such as coastal real estate and infrastructure and agriculture land in flood-prone and/or drought-potential areas.

To conclude, we reiterate that modelling analysis needs to be interpreted with caution. However, we believe that the analysis supports our view that a greater focus on climate-sensitive assets is likely to be rewarded across the climate mitigation scenarios.

Asset-class **impacts**

The following discussion provides further evidence to underpin the conclusions around the investment impacts of climate change for each asset class.

The analysis is qualitative, applying judgement and interpretation of the climate-change risks and evidence, as presented in this report. The key assumptions that underpin these conclusions are as follows:

- The interpretation of the investment impact is based on an *existing* portfolio of assets held today, projecting forward to consider the impact in 2030 for each scenario in question. The conclusions would be different if we were to consider building a portfolio of new assets starting in 2030. We focused on the impact for existing assets to analyse the current risks and opportunities that institutional investors need to manage today, in view of the climate scenarios and future outcomes.

- We have assumed that all the core asset classes examined in this study have *not* integrated climate change considerations at this present point in time. This means our analysis shows the range of potential impacts for portfolios that are “unsustainable” versus those that are more sustainable,[19] which was considered desirable in view of the aim of this study to analyse the tail risks associated with climate change. For institutional investors that have shifted the underlying nature of their asset exposure to be more sustainable, it may be appropriate to consider a sensitivity and direction of impact that is somewhere between the two.

[19] Sustainable assets refers to investments that generate a substantial proportion (typically, more than 25%) of their earnings through sustainable activities. At its broadest level, sustainable investment seeks to support sustainable economic development, enhance quality of life and safeguard the environment. This includes sustainable themes such as energy efficiency, low energy transport, renewable energy, bioenergy, carbon capture and storage, smart grid, water supply, usage and management, waste management, hydro energy, geothermal and biofuel, to name a few.

Listed equities

Equities may experience some degree of transformation under all the mitigation scenarios, although we expect most of the transformation should take place at the sector and/or regional level. The transformation is also likely to happen in *response* to policy developments, rather than ahead of them, as research indicates that the shorter-term pressures that investors and managers of listed companies come under are likely to constrain large-scale investments until the policy framework supports such a shift.[20]

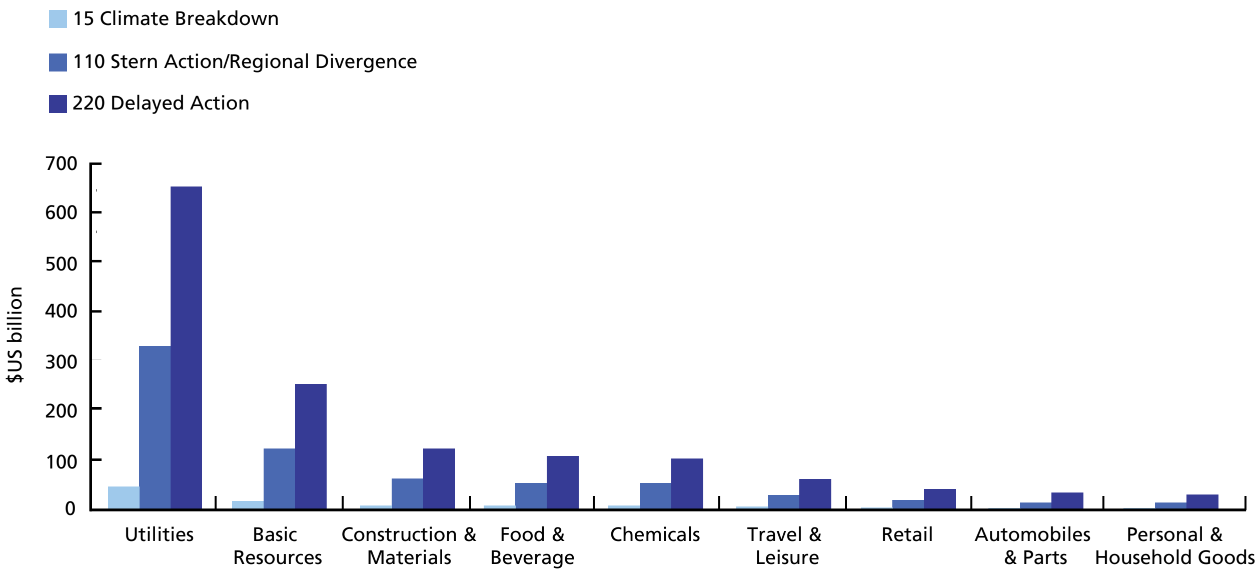
If the mitigation response is strong, the industries that would be worse off include fossil-fuel industries (coal mining, crude oil and gas extraction, petroleum refining, gas utilities), as well as certain carbon-intensive primary and manufacturing industries, including mining, most electric power utilities, and chemicals. Figure 7 shows the potential cost of the different carbon prices across the scenarios in this report, broken down by sector, based on current emissions levels.

It is no surprise that the utilities sector is the hardest hit, followed by basic resources and industrial goods and services. The magnitude of the impact (tonnes of CO_2e emissions *future carbon price per tonne of CO_2e) demonstrates how important the policy outcomes for the sectors in terms of the future adjustment costs that they will have to absorb. We acknowledge that some sectors may be more/less able to pass on or absorb this cost than others and that this should also be considered against future profits for the sectors. Nevertheless, the scale of the potential cost provides some indication of the level of adjustment that will be required across different sectors.

On the other side of the coin, the winning sectors would include firms operating within low-carbon sectors at bottleneck positions in the supply chain. These include the renewable and nuclear power supply chains, carbon capture and storage (CCS), biofuels and energy efficiency technologies such as smart grid components, and energy-use auditing methods.

Figure 7

Cost of carbon adjustment by sector



Source: Sector tonnes of CO_2e emissions data sourced from Trucost; Mercer calculations based on carbon price across the scenarios, where carbon price is shown as $ / t CO_2e

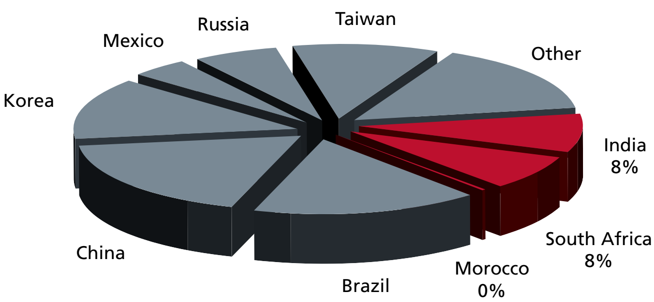
20 See WWF, Trucost and Mercer *Carbon Risks of UK Equity Funds* (2009), available at http://www.trucost.com/_uploads/downloads/Carbon_Risks_in_UK_Equity_Funds.pdf; see also Mercer 2009, *Research Identifies Large Scope to Improve Carbon Footprint of Investment Portfolios*, available at http://www.mercer.com/summary.htm?idContent=1351415, accessed 11 January 2011.

The countries most dependent on high-emitting industries at present would therefore experience the greatest shift in demand and be relatively worse off. Vivid Economics (2009)[21] identified the bottom five countries in terms of sectoral composition to be Australia, the US, Saudi Arabia, South Africa and Canada. The top five countries on the same measures are China/East Asia, Brazil, South Korea, Mexico and France.

Additional factors to consider are not only the adjustment to the cost of carbon as a result of policy and technological developments but also the physical impact risks that might affect countries to varying degrees. In other words, to what extent would a global equity portfolio be exposed to impact risks over the coming 20 years? And how much more concentrated is that risk for a global equity portfolio versus a more focused emerging-market equity portfolio for which the impact risks tend to be higher? While the timing of these risks is uncertain (as Appendix A illustrates), awareness of where the risks might lie over the coming decades would be helpful as part of overall risk management.

Figure 8 shows the weighting of the MCSI EM equities index as at the end of September 2010 to the most vulnerable countries, based on a study by Brenkert et al (2005). While estimates across studies vary in terms of the potential timing and cost of climate-related damage, this is a helpful starting point for investors to consider and monitor the potential source of risk over time.

Figure 8
Exposure of EM equity index to climate 'impact' risks



Source: Brenkert M et al (2005), as quoted in Yohe GE et al (2006). "Global Source: Vulnerability to Climate Change". *The Integrated Assessment Journal* 6 (3):35–44.

As can be seen, the highest-risk countries highlighted in red, according to the Brenkert et al study, are South Africa (8%), India (8%) and Morocco (0.2%). This means that around 16% of an emerging-market equity investment potentially faces costs around adaptation to climate change. Grantham LSE/Vivid Economics estimate the adaptation and residual damage costs under the worse-case Climate Breakdown scenario would be $71 bn, or 0.7% of the level of GDP in India/ South Asia in 2030, and $56 bn, or 2.1% of the level of GDP in Sub-Saharan Africa in 2030. Based on this evidence, we have assigned a higher sensitivity on emerging-market equities (moderate) to the TIP™ risk factors than for global equities (low).

At the overall asset-class level, aside from the sector and regional differences, the magnitude of the impact in terms of risk/return assumptions is expected to be greater for emerging-market equities, broad sustainability-themed equities and efficiency/ renewables. We also expect the most important climate factor risks for listed equities would come from technology and policy, although impact risks are notable for some emerging markets. A few highlights:

- **Technology** – This is the key enabling factor for economic transformation due to climate change, and while this may have a much greater impact in early stage investments such as private equity and infrastructure, it will also have a knock-on effect in listed equity as successful technologies are rolled out and emerging companies become more established. Investment in new technology has a negative impact on company cash flows initially, whether through research and development or through buying proven technology, but corporate investment would focus on technologies expected to generate a positive rate of return over the economic cycle. Sustainability-themed and efficiency/ renewables equities, with their clear focus on this type of investment, would have the greatest exposure to this factor.
- **Impacts** – The sensitivity of global equities to the physical impacts of climate change within the time horizon of this report is expected to be low, although specific regions may experience physical changes, usually but not exclusively in emerging-market

[21] This is defined as the structure of the composition of an economy in terms of emission intensive industries and activities. See Table 4 rankings that delineate sectoral composition rank in Vivid Economics *G20 Low Carbon Competitiveness* (2009), available at http://www.e3g.org/images/uploads/G20_Low_Carbon_Competitiveness_Report.pdf.

countries. This means that concentrated emerging-market equity portfolios potentially face higher costs related to adaptation to climate change that may affect corporate earnings in those markets. Sectoral differences in vulnerability to climate change may be concentrated in a relatively small number of sectors – such as agriculture, forestry, water and tourism – whose performance depends directly on weather conditions.

- **Policy** – Climate policy would typically increase operating costs through a higher cost of compliance; however, in certain sectors it may serve to encourage investment and innovation. We can expect to see traditionally carbon-intensive sectors – for example, fossil-fuel industries, primary manufacturing, mining, chemicals and electric power utilities – lose out. Correspondingly, regions with a high proportion of carbon-intensive sectors would be affected the most. By way of illustration, 26% of the MSCI Emerging Markets EMEA index is Energy compared with 10.5% for the All World, 10.9% in the EU, 5% in Asia Pacific and just 1% in the Far East. The winners would be the industries supplying technology and services to the energy-sector transformation. These are usually small sub-sectors of the equity market, and this is the opportunity targeted by sustainability-themed funds.

Table 7 presents the sensitivities of global equities, emerging-market equities, broad sustainability-themed equities and renewables to the TIP™ factor risks for each scenario. The magnitude (low, moderate, high and very high) of the sensitivity to climate change is presented at the top of the table, with the colour denoting the direction of the impact for each scenario.

Table 7

Sensitivities of global equities, emerging-market equities, broad sustainability-themed equities and renewables to the **TIP™** factor risks

Asset	Global equities sensitivity	Emerging-market equities	Broad sustainability-themed	Renewables
Sensitivity	*Low*	*Moderate*	*High*	*Very high*
Regional Divergence	Risk of increased uncertainty and volatility due to regional disparity on climate policy. Regional differences within major sectors will become exaggerated, where carbon-intensive industries in countries with carbon constraints will become less competitive relative to companies in countries without carbon constraints. Multinational companies may find the cost of operating across borders increasing due to a higher cost of complying with different national policies.	Higher volatility in emerging-market equities is likely, where a gap will open between those emerging-market countries that have the capacity and willingness to grow as a low-carbon economy versus those that are not as able or willing to adapt. Current evidence suggests that the emerging economies that are positioned to lead in this scenario include China/East Asia, South Korea, Brazil, Mexico, South Africa and India/South Asia.	This is a broadly positive environment for sustainability-themed equity, with sporadic policy encouraging some industries in some regions to grow strongly. Sustainability-themed investments stand to benefit in the leading regions – but those in the "wrong" regions or sectors will suffer more than traditional equity portfolios. Policy and technology will be the dominant drivers of new opportunities, driven by cost/efficiency savings as well as the expectation of further policy advances.	Similar to the broad sustainability-themed equities, the very high sensitivity to the climate risk factors means that supportive climate policy will attract investment in renewable energy to leading regions. The most supportive policies for renewable energy currently include parts of Europe – particularly Scandinavia, France, Germany, Spain – as well as the UK and Brazil.

Table 7

Sensitivities of global equities, emerging-market equities, broad sustainability-themed equities and renewables to the **TIP™** factor risks *(cont'd)*

Asset	Global equities sensitivity	Emerging-market equities	Broad sustainability-themed	Renewables
Sensitivity	*Low*	*Moderate*	*High*	*Very high*
Delayed Action	Higher volatility is likely to negatively impact global equities, as the climate policy turnaround is not fully anticipated. Carbon-intensive industries that benefit from the policy delay over the next 10 years will be penalised, particularly if they have invested in long-term infrastructure that becomes redundant.	Volatility increases for some emerging-market equities, notably those that continue to operate as BAU for the coming 10 years and fail to prepare for the dramatic policy U-turn. The fortunes of the emerging economies will diverge when faced with a high cost of carbon (such as Russia, parts of eastern Europe and China/East Asia versus Brazil, Mexico and South Korea).	Sustainability investments perform strongly following the announcement of the policy measures, with a more muted performance in the preceding period. Significant potential for outperformance of the theme versus a traditional global equity or emerging-market portfolio.	The policy turnaround will likely lead to outperformance of this sector compared to the other types of listed equity. Policy measures will directly benefit the companies in this universe, boosting returns and encouraging further investments.
Stern Action	A period of positive transformation due to supportive and transparent policy. Some carbon-intensive industries shrink or disappear while others face increased costs of mitigation or pollution penalties. These include agriculture and forestry as well as the energy, extraction and chemical industries. The cost of capital for companies in these sectors will increase. Investment in technology-development companies and those that provide goods and services to the energy sector will expand.	A supportive environment for emerging markets, with some countries also receiving significant adaptation transfers from developed markets. Mercer research shows that most investors are structurally underweight emerging-market equities, and hence, supportive climate policy is likely to further increase the attractiveness of emerging markets. The lower risk associated with the physical impacts of climate change under this scenario may further enable emerging-market companies to benefit from the expected growth and social development.	This is a favourable scenario for sustainability-themed equities, with supportive policy and technology flows. The upside will potentially be greater than for traditional listed equity funds and emerging-market equities. Over the longer term, the sustainability-leading companies will gradually be subsumed into the core listed equity indices, making it more difficult to distinguish between sustainability-themed equity portfolios and mainstream global equity portfolios.	Renewable energy-focused companies will be major beneficiaries under this scenario. With the highest sensitivity to the climate risk factors, they will benefit more than global equities, emerging-market equities or broad sustainability equities. Companies that focus their revenue-generating activities on renewables will outperform, spurring R&D investment in new technologies, smart-grid systems, nuclear, reforestation, electric vehicles hybrid plug-in, solar, biomass and Carbon Captive Storage.

Table 7
Sensitivities of global equities, emerging-market equities, broad sustainability-themed equities and renewables to the **TIP™** factor risks *(cont'd)*

Asset	Global equities sensitivity	Emerging-market equities	Broad sustainability-themed	Renewables
Sensitivity	*Low*	*Moderate*	*High*	*Very high*
Climate Breakdown	The evidence points to physical impacts not being a major cost for the markets to absorb at the aggregate level within the timeframe of this study; however, there may be an impact if equity markets price in the expected future degradation. Carbon-intensive industries will experience higher costs than less-intensive industries, but not to the extent that they would under mitigation policy scenarios.	The absence of investment in low energy infrastructure solutions could thwart China's ability to sustain economic growth, with increased pressure on resources from population growth and rising living standards. Some emerging-market countries will also experience severe physical impacts. For example, Grantham LSE/Vivid Economics estimate the adaptation and residual damage costs to be $71 bn, or 0.7% of the level of GDP in India/South Asia in 2030, and $56 bn, or 2.1% of the level of GDP in Sub-Saharan Africa in 2030. Within the MSCI EMEA index, the weightings of the most vulnerable countries equate to 16% that potentially face costs around adaptation to climate change.	This scenario is negative for sustainability-themed equities, as the absence of policy action will limit returns and future investments in technologies to cost-savings areas. Some sectors, such as energy efficiency, remain resilient while in the more climate policy sensitive sectors, such as R&D, the pricing of renewable assets and technologies such as CCS will suffer more.	This scenario is negative for investments in the renewable energy theme, as the policy inaction will cap investment returns and flows to around current levels, with investments in efficiency/renewables due to efficiency/cost savings being the most resilient.

Source: Mercer drawing from various sources, as referenced

Fixed income

The impact of the climate scenarios on fixed income portfolios will vary depending on the type of the fixed income asset. We expect that the impact on government bonds is likely to be relatively low, as government bonds have a comparably high sensitivity to sources of risk related to macroeconomic conditions rather than climate change factors, the former of which are only expected to change under the Delayed Action scenario.

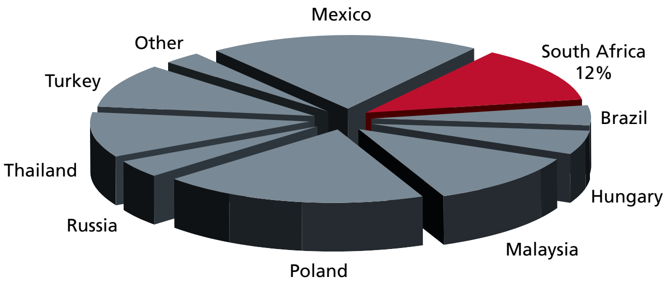
For investment-grade credit, the impact should be broadly similar to that of global equities, with some substantial regional and sector shifts taking place.

The impact would be most pronounced for emerging debt and a new fixed income vehicle commonly referred to as "green bonds" – a government, development bank or supra-national issued instrument designed to raise finances for expenditure on climate-change mitigation and adaptation. For example, the European Investment Bank has issued some Climate Awareness Bonds in recent years, with the proceeds being used for projects in renewable energy and energy efficiency. The World Bank has issued a series of green bonds since 2007 for similar purposes, and more recently the IFC issued its first Green Bond to raise money for investing exclusively in renewable energy, energy efficiency and other climate-friendly projects in developing countries. The US Treasury also issued Clean Renewable Energy Bonds in its 2009 budget.[22]

An additional factor to consider is the physical impact risks that might affect issuing countries to varying degrees and how much these risks could affect a fixed income portfolio. Figure 9 shows the weighting of the JP Morgan GBI EM Bond index as at end September 2010 to the most vulnerable countries, based on a study by Brenkert et al (2005). While estimates across studies vary in terms of the potential timing and cost of climate-related damage, this is a helpful starting point for investors to consider and monitor the potential source of risk over time.

Figure 9 highlights in red the country identified by the Brenkert et al study as being the most vulnerable to the physical effects of climate change. As can be seen, the only high-risk country in terms of climate vulnerability within this index is South Africa (highlighted in red at 12%). This means that 12% of an emerging-market debt concentrated allocation potentially faces high costs around adaptation to climate change. Grantham LSE/Vivid Economics estimate the adaptation and residual damage costs under the worse-case Climate Breakdown scenario to be $56 bn, or 2.1% of the level of GDP in Sub-Saharan Africa in 2030. Based on this evidence, we have assigned a higher sensitivity on emerging-market debt (moderate) to the TIP™ risk factors than for global bonds (low).

Figure 9
Exposure of EM bond index to climate 'impact' risks



Source: Brenkert M et al, as quoted in Yohe G et al (2006). "Global Source: Vulnerability to Climate Change". *The Integrated Assessment Journal* 6 (3):35–44.

On balance, we expect that the most important source of climate change risk for fixed income assets would come from climate policy that will alter the demand/supply balance of bonds and physical impacts, more so than technology, as will be explained more fully below.

- **Technology** – Government bonds and emerging-market debt have a low sensitivity to technology, as the private sector is more likely than governments to finance such investments via debt issuance. However, investment-grade credit would experience a degree of transformation under the climate scenarios, particularly in the carbon sensitivity sectors and those that play a key role in the financing of research and development and commercialisation of new low-carbon enabling technology. The extent to which green bonds are used to finance investment in emerging markets and developed economies would also affect the demand/supply balance for bonds and the availability of capital for investment in the development and deployment of technology.

[22] Further details on green bonds are available at http://climatebonds.net/.

- **Impacts** – Certain sectors and regions are vulnerable to extreme weather events, and the risks increase beyond 2050. Climate-vulnerable regions would be negatively affected by the impact of climate change that could escalate over time, with emerging markets being the most sensitive. For this reason, we have assigned a higher sensitivity of emerging market to impact risks, as it may directly affect demand for, and supply of, emerging debt and green bonds to finance adaptation measures in vulnerable countries (such as India/South Asia and Africa).

- **Policy** – Under some scenarios, climate policy is likely to lead to increased public spending on energy infrastructure and on other public goods (for example, the provision of information on energy-saving measures) and the promotion of energy efficiency in the public sector. The extent to which this investment is financed by private-sector issuance rather than by the public sector would be important for gauging future government bond issuance needs. Carbon pricing could, for example, be implemented via a carbon tax that would increase the tax receipts received by governments. If carbon pricing was implemented via cap-and-trade schemes, then the solution would be market based and, depending on the design, potentially bring lower implications for public finances. Emerging debt is likely to be more sensitive to climate policy developments than sovereign debt or investment-grade credit. This is because some emerging economies have a higher sensitivity to the climate policy framework, particularly around decisions related to adaptation payments from developed to developing economies, which, in turn, may be financed via green bonds.

Table 8 presents the sensitivities of government bonds, emerging debt, investment-grade and credit to the TIP™ factor risks for each scenario. The magnitude (low, moderate, high and very high) of the sensitivity of the asset to the climate factors is presented at the top of the table, with the colour denoting the direction of the impact.

Table 8

Sensitivities of government bonds, emerging debt, investment grade and credit to the **TIP™** factor risks

Asset	Government bonds	Emerging market debt	Investment-grade credit
TIP™ sensitivity	*Low*	*Moderate*	*Low*
Regional Divergence	Governments with a proactive approach to climate policy could issue more debt to finance expenditure on programs to shift to a low-carbon economy. These may be hypothecated financing instruments (such as green bonds). Countries (e.g. Russia, Canada, the US, Australia) that are heavily dependent on high-emitting sectors that lag in terms of climate change policy may attract a higher country risk premium.	The market and/or credit rating agencies may attach a higher risk premium to some emerging-debt issuers that are lagging in terms of climate policy response (e.g. Russia) and/or are more vulnerable to the physical impacts of climate change (such as India/South Asia, Africa and parts of China/East Asia).	Credit rating agencies may begin to factor in future climate risks, which would exaggerate the differences between leading and laggard companies in terms of the sectors they operate in, including fossil-fuel industries (coal mining, crude oil and gas extraction, petroleum refining, gas utilities) and carbon-intensive primary and manufacturing industries, including mining and chemicals.

Table 8
Sensitivities of government bonds, emerging debt, investment grade and credit to the **TIP™** factor risks *(cont'd)*

Asset	Government bonds	Emerging market debt	Investment-grade credit
TIP™ sensitivity	*Low*	*Moderate*	*Low*
Delayed Action	After some delay, subsidies and/or taxation promote rapid deployment driven by the public sector. The possible introduction of a carbon tax could be inflationary and negative for an existing bond portfolio, although bonds will likely benefit from safe-haven status as risk appetite declines in the initial aftermath of the policy measures.	Higher risk aversion in the market due to dramatic policy measures could lead to a higher risk premium attached to emerging debt initially after the policy U-turn. The policy measures are dramatic but focused on local measures rather than supportive of emerging markets and adaptation needs, increasing the role and importance of development banks (such as green bond issuance).	Companies focused on low-carbon deployment attract a premium; companies with high-carbon sensitivity suffer cost imposition. An unexpected introduction of a high cost of carbon could be inflationary. This could place upward pressure on the cost of financing, particularly for companies in carbon-sensitive sectors of the economy.
Stern Action	Increased bond issuance likely to help finance public spending on energy infrastructure and on other public goods related to climate-change policies and the promotion of energy efficiency (possibly via green bonds). The scenario assumes the private and public sectors will share the adjustment costs, and hence, the impact of budget deficits (and bond issuance) is expected to be neutral.	Supportive environment for emerging markets from climate policy, leading to a decline in emerging-market debt risk premiums. Adaptation transfers from developed nations to those developing nations that are vulnerable to climate change reduce future impact risks.	Coordinated policy and technology development provides new opportunities for some corporate issuers to evolve, as well as sufficient time for negatively impacted sectors to adapt and transform to a low-carbon economy.
Climate Breakdown	This scenario is broadly neutral for government bonds, with a risk of rising financing risks for developed countries as future adaptation support for vulnerable regions increases.	Climate-vulnerable regions may be negatively affected by the impact of climate change that will escalate over time. While the regions most vulnerable are not major issuers of debt held in emerging-market debt portfolios, there is likely to be a re-pricing of risk towards emerging-market assets. Currently, South Africa is the most vulnerable country that features in the JPM EM Bond Index, with a 12% weighting. This could increase as other emerging-market countries develop their local bond markets.	As for global equities, the evidence points to physical impacts not being a major cost for the markets to absorb at the aggregate level within the timeframe of this report; however, there may be an impact if credit markets and/or rating agencies start to build expected future degradation into risk premiums.

Source: Mercer, drawing from various sources, as referenced

Private equity

Private equity assets will be a core part of the transformation to a low-carbon economy across all the mitigation scenarios, as investment in low-carbon technology would require a high degree of private sector financing due to the lack of public sector finances with structurally high government deficits, as well as the short-term constraints that are likely to limit the extent to which the public market is willing to invest.

On balance, we expect that the most important source of climate change risk for private equity assets will come from climate policy and technology (for venture capital funds), rather than from impacts, as will be explained more fully below.

- **Technology** – Venture capital is highly sensitive to technology, as one would expect, given that private equity could play a key role in the research and development and commercialisation of low-carbon enabling technology. This is particularly pronounced for renewable-energy venture capital.
- **Impacts** – This is a low source of risk for private equity out to 2050, although this would vary by business type and location, which would need to be taken into account at the asset placement level.
- **Policy** – There is a high degree of sensitivity across the board to changes in climate policy that may be introduced via legislation or other market-based mechanisms. Policy changes will help enable and encourage deployment of new technologies via private equity through creating appropriate incentives and pricing signals. Indeed, many private equity funds with a cleantech focus to date have tended to focus on the later-stage deployment and commercialisation of proven technologies rather than on taking technology development risk.

Private equity investors tend to have a three-to-five-year horizon when evaluating direct investment opportunities[23]; hence, the investments that will proliferate are likely to be those that attract the greatest potential return within that horizon. This would allow private-equity investors to be slightly ahead of government policy and to take some risks around technology in terms of deployment – at least more so than traditional listed equity investors. The structure of the traditional private equity portfolio is likely to make a gradual transition to include more energy-related low-carbon investments that may be more in the venture capital end of the spectrum, although leveraged buyout (LBO) activity is also expected to increase. This conclusion is reinforced by a private equity study by Bain & Co. (2010)[24] that predicted the strongest growth area expected within the private equity market would come from the energy sector.

The opportunities within private equity are highest under the Regional Divergence and Stern Action scenarios, driven by policy and technology. In terms of the sectors within private equity, the greatest opportunities are likely to be in the renewable energy, CCS, smart grid, electric cars and battery charging and replacement points, water/waste including underground reservoirs (water storage), increased membrane treatment, biogas and desalination plants, and R&D across all sectors for new breakthrough technologies and deployment of technologies in the shift to a low-carbon economy.

The risks are highest for private equity under the Delayed Action and (to a lesser extent) the Climate Breakdown scenarios due to an increase in uncertainty surrounding policy and delay in investment in technology solutions. Under Delayed Action it is also assumed that a largely unexpected increase in the cost of carbon hits the high-carbon sectors of an existing private equity portfolio quite hard. The investments most at risk would include investments in the industrials sector, which, together with consumer products and health care, account for more than 60% of the private equity market (Bain & Co 2010:22).

In addition to the cost of carbon risk for companies within a private equity portfolio, the risk of a flood of capital that leads to a bubble in valuations is also a risk under the Stern Action and Regional Divergence scenarios that would need to be taken into account. Under these scenarios there is also an increased risk that technology advancements move quickly and supersede existing investments.

[23] This is distinct from the horizon that an institutional investor might have when allocating to a private equity fund, which typically has a much longer horizon given high upfront costs and the j-curve effect, where assets take some time to place and, hence, yield a return.

[24] Bain & Co (2010).

Table 9 presents the sensitivities of private equity LBO, venture capital and renewable energy to the TIP™ factor risks for each scenario. The magnitude (low, moderate, high and very high) of the sensitivity of the asset to the TIP™ risk factors is presented at the top of the table, with the colour denoting the direction of the impact.

Table 9
Sensitivities of private equity LBO, venture capital and renewable energy to the **TIP™** factor risks for each scenario

Asset	Private equity LBO	Private equity venture capital	Private equity renewable energy
Sensitivity	*Moderate*	*High*	*Very high*
Regional Divergence	The transformation that will take place in some regions that implement climate policy and invest in technology will be significant, with LBO activity expected to increase as the economies in those regions shift from high- to low-carbon industries. The economies likely to experience the greatest shift in this transformation are those that are high-emitting nations but implement policy measures – at present, this could represent the EU, China/East Asia, the UK, states within the US, and Japan.	As for LBO, with the key difference being a very high opportunity related to technology in some regions. The countries with the highest expenditure on low-carbon solutions and the deepest venture capital markets at present include the EU, the US, China/East Asia, Japan, the UK and parts of Latam (Brazil and Mexico).	Renewable investments may be highly sensitive to the climate policy variability by countries. The regions with the most supportive policies for renewable energy and the deepest investment markets based on the current policy environment and clean energy markets include parts of Europe – particularly Scandinavia, France, Germany and Spain – and the UK, China/East Asia, states within the US, Brazil, India/South Asia and Japan.
Delayed Action	Subsidies and/or taxation (hard regulations) promote rapid technology deployment. Funds focused on low-carbon deployment attract premium, while existing private equity funds with high-carbon sensitivity suffer cost imposition. An increase in bankruptcies is likely for a period following policies and a reduction in LBO activity.	On the basis that policy changes are not fully anticipated, private equity venture capital assets that are dominated by high-carbon investments would face increased unexpected costs in response to a dramatic policy shift. If a private equity portfolio has a higher degree of low-carbon investments as the starting point, then the assets would be more resilient.	The policy U-turn may lead to strong performance of renewable assets after the measures are implemented. Due to late action the policy response will focus more on deployment of existing technology. The main "proven" technologies include wind, solar, sugar-based ethanol, and cellulosic and next-generation biofuels.
Stern Action	Balance between R&D and deployment is likely due to supportive policy environment. Opportunities extend to new and existing funds to capture low-carbon transformation investments, with policy clarity and consistency reducing uncertainty. An increase in LBO activity is likely as a period of creative destruction unfolds as companies in low-energy sectors outperform high-carbon or energy-intensive businesses.	As for LBO, but the activity is expected to focus on identifying new opportunities for both development and deployment of new technologies. Further technology risk may be taken into venture capital funds than is currently the case, encouraged by the supportive policy framework that makes such investments economically viable.	A positive scenario, as these assets should play a key role in the early stages of the R&D development and deployment (including wind, solar, CCS and geothermal). Over the long term, the "mainstreaming" of renewable energy may lead to a similar risk/return profile to traditional venture capital private equity funds, as there would be less opportunity for specialist portfolio managers to have an informational advantage over their generalist peers.

Table 9
Sensitivities of private equity LBO, venture capital and renewable energy to the **TIP™** factor risks for each scenario *(cont'd)*

Asset	Private equity LBO	Private equity venture capital	Private equity renewable energy
Sensitivity	*Moderate*	*High*	*Very high*
Climate Breakdown	Neutral overall for LBO activity in the timeframe of this study, although higher physical impact risks will need to be priced into certain types of assets. New opportunities will proliferate in adapting to climate change in the absence of mitigation, such as flood defence, water management and desalination. The nature of investments in underlying companies in terms of type of business and physical location increases in importance as part of the due diligence process.	Same as for LBO, but higher sensitivity to "no mitigation" policy will reflect the possible impact on existing private equity asset valuations for low-carbon investments that have been priced in policy action (i.e. they could lead to a downward re-pricing of cleantech assets held in a portfolio).	This is a negative scenario for venture capital renewable energy, particularly for existing private equity asset valuations that have likely priced supportive policy action within this horizon (out to 2030).

Source: Mercer, drawing from various sources, as referenced

Infrastructure

Infrastructure assets will be a core part of the adaptation and mitigation efforts of governments around the world. As such, the decarbonisation of new/existing assets as well as adaptation to climate change through the replacement of assets or construction of new assets will be important drivers behind long-term infrastructure investment trends internationally.

The long-term nature of infrastructure investments, with a 10+ year horizon when evaluating the attractiveness of an asset, means that future policy changes and technology advances, as well as physical impacts due to climate change, are more likely to be taken into account in the evaluation process. Moreover, we expect that the nature of a traditional infrastructure portfolio would likely transition over time to embed more of the new opportunities available and to move away from high energy intensive assets. This could entail, for example, a shift in the nature of an infrastructure portfolio to a higher allocation of non-core assets, such as development projects and emerging market investments, than is currently the case.

We expect that the most important source of climate-change risk for infrastructure assets will come from a combination of climate policy and technology, with impact risks being limited to a more narrow set of assets in particular regions. A few overall observations on the sensitivity of infrastructure to TIP™ factors:

- **Technology** – Technology should play a role in enabling the upgrade and adaptation of existing infrastructure towards low-energy solutions. For example, energy power distribution could be aided by new advances regarding smart grids and technologies in renewable energy, nuclear power and CCS. Transport transformation could be assisted by electrification of rail and motor vehicles and new technologies in road surfacing. Improved drainage and flood-protection measures in airports could take place. New advances in irrigation, water storage and desalination could also have an impact on water.

- **Impacts** – The long-term nature of infrastructure assets and the fact that many are built with a 100+ year life span increases the importance of due diligence and environmental risk assessments in any new building infrastructure or improvements. Some of the long-term risks include a flood risk for assets in coastal areas, damage caused by knock-on effects of heat waves and damage caused by storms (wind, rain, snow). This could lead to interruptions in electricity and water supply, disruptions to road and rail networks, softer road surfaces, restrictions on water usage, power station inoperability (for example, nuclear stations in France during the heat wave during 2010) and blackouts. The evidence suggests that these risks may vary by investment type and location, which would need to be taken into account as part of the evaluation of the investment opportunity (be it via a fund manager or through direct investments).

- **Policy** – Given the public/private partnership nature of many infrastructure investments and the socioeconomic needs that infrastructure assets fulfil, policy and regulatory changes related to climate change should be important drivers of infrastructure returns under all the mitigation scenarios. Such policies might take place at the global or national level and will likely be implemented using a variety of approaches for the design of new, and retrofit of existing, infrastructure with respect to climate-change mitigation and adaptation. For example, this may involve changes to planning applications at regional and local levels, as well as new standards of engineering and measures to encourage integration of solutions into planning processes and construction.

Overall, the biggest opportunities within infrastructure may be within the Stern Action and Regional Divergence scenarios, driven by both policy and technology factors. The location of infrastructure assets may be important for investors to consider, as many of the fast-growing developing economies have an opportunity to build new infrastructures that are more climate-resilient from the outset, potentially creating an advantage over developed countries whose existing assets have high replacement and upgrade costs that will slow down their rates of investment. In terms of types of infrastructure assets by sector, the greatest opportunities related to climate change for institutional investors are likely to be in energy, transport and water/waste.[25] Within energy, the

[25] URS *Adapting Energy, Transport and Water Infrastructure to the Long-Term Impacts of Climate Change* (2010).

areas include renewables, nuclear and CCS, but with more focus also on transmissions and distributions networks, decentralised electricity and heat generation, additional fuel capacity storage, electric vehicle recharging points, hydrogen and biogas.

The opportunities within transport include road, rail and bridge replacements; sustainable drainage systems; electrification of rail and overhead electrical lines; electric cars and battery charging and replacement points; road surfacing; improved drainage and flood-protection measures; and larger berths and improved port design.

In water/waste, opportunities could include underground reservoirs (water storage), increased membrane treatment, biogas and desalination plants.

Just as these sectors pose the greatest opportunity, they also present the greatest potential risk under the “no mitigation” scenario of Climate Breakdown. In brief, technology advancements could reduce the value of some infrastructure assets that are less advanced or unable to utilise the improvements or, in the most extreme case, they could render some infrastructures redundant (coal power stations perhaps, in the very long term). This risk is highest under the Stern Action and Regional Divergence scenarios, where the rates of technological progress are expected to be the highest. The highest impact risks on some infrastructure assets due to physical changes to the environment would be under the Delayed Action and Climate Breakdown scenarios, where late or no action on policy increases the prospect of higher environmental damage in the future (and therefore higher risk premiums for some infrastructure assets may be required).

Policy or regulatory risks would be highest under Regional Divergence, where there may be some uncertainty about the variation on the direction of policy across regions and hence the long-term path of investment in infrastructure projects. Delayed Action would also be disruptive to the extent that the abrupt policy changes are not anticipated in project planning.

Table 11 (on page 56) presents the sensitivities of infrastructure core unlisted and renewables unlisted to the TIP™ factor risks for each scenario. The magnitude (low, moderate, high and very high) of the sensitivity of the asset to the TIP™ risk factors is presented at the top of the table, with the colour denoting the direction of the impact.

Table 10
Infrastructure types by sector

Economic				**Social**
Transport	*Energy*	*Water/Waste*	*Communication*	
Roads, bridges and tunnels Railway networks Airports Ports Ferries	Pipelines Fuel processing, storage and transport Contracted power generation and pollution control Energy distribution systems	Water distribution Waste collection Water supply Water treatment Waste treatment and disposal	Cable networks Satellites Transmission/ broadcasting	Health care (hospital, etc.) Education Penitentiary infrastructures

Source: Adapted from a combination of CDC (2010) report and *Adapting Energy, Transport and Water Infrastructure to the Long-term Impacts of Climate Change*, URS, January 2010. A report commissioned by the UK government’s cross-departmental infrastructure and adaptation project

Table 11
Sensitivities of infrastructure core unlisted and renewables unlisted to the **TIP™** factor risks for each scenario

Asset	Infrastructure, core unlisted	Infrastructure, renewables unlisted
TIP™ sensitivity	*High*	*Very High*
Regional Divergence	This scenario produces some new opportunities for infrastructure, but it increases volatility due to political and regulatory uncertainty over which regions will lead and lag. Replacement of existing infrastructure will generally be highest in developed economies where stock is old, unsuitable for climate change and unsustainable from an energy-efficiency perspective. Investment in new infrastructure that is geared towards low carbon and adaptation to climate change will be stronger in the fast-growing developing economies, including China/East Asia, Brazil, Mexico and South Korea.	The high sensitivity to the climate factors means that investments may be highly sensitive to the climate policy variation by countries. The North American market is focusing on smart-grid and technology solutions to improve efficiency of delivery more than adaptation of infrastructure assets. Electrification of vehicles and recharge solutions may also attract investments. The UK and Europe are leading the development and deployment of many renewables and decentralisation of electricity generation. The regions with the greatest need for water storage and desalination include those facing water shortages as population growth and changing climate conditions reduce availability. The studies suggest this will be in MENA, Central America, the southern portion of the US, southern countries in Africa, and southern Australia.
Delayed Action	This scenario brings a mixed profile for infrastructure, as policy changes occur late and are costly for existing assets that have not fully anticipated the adjustments required. It could produce new opportunities for assets that price in additional costs and risks as compensation. A possible inflation rise owing to a carbon price shock is generally supportive in some infrastructure assets, which could offset cost pressure from policy. Overall volatility increases to reflect unexpected adjustment costs.	The higher sensitivity of renewable energy infrastructure assets to the climate risk factors means that the policy U-turn will lead to strong performance after the measures are implemented. Due to late action the policy response will focus more on deployment of existing technology rather than on R&D. The main "proven" technologies include wind, solar, sugar-based ethanol, and cellulosic and next-generation biofuels. As well as the energy sector, it may also bring investments in transport efficiency infrastructure and water/waste management that focus on cost/efficiency savings.
Stern Action	This scenario brings attractive opportunities for investors, with policy clarity and investment reaching high levels in low-carbon infrastructure assets across transport, energy and water/waste globally. Over the long term, the "mainstreaming" of renewable energy may actually lead to some merging between the composition of a core unlisted infrastructure asset and low-carbon/low energy assets.	This is a positive scenario, as renewable infrastructure investments will play a key role in the early stages of both R&D and deployment. Opportunities include renewable energy; road, rail and bridge replacements; sustainable drainage systems; electrification of rail and overhead electrical lines; electric cars and battery charging and replacement points; road surfacing; improved drainage and flood-protection measures; and improved port design. In terms of water/waste, opportunities include underground reservoirs (water storage), increased membrane treatment, biogas and desalination plants.

Table 11

Sensitivities of infrastructure core unlisted and renewables unlisted to the **TIP™** factor risks for each scenario *(cont'd)*

Asset	Infrastructure, core unlisted	Infrastructure, renewables unlisted
TIP™ sensitivity	*High*	*Very High*
Climate Breakdown	Coastal infrastructure will likely attract a premium to reflect risk of damage from rising sea levels and increased severity of storms/extreme weather. For energy assets, climate change may lead to transformer thresholds being exceeded and energy-generation efficiencies could be negatively affected; some reinforcement may be required of energy transportation and distribution systems. Low-lying areas most prone to flood risk where water availability risk is highest include those in MENA, Central America, the southern part of the US, southern countries in Africa, and southern Australia. Flood and drought risks need to be built into the design of new infrastructure and replacement of existing stock.	This is a negative scenario for sustainable infrastructure assets, particularly for planned or existing investments that have been built on the assumption of future supportive policy action.

Source: Mercer, drawing from various sources, as referenced

Real estate

As for infrastructure, the long horizon of real estate and the "real" nature of investments, in the sense that it constitutes a tangible asset, increase the importance of climate-change risk factors as an extension of evaluating the risk/return profile of property assets over the long term. Climate policy is the key driving force, but advances in technology with regard to energy efficiency are equally as important, as will be evaluating the risks around potential damage due to climate-related risks. To varying degrees, real estate portfolios are starting to transition towards a greener portfolio as new environmental regulations and building efficiency measures increase the standards of property assets.

There are a number of different types of vehicles through which investors can access real estate investments; this paper focuses on unlisted (direct) core assets. As Table 12 (on page 59) illustrates, climate change has the potential to affect real estate income return through changes in operating costs and occupancy rates. In addition, capital growth may be affected through changes in depreciation and expected rental growth.

We expect that the most important source of climate-change risk for real estate assets will therefore come from a combination of climate policy and technology, with impact risks being limited to a more narrow set of properties in particular regions. A few overall observations on the sensitivity of real estate to TIP™ factors:

- **Technology** – Most technologies available in the real estate sector have already been proven in the market with predictable performance and cost.[26] These focus on energy efficiency and demand reduction. The largest and most cost-effective savings occur when buildings are designed from scratch with energy efficiency in mind (which will be possible in many emerging markets). However, due to the long lives of buildings[27] and the large global stock of inefficient buildings, the largest carbon-saving potential over the next few decades is actually from retrofitting (in particular, installing better insulation to reduce heating and cooling needs), not from new buildings.

- **Impacts** – The physical impacts of climate change are expected to be relatively small between now and 2050. However, the future risk of extreme events and weather changes would be part of how the market evaluates risk under some scenarios. The main changes that are anticipated are in demand for heating and cooling as well as for protection against intense precipitation and flooding (both coastal storm surges and fluvial).

- **Policy** – Given that the building sector contributes to 30% of global greenhouse gas (GHG) emissions and is a sector in which emissions can be reduced relatively cheaply with proven technologies,[28] it may be a key target for policymakers under mitigation scenarios. An estimate from McKinsey shows that emission-abatement potential in the building sector could lower emissions in 2030 from 12.6 Gt CO_2 per year to 9.1 Gt CO_2 per year. Furthermore, the Intergovernmental Panel on Climate Change (IPCC) reported that net-cost additions to achieve stabilised CO_2 levels by 2050 may be 7% of total building costs worldwide.[29] Without a global response to mitigation (that is, the Climate Breakdown scenario), emissions from buildings could more than double in the next 20 years.[30]

[26] McKinsey and Co. (2009), p. 105.

[27] McKinsey estimates that the overall lifespan of buildings is approximately 35–70 years, with the average being as long as 60–70 years in developed countries.

[28] The most basic technological options for mitigating existing buildings' emissions include more efficient heating, ventilation and air conditioning (HVAC) systems; reduced electricity consumed by lighting and appliances; solar thermal water heaters; heat pumps; and insulation and double glazing.

[29] World Business Council for Sustainable Development *Energy Efficiency in Buildings: Transforming the Market* (2009), p. 1.

[30] UNEP *Sustainable Buildings and Climate Initiative, Buildings and Climate Change: Summary for Decision Makers* (2009), p. 3.

Table 12

Real estate and climate change impacts

Climate change transmission mechanism	Return drivers	
Increase in cost base due to regulatory requirements leading to higher upfront cost of building materials, fittings, etc.	**Operating costs**	Tax, maintenance, replacement, depreciation
Reduced utility costs, tax and depreciation due to efficient water and energy technologies		Water and energy costs, tax, depreciation
Higher utility costs and insecurity, driven by higher water and energy insecurity		Water and energy costs, maintenance, insurance
Increased/reduced utility costs due to higher requirement for cooling – less heating in high latitudes		Water and energy costs, tax, maintenance, depreciation, insurance
Risk of flooding and extreme weather conditions leading to location discounts/premiums in rental incomes	**Occupancy rates**	Location
Increased occupancy rates due to reduced utility costs from efficient water and energy technologies (i.e. increased demand for "green buildings")		Location and expected rental growth
More tourism in mid- to high-latitude regions and decreased tourism at low latitudes		Travel demand (countries that rely more heavily on tourism will be prepared to invest more into the infrastructure of the area to promote construction and tourism)
Changes in access to logistics will affect occupancy rates		Logistics

Source: Mercer, adapted from various sources

According to RREEF research,[31] the leading markets in terms of sustainable building include western Europe, Australia, Canada and Japan. Sustainable practices are still lagging in faster-growing emerging economies, although these regional variations are expected to change over time as global flows of capital and technology intensify. Government regulation would continue to be a significant driver for energy-efficient low-carbon buildings in developed and emerging countries through setting minimum standards for new construction through building codes (such as in the US and Europe), efficiency of existing buildings (India/South Asia), transparency regarding efficiency rating (Japan), and phasing in escalating sustainability standards for all residential and commercial buildings (California).[32]

Overall, the opportunities within real estate are highest under the Stern Action and Regional Divergence scenarios, driven by both policy and technology factors.

[31] RREEF Research *Globalization and Global Trends in Green Real Estate Investment* (2008).

[32] *ibid.*

Table 13

Real estate opportunities

Theme	Regions
Energy and water efficiency	Efficiency in buildings and appliances is the area where most opportunities exist across all regions. However, the greatest potential for low-cost mitigation by 2030 is in electricity savings in non-Organisation for Economic Co-operation and Development (OECD) countries from more efficient cooling systems and appliances. In China/East Asia, measures to promote the uptake of more efficient air conditioning are significant. Within the OECD, opportunities are primarily in more efficient heating and cooling systems and appliances from retrofitting, rather than from new build (in particular, installing better insulation to reduce heating and cooling needs). Out of the OECD countries, the US holds the greatest opportunities for both new low-carbon construction and retrofits based on projected green construction volume – followed by the UK, Japan and Germany.[33] In terms of the types of real estate, the most rapid transformation is expected in buildings where considerable energy savings can be made, such as high-rise office buildings, high-profile uses such as retail centres, and urban in-fill sites.[34]
Heat pumps	According to the Climate Group, heat pumps will be fitted in 50%–70% of buildings in the OECD by 2050. The US is likely to represent the greatest opportunities in both new construction and retrofits, followed by the UK, Japan and Germany.
Solar space and water heating	Policy intervention may reduce capital costs for solar space and water heating, representing notable opportunities in the Southern Hemisphere. Incentives are already established or under way in countries such as Australia, China (where basic models are around 80% cheaper than in Western countries) and Spain.

Source: Mercer, compiled from various sources as referenced

[33] *ibid.*

[34] *ibid.*

The risks for real estate are more apparent under the Delayed Action and Climate Breakdown scenarios, in both cases driven by an increase in the physical risks to the environment that might negatively affect some real estate assets, depending on their location and/or carbon preparedness in terms of energy efficiency.

Table 14
Real estate risks

Theme	Regions
Lack of carbon preparedness	An unexpected increase in the cost of carbon could hit real estate across all regions, particularly under the Delayed Action scenario. The impact will be larger the lower level of carbon preparedness of the real estate portfolio.
Sea-level rise and extreme weather events	Low-lying coastal areas in populated areas such as Bangkok, New Orleans and Shanghai are vulnerable to rising sea levels, especially those due to floods and storms. From an investment perspective, the impact of cyclones may be most significant, affecting countries of all income levels, including upper-middle-income and high-income levels.
Heating and cooling	An increase in heating and cooling demand in the Northern Hemisphere may result in net higher expenditure on building maintenance to improve insulation and cooling capacity – particularly when retrofitting buildings.
Precipitation and flooding	There may be some costs to individual properties to avert storm damage, as well as adaptation costs for public works to improve drainage and infrastructure resilience in wetter areas.
Water availability	Water scarcity is expected to be potentially significant in Asia, Africa and Latin America. Risk of water shortages is greatest in Asia (circa 1 billion people would face reduced water supplies and extreme weather events with a 1–5 degree temperature increase).

Source: Mercer, compiled from various sources as referenced

Table 15 presents the sensitivity of core unlisted real estate to the TIP™ factor risks for each scenario. The magnitude (low, moderate, high and very high) of the sensitivity of the asset to the TIP™ risk factors is presented at the top of the table, with the colour denoting the direction of the impact (negative, neutral or positive) for each scenario.

Table 15

Sensitivity of core unlisted real estate to the **TIP™** factor risks for each scenario

Asset	Real estate, core unlisted
TIP™ sensitivity	*High*
Regional Divergence	It will be important to consider climate change preparedness and vulnerability at the regional level when considering real estate investments. Those regions that are most at risk from the physical impact of climate change will attract a higher risk premium under the less internationally coordinated emission reduction outcome as it increases future impact risks. Efficiency in buildings and appliances will be where most opportunities exist. In China/East Asia, measures to promote the uptake of more efficient air conditioning may present opportunities. Within the OECD, opportunities will primarily be in more efficient heating and cooling systems and appliances from retrofitting (in particular, installing better insulation to reduce heating and cooling needs) rather than in new build.
Delayed Action	This scenario primarily brings risks for real estate where policy changes occur late and require short and sharp adjustment costs. Real estate assets are very sensitive to changes in regulation and will be the target for such measures and quick action. Investors in real estate assets that are not up to a high standard on energy efficiency grades will be exposed to risk of obsolescence and high adjustment costs to improve the efficiency of their buildings after the policy measures have been introduced. Portfolios that have already been "greened" to a high standard will be more resilient to the policy measures.
Stern Action	This scenario brings opportunities to improve energy and water efficiency management. The most rapid transformation is expected in high-rise office buildings, high-profile uses such as retail centres, and urban in-fill sites.[35] Heat pumps will be fitted in the majority of buildings, with the US leading in new construction and retrofits, followed by the UK, Japan and Germany. Policy may reduce costs for solar space and water heating. Incentives exist in Australia, China/East Asia (where basic models are around 80% cheaper than they are in other countries) and Spain.
Climate Breakdown	This scenario is likely to be negative for real estate assets. Low-lying coastal areas in populated areas, such as Bangkok, New Orleans and Shanghai, are vulnerable to rises in sea level, especially those due to floods and storms. From an investment perspective, the impact of cyclones may be most significant, affecting countries of all income levels, including upper-middle-income and high-income levels. An increase in heating and cooling demand in the Northern Hemisphere may result in net higher expenditure on building maintenance to improve insulation and cooling capacity – particularly when retrofitting buildings. There may be some costs to individual properties to avert storm damage as well as adaptation costs for public works to improve drainage and infrastructure resilience in wetter areas.

Source: Mercer, drawing from various sources as referenced

[35] *ibid.*

Commodities

We consider three types of commodities: timberland, agriculture land and the carbon market. We focus on these investments since they can be invested in outside a commodities futures basket. This was a key consideration for our analysis, as it is more difficult to ascertain the long-term effect of the climate scenarios on a broad commodity futures basket, since the impact may vary quite substantially across different types of commodities. A few observations on the technology, impacts and policy factors:

- **Technology** – Technology would have a limited impact on agricultural land and timberland, although crop technology would help with adaptation efforts (for instance, heat-tolerant and drought-tolerant crops). Biomass electricity generation and transport biofuels are creating new and important markets for forest resources. Under mitigation scenarios, this could increase demand for sustainably produced forest and manufacturing residues, as well as for different types of agriculture for biofuels (although sustainability guidelines are vital around the latter to limit knock-on damage to the environment and food security[36]). For carbon, since the price is partly determined by the supply and demand of the carbon emission permits and whether the permits can be exchangeable across different markets, technology may play a role to the extent that the technology enables the reduction in emissions but is not the dominant driver of the price.

- **Impacts** – Timberland and agricultural assets/land face a direct risk of damaging physical impacts that could substantially reduce the value of investments (storms, flooding, insect plagues, etc.). Overall, the impact on agricultural land and timberland is high but can vary a lot across regions; in some regions crop yields will increase, while in others they will decrease, possibly making agriculture in certain crops no longer feasible. Physical changes in the environment may also play an important role in determining the carbon price over the long term, as the carbon price could increasingly act as a barometer of climate-event risks.

- **Policy** – Climate policy may be an important feature of how investments in agricultural land, timberland and carbon perform over the coming decade. The mix of policy options (including but not limited to emission trading schemes and projects) and the degree to which they promote incentives to reduce emissions through sustainable agricultural techniques, reforestation and avoiding deforestation, increased demand for sustainably sourced materials (such as timberland) and the resultant cost of carbon will all have an impact on the price and costs of production for investments in agricultural land, timberland and carbon.

Agriculture land

The uncertainties with regard to climate change impacts on agriculture in terms of international trade, markets and investments are very high. Nevertheless, research suggests that climate change may affect the prices and volumes of goods traded between developed and developing countries, particularly agricultural raw materials and food, with wider macroeconomic consequences.[37]

One of the sources of risk for investors in agricultural land relates to how climate policy and the extent to which emissions from agriculture and land use could be incorporated into a global mitigation regime. Emissions from agriculture and land-use change account for about a third of all anthropogenic greenhouse gas emissions (Smith et al, 2007; FAO, 2008). In addition, they raise the prospect of extensive low-cost mitigation. According to McKinsey and Company (2009), roughly a third of the global abatement potential available at a cost of less than $20 in 2030, some 9.4 Gt CO_2e, lies in reducing emissions in these sectors, through such options as soil management and reduced forest conversion. Therefore, whether measures to abate these emissions are put in place could have a decisive impact on the costs of agricultural crop production and should be taken into account by investors.

[36] The European Commission released two documents clarifying how member states should implement the biofuel components of the Renewable Energy Directive by the end of 2010.

[37] Ludi et al (2007).

Another source of risk for agricultural investments relates to the impact of climate change on cash flows from changes in crop prices. Within the horizon of this study, Grantham LSE/Vivid Economics showed that climate change, along with other socioeconomic drivers, is expected to place some upward pressure on agricultural prices across all the scenarios. The scenarios diverge the further the horizon, where the "no mitigation" Climate Breakdown scenario expected to result in a higher price rise out to 2050. As such, across the scenarios the impact of climate change on crop prices is broadly similar, having the effect of driving up prices and, hence, cash flows that underpin investments.

But crop prices only tell part of the story for investors. The reliability of crop-yield production and efficiency improvements to agricultural practices, including sustainable farming methods, are also important considerations given the rising pressures on water availability, land supply and uncertain weather patterns. Climate change increases the uncertainties around crop production and the need to invest in more sustainable techniques (as will be discussed below); hence, investment in "real" agricultural assets as distinct from trading commodity futures would be affected in different ways.

The concept of "sustainable agriculture" seeks to minimise environmental damage and to ensure longer-term productivity through reducing chemical inputs and energy use in farming systems, promoting the efficient use of water, the use of complementary planting/permaculture, and the development of land for ecosystems services (such as water catchments, flood mitigation, biodiversity offsets). Most agricultural assessments of global environmental change have not focused explicitly on sustainability issues and have neglected the considerable impacts of shifting agricultural zones, alterations in commercial fertilizer and pesticide use, and changes in the demand for water resources.[38] Nevertheless, this is becoming an important consideration for investors in agricultural assets and would likely improve the resilience of an allocation to agricultural land across the climate scenarios.

Timberland

Timberland investment involves purchasing both plantations and naturally occurring forests in order to harvest the wood on a sustainable basis. Mercer's in-house research considers that the major factors that drive the performance of timberland as an investment include:

- Biological growth – As a tree grows, there will be more wood to harvest; hence, its value would increase over time, with the life cycle spanning some 40–60 years. In addition, the wood from larger trees is typically used for more valuable products.
- Timber product prices – The price of timber is affected by a number of macroeconomic variables (including GDP growth, the housing market, interest rates, etc.) as well as microeconomic factors (such as government regulation, alternatives to wood and rainfall).
- Land values – Land values are related to local supply-and-demand conditions and vary from market to market. Land prices, although influenced by timber prices, are typically far less volatile.
- Ecology – Additional returns may also be generated from the voluntary carbon market and projects involving forestry and biomass that generate carbon credits (and some fossil fuel switching).[39]

Drawing from a study by the World Resource Institute,[40] one source of uncertainty around climate change for timberland investments is related to physical impacts, where changes in temperature, droughts, floods, storms, fires and insect infestations can reduce forest productivity. A reduction in forest productivity could have a negative impact on crop yields and land values.

Climate policy and demand/supply side impacts are another key consideration for investors. Forests cover almost 30% of the world's land area and deforestation is said to contribute some 18%–25% of total greenhouse gas emissions. The potential reduction in emissions by avoiding deforestation is said to be as high as 60% of

[38] Rosenzweig and Hillel (1995).

[39] For further explanation, see http://pdf.wri.org/trees_in_the_greenhouse.pdf.

[40] Aulisi et al (2008).

potential mitigation by 2030, dominating any increased demand for timber-based materials due to more sustainable building practices (Stern, 2007). Avoiding deforestation would be a broadly positive outcome for investors in *existing* timberland assets, as it would increase land values, drive up timber product prices, as well as increase investment opportunities around carbon credits.

On the other hand, such policy measures could reduce the appeal of *new* timber investments depending on the extent to which the valuations are driven up by these factors, and also the premium that would be attached on existing plantations given rising costs of deforestation for new harvests. The detail of the policy measures around creating the right incentives for investors in new timberland assets would therefore be important.

A report authored by Forum for the Future (2009)[41] discusses the prospects for policy within the reduced emissions from deforestation and degradation (REDD) and afforestation, reforestation and sustainable forest management (REDD+) schemes. While these schemes are excluded from Kyoto, under a strong mitigation scenario such as Stern Action, we expect they would feature in the climate policy response and, hence, their implications would need to be considered by investors. The Forum for the Future report suggests a number of areas for policy design of relevance to institutional investors in timber assets, including creating regulations and incentives related to allocation of capital to REDD+ projects – such as political influence and increasing costs associated with governance/ compliance – to reduce the risks that may destabilise cash flows.

The World Resources Institute (WRI) report concluded that many risks and opportunities related to forestry businesses will vary greatly by a company's geographic location, position in the value chain, and the sustainability of operations, noting that "companies with experience in sustainable forest management and supply chains may be better positioned to capitalize on new climate change regulations and market forces." Given the uncertainties that prevail, we believe the same advice holds true for institutional investors in timberland assets.

Carbon

A number of carbon emission trading schemes have been established following the adoption of the Kyoto Protocol in 1997. Carbon emission permits can be categorised into two major types – allowance-based and project-based. Allowance-based permits are allocated by regulators under cap-and-trade schemes, with the major type of allowance-based permit traded in the EU Emissions Trading Scheme (EU ETS). The allowances are called European Union Allowances (EUAs) and are allocated under the National Allocation Plan of each member country within the EU ETS.[42] In addition, there are some regional voluntary markets such as the Chicago Climate Exchange and the New South Wales Greenhouse Gas Reduction Scheme in Australia.

Project-based permits are generated by participation in certified projects under arrangements such as the Clean Development Mechanism (CDM) and Joint Implementation (JI). Carbon emission permits generated from these certified projects are called Certified Emission Reductions and Emission Reduction Units, respectively.

This paper focuses primarily on the allowance-based carbon emission mechanisms, rather than project-based mechanisms. Allowance-based mechanisms produce a measureable output in terms of the carbon price that is traded on an exchange. In addition, the nature and design of project-based permits are likely to change significantly over the coming five to 10 years as a result of policymaker deliberations in response to feedback on improving these mechanisms. At present, investments will be constrained by obvious limitations (such as low market liquidity and limited regional focus).[43]

A number of supply-and-demand side factors are influencing investments. The supply side primarily relates to how many carbon permits have been allocated. The demand side is linked to the volume of carbon emitted during a period, which in turn is influenced by short- and long-term factors such as weather patterns, relative fuel price, climate policy changes, consumption trends and economic growth.

[41] Chapple A. *Forest Investment Review* (Forum for the Future, DfID and DECC, 2009), available at http://www.forumforthefuture.org/files/Introduction_FIR.pdf.

[42] The bulk of exchange trading activity in EUAs is concentrated on the European Climate Exchange (ECX) CFI contracts that are traded on the ICE Futures exchange in London. ECX accounts for some 80% of EU ETS exchange transactions (including OTC contracts cleared through exchanges), with the balance traded on Nord Pool, Powernext and the European Energy Exchange. Source: *Barclays Capital Global Carbon Index Guide 2008*, p. 5.

[43] For further discussion on carbon as an investment opportunity, see "Carbon Risk and Carbon Trading: Investment Considerations", available at www.mercer.com/ri.

Unlike other commodities, carbon is unlikely to act as a hedge against inflation, although it does have a higher sensitivity to climate change factors than the other commodities and, hence, could be viewed as protection against climate risks. More information on the supply-and-demand side drivers of the carbon market includes:

- Government/regulatory policy within and across regions in relation to the level to which carbon emissions should fall over the long term and the path taken to the long-term position
- The balance between carbon pricing and other methods of reducing emission – such as policy oriented towards innovation, research and development and encouragement of various mitigation strategies
- The rate of breakthrough in a wide range of technologies, including in the cleantech energy/cleantech sector
- The rate at which industry and society more generally adopt carbon-saving technology, including that which already exists
- Cost curves and relative prices of oil, gas and coal
- Weather patterns and changes in climactic conditions that can affect short-term energy generation and demand side factors
- The rate of economic growth in key countries

Table 16 presents the sensitivities of timberland, agricultural land and carbon to the TIP™ factor risks for each scenario. The magnitude (low, moderate, high and very high) of the sensitivity of the asset to the TIP™ risk factors is presented at the top of the table, with the colour denoting the direction of the impact (negative, neutral or positive) for each scenario.

Table 16

Sensitivities of timberland, agriculture land and carbon to the **TIP™** factor risks for each scenario

Asset	Timberland	Agriculture land	Carbon
Sensitivity	*High*	*High*	*Very high*
Regional Divergence	This scenario is neutral overall for timberland assets, although some regions are leading in promoting sustainable forestry and alignment with the REDD and REDD+ frameworks. Some examples of adaptation finance include the Forest Carbon Management programme in Canada, the California Climate Action registry in the US, Brazil's Amazon Fund, the Congo Basin Forest Fund and various funds under the International Climate and Forest Initiative supported by countries such as Australia and Norway.[44]	Agricultural prices are expected to rise by around 30% under this scenario due to climate change,[45] which is not dissimilar to the other scenarios out to 2030. The regional differences become magnified beyond 2050 with an increase in global unrest and geopolitical risk due to food shortages. There are substantial increases in the risk of hunger among the poorest countries,[46] especially in Sub-Saharan Africa and South Asia, where a large portion of the population depends on agriculture, and where capacities at the national and farm levels to adapt to climate change are lowest.	This scenario is neutral overall for carbon, with the participating regions leading to a rise in the price of carbon to as high as \$110/ tCO_2e (for participating regions and industries only). By 2020, there will still be different carbon prices in different trading schemes and other non-market mechanisms that are utilised. In most cases, the carbon emission permits are allocated free to emitters; by 2030, there will be linked trading schemes with increasing coverage of global emissions.

[44] For further details, see http://www.forumforthefuture.org/files/Appendix_FIR.pdf.

[45] Grantham LSE/Vivid Economics estimates.

[46] Parry et al (2004).

Table 16

Sensitivities of timberland, agriculture land and carbon to the **TIP™** factor risks for each scenario *(cont'd)*

Asset	Timberland	Agricultural land	Carbon
Sensitivity	*High*	*High*	*Very high*
Delayed Action	Dramatic policy U-turn increases the penalties for deforestation dramatically, increasing the price of timberland product prices, land values and the premium attached to carbon trading related activities. Existing timberland assets will appreciate in value and new investments will become more expensive to invest in. A shift towards sustainable forestry products will be demanded by customers. Compliance and monitoring costs with policies will increase.	Agricultural prices will rise at a similar level to that of Regional Divergence. The dramatic policy turnaround is expected to produce some positive benefits. Policymakers promote sustainable agriculture practices, increasing the reliability of long-term crop production but increasing crop production costs in the short term. The delayed action also increases risks of climate change damage, meaning some regions may experience a reduction in available land for cultivation (Latam, SE Asia and Africa)[47] – hence, neutral overall.	This is neutral for carbon investments until the policy measures are introduced, following which time, it will be very positive with a dramatic and unanticipated rise in the carbon price. By 2020, there will be cap-and-trade schemes set up in OECD countries, accompanied by taxes and regulation, and by 2030, there will be very high costs of mitigation, with global prices as high as \$220/tCO_2e.
Stern Action	Climate policy creates incentives to reduce deforestation and protect native forests via REDD and REDD+. The demand for sustainably harvested forest resources may increase to fulfil the growing need for timberland. Policies increase the demand for sustainable forestry products.[48] Existing assets perform strongly and new investments are more expensive as land values and timberland costs rise.	This is the most positive scenario for agricultural investments, as prices are expected to rise in similar fashion to the other scenarios, but the global policy efforts and efficient policy approach promote sustainable crop methods, reducing the risk of disrupted production. Substantial capital is available to assist countries in adapting to climate change in farming methods. Sustainable farming and heat-tolerant and drought-tolerant crops will be introduced, improving climate resilience and production reliability.	This is a very positive scenario for carbon, with the supportive policy environment increasing the carbon price and its relevance to business practices across industries and regions. By 2020, there will be linked OECD trading schemes, and emission trading schemes will also be introduced in BRIC countries (Brazil, Russia, India, China), with the majority of allowances auctioned plus complementary taxes and price measures. The carbon price will be \$110/tCO_2e.
Climate Breakdown	Changes in forest productivity are likely due to an increased risk of degraded ecosystem services that will require new strategies for management and adaptation. In particular, climate change could create water supply concerns in regions where tree plantations are most productive.	Climate change physical impact risks increase, potentially reducing the availability of prime cropland but increasing the availability of marginal cropland. The beneficial effects are likely to be experienced in North America and Russia, with the biggest losses in Africa and Latam. Risk of protectionist policies in response to food shortages could create unrest and additional geopolitical risk premium for agricultural investments.	EU ETS phase II will end by 2012. By 2020, there will be a new EU ETS and possibly regional trading in some US states. There will be a low-carbon price (\$15/tCO_2e) and a small coverage of global emissions. By 2030, the share of global emissions in carbon trading falls as non-OECD emissions rise.

Source: Mercer, drawing from various sources, as referenced

[47] Grantham LSE/Vivid Economics, unpublished research adapted from Fischer et al (2002).

[48] *World Resources Institute Annual Report 2008*, available at http://www.wri.org/publication/wri-annual-report-2008 pdf.

Country and **regional impacts**

The following discussion summarises the analysis that underpinned the conclusions regarding the investment impacts of climate change for each country and region. As for the asset classes, the analysis is largely qualitative in nature, requiring judgement and interpretation of the climate change risks and evidence as presented in this report.

A few key assumptions and considerations:

- There are limitations of country coverage due to data availability, although the countries included are the largest in terms of technology investment markets and emissions levels.

- The rate of change in technology investment and climate policy is moving quickly; hence, the conclusions drawn in this discussion require periodic review and updating.

- Country-level risk on each TIP™ risk factor might not capture the developments at the sector level within countries, such as supportive policy measures in buildings, or renewables, for example. While such measures might still position a country as less well-positioned for transformation than others at the aggregate level, these opportunities will emerge and need to be considered on a case-by-case basis.

Some highlights of the country/regional analysis for each factor are summarised below.

Technology

- "Leaders" – The regions that are best positioned to capture the technological transformation are the EU and China/East Asia, as both regions move forward to reduce emissions and attract investment at a faster pace than the other countries. In the EU, the additional cumulative investment levels versus BAU could reach $1 tr by 2030. In China, it could reach $1.3 tr by 2030, making it the largest low-carbon investment market in the world.

- "Improvers" – While the size of investments in low-carbon energy is comparatively low in Japan and India/South Asia, it is growing, putting these countries in the "improver" category. Incremental cumulative investment flows into technology are estimated to reach $220 bn in Japan by 2030 and $450 bn in India/South Asia over the same period.

- "Mature but declining" – The US market is currently one of the deepest in low-carbon energy and efficiency; however, indications point to a slowing in the pace of investments due to political impasse. By 2030, additional cumulative technology investment inflows could reach $1.3 tr in the best-case Stern Action scenario, or a lower $650 bn in the more likely Regional Divergence scenario.

- "Laggard" – There is little indication that Russia is going to be at the forefront of technology investment, where we expect incremental cumulative investment flows into technology to be a modest $35 bn by 2030 in the Regional Divergence scenario.

Impacts

- Impact risks are highest in the Climate Breakdown scenario, particularly for India/South Asia. This could destabilise the market and increase the premium demanded by investors. Total adaptation and residual damage costs in India/South Asia are estimated to be $71 bn, or 0.9% of the level of GDP by 2030, increasing to $309 bn or 0.6% of the level of GDP by 2050.

Policy

- Policy risks are greatest around the Delayed Action scenario for all regions, as the higher level of emissions and the higher costs of delayed policy create instability. This suggests that a delayed policy response is costly for all countries and regions – there are no winners, as they all face the future (higher) adjustment costs, with the higher cost hitting China particularly hard given its trajectory of rising emissions. We estimate that the policy delay may increase adjustment costs in China by four times versus the Stern Action scenario.

The following tables (starting on the next page) present the sensitivities of the EU, the US, Japan, China/East Asia, Russia and India/South Asia to the TIP™ factor risks for each scenario. The magnitude (low, moderate, high and very high) of the sensitivity of the asset to the TIP™ risk factors is presented at the top of the table, with the colour denoting the direction of the impact (negative, neutral or positive) for each scenario.[49]

[49] As before, all references to future T, I or P factors have been discounted by 3% and the technology data refer to the incremental investment flows versus a business-as-usual baseline. The technology inflows refer to those areas that will benefit from the low-carbon transformation, such as energy efficiency, renewable energy, biofuels, nuclear and CCS.

Table 17

Sensitivities of the EU, US and Japan to the **TIP™** factor risks for each scenario

Asset	EU	US	Japan
Sensitivity	*Moderate*	*High*	*Moderate*
Regional Divergence	There is low policy risk as one of the "leading" regions. Additional cumulative investment levels versus BAU are around $1 tr by 2030. Achieve GHG reduction goals of -20% of 1990 level by 2020 (possibly rising to -30%) and -60% to -80% by 2050. Transformation takes place as a result of policy measures, including the cap on the EU ETS, caps for non-EU ETS sectors, incentives for renewables, targets for improving efficiency via building standards, refurbishment, vehicle manufacturers and substantial financial resources for green energy programmes, including CCS demonstration.	Opportunities in technology lag the leading regions as policy efforts falter due to political impasse, raising uncertainty for investors. Additional cumulative technology investment inflows accumulate to $650 bn by 2030. Failure to achieve GHG reduction goals equal -17% of 2005 or -4% versus 1990 levels. Delay in passing the climate change bill and the movement of public opinion away from climate policy increase the policy risk for investors. Some states within the US have progressive policies[50] and continue to attract capital.[51] There are national frameworks, with support at the political level required to increase investment. Close monitoring of progress is required.	Policy implementation risks increase investment uncertainty. Additional cumulative investment flows of over $100 bn are seen by 2030, with new opportunities as an "improving" nation on policy implementation. Japan has set policy targets, but indications are that these may not be met.[52] Fail to fully meet GHG emission reduction goals of -25% of 1990 by 2020 and -60% by 2050. Policies include an increase in nuclear power, the reintroduction of subsidies for photovoltaic power, programmes to make transport more efficient and spending to promote efficiency in buildings. Substantial additional domestic measures required to meet the targets. Close monitoring of progress required.
Delayed Action	There is higher risk for investors regarding policy uncertainty, with investment flows slowing in low-carbon opportunities due to policy stalemate internationally. Incremental cumulative investment flows into technology are estimated to be around $700 bn by 2030. This is 30% lower than Stern Action and Regional Divergence levels. Adjustment costs increase with higher carbon costs, but the EU will be more resilient in responding than most other regions, as the EU countries generally rank highly in terms of carbon competitiveness.[53]	High cost implications for the US are likely under this scenario, as the indications are that the US ranks relatively poorly in terms of carbon competitiveness.[54] We estimate that the policy delay increases adjustment costs by a factor of 2.5x versus Stern Action. Incremental cumulative investment flows are estimated to be around $900 bn by 2030. This is about a third lower than Stern Action levels. The high CO_2 intensity of the US economy also means the rise in inflation and interest rates will hit the US harder as CO_2-intensive economies see a significant increase in inflation from a carbon-price shock.[55]	Higher costs will also be negative for Japan, with political impasse globally curtailing policy efforts until 2020. This reduces investment inflows by over 30% compared to Stern Action, with incremental cumulative investments estimated to be around $160 bn by 2030. As for the EU, we estimate that the adjustment costs will increase by a factor of 2.5x that of Stern Action. However, Japan will be quite more resilient than many other countries, as it ranks in the top three in terms of carbon competitiveness.[56]

50 While the United States is not a signatory to the Kyoto Protocol, emissions trading has commenced on a small scale with the Regional Greenhouse Gas Initiative. This involves states in the northeast of the country, and there is also a proposal to trade allowances between a group of Canadian provinces and US states, largely on the western seaboard, called the Western Climate Initiative.

51 Deutsche Bank *Global Climate Change Policy Tracker: An Investor's Assessment* (October 2009).

52 Vivid Economics (2009). The Carbon Productivity Index shows a significant gap between the reduction in carbon emissions in Japan versus the rate of reduction required to meet their targets.

53 Vivid Economics (2009): Carbon Competitiveness, Figure 1.

54 Source: Vivid Economics (2009): Carbon Competitiveness by Country, Figure 1.

55 Grantham LSE/Vivid Economics: Mapping Evidence Report, Table 30.

56 Vivid Economics (2009): Carbon Competitiveness, Figure 1.

Table 17

Sensitivities of the EU, US and Japan to the **TIP™** factor risks for each scenario *(cont'd)*

Asset	EU	US	Japan
Sensitivity	*Moderate*	*High*	*Moderate*
Stern Action	As for Regional Divergence, with even lower policy risk due to globally coordinated action. New investments in technology where the additional cumulative investment levels versus BAU is estimated to be around $1 tr by 2030. The investment opportunities deepen, with the largest emission reductions coming through in renewable energy (wind, solar) that will continue to dominate the market, with markets related to energy efficiency in buildings, and transport, nuclear and commercialisation of CCS.	The outlook for the US in this scenario is much more positive than the other mitigation scenarios, as the policy risk for investors is reduced, allowing investment in technology to flow. Measures include the long-term extension of the renewable energy production tax credit, as well as tax credits for efficient vehicles and efficiency measures in buildings. The largest emission reductions come through the building, transport and biofuel sectors. Renewables and CCS expand considerably. The additional cumulative investment level versus BAU is estimated to be around $1.3 tr by 2030.	Policy implementation risk in Japan declines under this scenario in a globally coordinated framework. Policies include a substantial increase in nuclear power, subsidies for photovoltaic power, programmes to make transport more efficient and spending to promote efficiency in buildings. Investment in nuclear, hydro, wind and other renewables proliferate. The additional cumulative investment level versus BAU is estimated to be over $220 bn by 2030.
Climate Breakdown	The risks of rising impact costs may increase within the EU for climate-vulnerable regions, such as southern Europe, where extreme heat, fire and drought risks increase. Total adaptation and residual damage costs are estimated to be $18 bn, or 0.1% of the level of GDP by 2030, increasing to $48 bn, or 0.3% of the level of GDP by 2050.[57] With concerns about industrial competitiveness on the rise, the EU ensures that firms covered by its ETS face a generous cap on emissions, depressing the carbon price.	There are some possible benefits from climate change for the US, such as increasing cereal yields in parts of North America. Coastal areas price in flood risk in major cities and extreme weather events. Total adaptation and residual damage costs are estimated to be $64 bn, or 0.4% of the level of GDP by 2030, increasing to $150 bn or 0.7% of the level of GDP by 2050.[58] Federal plans to trade emissions in the US founder in Congress, which proves a major blow to global ambitions on climate change. There is no additional investment in technology related to low-carbon beyond BAU.	Total adaptation and residual damage costs are estimated to be $10 bn, or 0.1% of the level of GDP by 2030, increasing to $23 bn, or 0.1% of the level of GDP by 2050.[59] There is no additional investment in technology related to low-carbon beyond BAU.

Source: Mercer, drawing from various sources, as referenced

[57] Grantham LSE/Vivid Economics estimates, using the PAGE2002 model.

[58] *ibid.*

[59] *ibid.*

Table 18

Sensitivities of China/East Asia, Russia and India/South Asia to the **TIP™** factor risks for each scenario

Asset	China/East Asia	Russia	India/South Asia
Sensitivity	*High*	*Moderate*	*Moderate*
Regional Divergence	Policy risk is low, as China is also a "leading" region under this scenario, with additional cumulative investment levels versus BAU rising to over \$1.3 tr by 2030, making it the largest low-carbon investment market in the world. China achieves its national climate plan and goal to cut emission intensity by 40% to 45% from 2005 to 2020. National policies would be implemented, increasing investment opportunities in nuclear and renewables in power generation (including CCS), along with opportunities related to rebalancing the Chinese economy towards services and standards for building efficiency.	Incremental cumulative investment flows into technology are estimated to be a modest \$35 bn by 2030. Russia announced an intended reduction in emissions, relative to 1990, of 10%–15% by 2020. This represents a substantial increase in emissions relative to today's level and puts Russia in the "laggard" higher risk category for investors. In the absence of a framework and policy efforts to reduce emissions, along with continued reliance on fossil fuel energy sources, investment in technology will remain low.	The policy implementation risk in India/South Asia increases uncertainty for investors, as progress so far on improving carbon productivity has been slower than for other regions.[60] The size of investments in low-carbon energy is comparatively low, but growing, putting India in the "improver" category. Incremental cumulative investment flows into technology are estimated to be around \$220 bn by 2030, which is around 2% of India's projected GDP. India goes some way to achieving its aim to reduce emission intensity from 2005 to 2020 by 20% to 25%. Opportunities are highest in wind, due to a government-imposed renewable portfolio standard, which starts at 5% in 2010 and increases to 15% by 2020.
Delayed Action	As the world's future largest emitter of CO_2 under this scenario, China would bear the highest adjustment costs of all the regions under this scenario. We estimate the policy delay will increase adjustment costs by 4x versus Stern Action. Incremental cumulative investment flows into technology are estimated to be over \$1 tr by 2030. This is still substantial but around 30% lower than Stern Action levels. Some studies also point to a potential risk of physical damage to the environment due to policy delay, including flood risk and disruption to water supply.[61]	As the 17th largest emitter of energy CO_2 per capita in 2007, Russia's failure to reduce carbon emissions will increase adjustment costs considerably under this scenario. We estimate the policy delay will increase adjustment costs by a factor of 2.5x versus Stern Action. Incremental cumulative investment flows into technology are estimated to be around \$140 bn by 2030. This is about 20% lower than Stern Action levels. As for the US, the high CO_2 intensity of Russia means the rise in inflation and interest rates will hit Russia harder as CO_2-intensive economies see a significant increase in inflation from a carbon-price shock.	Higher adjustment costs for India/South Asia are also expected, with India ranking in the bottom 3 in terms of carbon competitiveness.[62] We estimate the policy delay will increase adjustment costs by a factor of 2.5x versus Stern Action. Incremental cumulative investment flows into technology are estimated to be around \$350 bn by 2030. This is 20% lower than Stern Action levels. India/South Asia may also be riskier for investors due to higher impact risks associated with physical changes to the environment, with increased risk of flooding, drought and disruption to water supply.

[60] Vivid Economics (2009): Carbon Productivity, Figure 3.

[61] Yohe et al (2006) identifies China and Argentina among the most vulnerable individual countries. However, other studies place China as a lower risk.

[62] Vivid Economics (2009): Carbon Competitiveness by Country, Figure 1.

Table 18

Sensitivities of China/East Asia, Russia and India/South Asia to the **TIP™** factor risks for each scenario *(cont'd)*

Asset	China/East Asia	Russia	India/South Asia
Sensitivity	*High*	*Moderate*	*Moderate*
Stern Action	Globally coordinated action further reduces policy risk for investors in China. New investments in technology where the additional cumulative investment levels versus BAU is estimated to be over $1.3 tr by 2030. The investment opportunities deepen, particularly in wind, solar, hydro, CCS commercialisation and other renewables and energy efficiency measures. The imposition of a feed-in tariff and an abundance of low-interest state bank loans, along with cheap turbines, continue to fuel a surge in wind investment. In the solar photovoltaic industry, manufacturers increase their share of global production considerably.	Russia is the only country included in this study, which may prove to be a higher risk for investors under this scenario. Russia's heavy reliance on high-carbon energy-intensive industries and lack of preparedness in terms of reducing emissions will be costly, even in an efficient policy framework. Modest investment opportunities in technology emerge in the transition, where the additional cumulative investment levels versus BAU is estimated to be over $180 tr by 2030. The key areas will be energy efficiency and investment in nuclear, renewables and CCS.	Policy slippage risk in India declines under this scenario in a globally coordinated framework. India also benefits from adaptation finance from developed markets to help it prepare for future damage due to climate change. Investment expands in nuclear power plants and renewables in power generation, particularly hydro, wind and solar. There will be policies to promote cleaner transport, including the use of mass transport and more efficient cars. Continue the implementation of CDM projects and expand CDM to more sectors. The additional cumulative investment levels versus BAU is estimated to be over $450 bn by 2030.
Climate Breakdown	The absence of investment in low energy infrastructure solutions in this scenario could thwart its ability to sustain economic growth, with increased pressure on resources from population growth and rising living standards. China's reliance on fossil fuels grows rapidly – an increase in emissions of over 2.5x versus Stern Action levels to 2030. This significantly increases the future carbon liability for China and, hence, risks for investors if/when policymakers do respond beyond 2030. Total adaptation and residual damage costs are estimated to be $30 bn, or 0.1% of the level of GDP by 2030, increasing to $76 bn, or 0.2% of the level of GDP by 2050.[63]	Vulnerability is lower in Russia, for whom initial changes in climate are likely to be beneficial on aggregate as crop yields increase in response to rising temperatures. However, as for China, continued reliance on fossil fuels is associated with an increase of emissions of 1.5x versus Stern Action levels to 2030. This increases future carbon costs and risks for investors if/when a cost of carbon is enforced further in the future. Total adaptation and residual damage costs estimated to be $12 bn, or 0.3% of the level of GDP by 2030, increasing to $23 bn, or 0.3% of the level of GDP by 2050.[64]	In India/South Asia, risks related to physical damage to the environment resulting from the lack of policy action will be the highest of the countries included in this study, particularly water pressures and flood risk, which could destabilise the market and increase the premium demanded by investors. Emissions of energy-related CO_2 in India are 1.5x the level they would be versus Stern Action – hence, carbon risks increase for future policy measures that enforce a carbon price beyond 2030. Total adaptation and residual damage costs are estimated to be $71 bn, or 0.9% of the level of GDP by 2030, increasing to $309 bn, or 0.6% of the level of GDP by 2050.[65]

Source: Mercer, drawing from various sources, as referenced

[63] Grantham LSE/Vivid Economics estimates, using the PAGE2002 model.

[64] *ibid.*

[65] *ibid.*

Mapping evidence **to the scenarios**

This section was produced by Grantham LSE/Vivid Economics. It formed the basis for Mercer to later develop and formulate the TIP™ factor risk framework to translate the evidence into impacts for asset allocation.

Uncertainties around the outcomes

Some uncertainties for the investor originate in climate physics. One of the most important sources of risk for assessing the potential economic impacts is a change in precipitation patterns, which is also particularly hard for climate scientists to predict. Furthermore, the most consequential changes may come from changes in the frequency and severity of extreme precipitation events, particularly drought. These extremes are even less well-understood than the averages both because the climate simulations have not been run sufficiently to characterise infrequent events and because it is harder to calibrate the models for these events.

Another concern for the investor is the widespread assumption in the literature that policies are optimal, strategies efficient and institutions robust. In reality, the delivery of adaptation and mitigation will fall short of the ideal.

In addition to uncertainties around the scientific evidence and the likely shape and form of climate policy measures, investors also face uncertainties related to the rate of change in technology development and deployment and what this means for their investments in different businesses, industries and regions in the future.

The uncertainties present today, coupled with the surprising smallness of scale of the research activities exploring these questions and the degree of difficulty of the tasks confronting them, suggest that uncertainty will be an enduring feature of climate change for investors for some time yet.

Macroeconomic impacts

The total impact of climate change on economic output can be broken into three contributory factors:

- Mitigation costs: the added costs of reducing greenhouse gas emissions
- Adaptation costs: the added costs of adapting economies to climate change (for example, by heightening sea defences)
- Residual damage costs: adaptation may not entirely eliminate the economic costs of physical climate change; hence, this represents the residual damage to the physical environment in addition to adaptation costs

Grantham LSE/Vivid Economics applied the World Induced Technical Change Hybrid (WITCH) model to estimate the macroeconomic impacts of these three factors for the Stern Action and Climate Breakdown scenarios, describing it as a "top down" model that has considerable technological detail. It is also multi-regional. For the Regional Divergence and Delayed Action scenarios, they applied sensitivity analysis to explore the future potential outcomes from each scenario.[67] In climate-change economics, the impacts of physical climate change, adaptation and mitigation on GDP growth are conventionally expressed as the percentage difference in the level of GDP, relative to a baseline, in a particular year. Table 19 (on page 78) summarises the results on that basis.

- **GDP impact:** The results show that the level of GDP for the Delayed Action scenario would be 5% lower than it would otherwise have been in 2050, in the absence of efforts to cut carbon emissions. According to Grantham LSE/Vivid Economics, this would translate to a decline in annual average growth by around one-tenth of one percentage point every year to 2050. From an asset-allocation perspective, this cost is not significant enough to justify changing the asset-class assumptions related to GDP growth across the climate scenarios in that period.
- **Inflation impact:** The long-run equilibrium results showed a potential inflationary impact under the Delayed Action scenario, with inflation being neutral for all other scenarios. In Delayed Action, it is assumed that a carbon tax (or its equivalent) is introduced and not fully anticipated; thus, the inflationary effect of a carbon-price shock can be considerable, with Grantham LSE/Vivid Economics estimating it to be in the range of 0.6%–2.1% higher. For the purposes of asset-allocation assumptions, we would recommend some caution interpreting these results, as the inflation impacts would vary by region; hence, having an inflation increase in the midpoint of this range under Delayed Action is reasonable, with inflation remaining unchanged across the other scenarios.
- **Interest rates:** Using a simple model of central bank behaviour by applying a coefficient of 1.5 on inflation using the Taylor Rule results in a potential initial increase in central bank interest rates in the range of one to three percentage points under Delayed Action. For the other scenarios, there is no impact on interest rates. For the purposes of asset allocation, we have assumed a rise in the risk-free rate at the lower end of this range for the Delayed Action scenario, with interest rates remaining unchanged for the other scenarios.
- **Investment uncertainty:** The degree to which each scenario may create uncertainty for investors varies significantly across the scenarios, depending on the rate of transformation to a low-carbon economy and the timeliness, transparency and level of global coordination around climate policy. The uncertainty is highest under Delayed Action, where investors do not fully anticipate the changes, followed by Regional Divergence. Stern Action is the scenario that provides the most clarity for investors within the horizon of this study, while Climate Breakdown presents the greatest long-term risk as the economic impacts of climate change increase significantly beyond 2050 (see Box 1 on page 79). As highlighted earlier in this report, as with systemic risks in the past (the IT bubble, credit crisis), the source of uncertainty for investors over the next 20 years is likely to come from unanticipated events and the way the market behaves in response to such developments, rather than being led by changes to long-run macroeconomic outcomes.

[67] This was delivered to Mercer and the project group as the "scenarios report" for this project.

Table 19
Uncertainty and macroeconomic impact

Scenarios	Degree of investment uncertainty	GDP impact (% change from GDP level)		Inflation impact (% change CPI)		Interest rates (% change cash rate)	
		2030	2050	2030	2050	2030	2050
Regional Divergence	Impact varied by regions, with leaders and laggards creating higher uncertainty	-1.2	-3.9	Neutral	Neutral	Neutral	Neutral
Delayed Action	High level of uncertainty before policy changes, which are not anticipated; uncertainty declines following policy measures	-1.3	-5.2	+0.6% to 2.1%, varies by region		+0.9% to 3.2%, varies by region	
Stern Action	Low uncertainty due to climate policy transparency that is coordinated and anticipated	-1.1	-4.3	Neutral	Neutral	Neutral	Neutral
Climate Breakdown	Low uncertainty until 2050, but then increasing, possibly abruptly	-0.5	-1.0	Neutral	Neutral	Neutral	Neutral

Source: Grantham LSE/Vivid Economics estimates based on mitigation, adaptation and residual damage costs

The GDP estimates are in line with those made in the Stern Review, which used the more standard method of expressing costs in terms of the level of GDP. The large estimates produced by the Stern Review of the physical impact of climate change are driven, in large part, by what happens after 2050 and, indeed, after 2100. Box 1 (on page 79) explains this. However, due to the inertia in the climate system, we need to cut carbon emissions in the near term in order to avoid these impacts in the long term. One should also bear in mind that the models used to estimate the costs of physical climate change in particular are widely understood to be imperfect, and some have suggested that they underestimate the economic cost of climate change.

Box 1:
The full and long-run economic cost of climate change

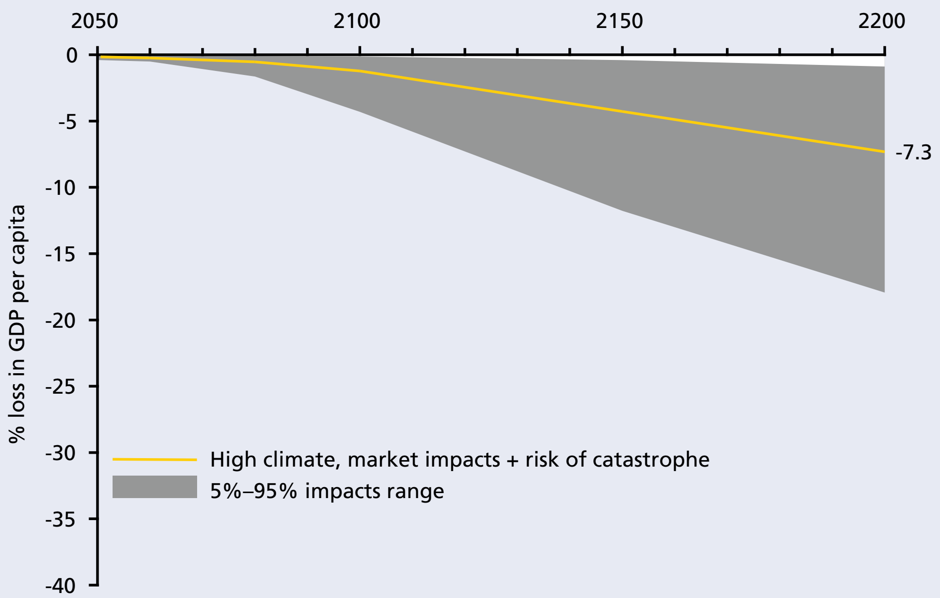
The residual damages of climate change are calibrated on so-called "market" sectors such as agriculture, energy and forestry. The distinguishing feature of these sectors is that goods and services have market prices, and so climate damage has a real effect on economic output and, therefore, potentially on other macroeconomic variables, which is the focus of this study.

However, the full cost of climate change on economic welfare extends beyond these sectors to take in impacts on so-called "non-market" sectors such as natural ecosystems and human health (over and above effects on labour productivity). These impacts are valuable to human beings, to the extent that they are willing to pay to avoid them, or willing to accept compensation for them (that is, the concept of the value of a statistical life). But they are not experienced as measurable changes in macroeconomic performance, because market prices do not exist. This is one reason why the estimates necessarily understate the true welfare cost of climate change. Using central estimates, PAGE2002 projects that over half of the welfare cost of climate change for 2.5°C warming is due to these "non-market" damages.

Another factor that is ignored in the above, due to the effect of averaging across large world regions, is the possibility of strong and direct economic impacts at the level of individual countries. Small economies in particular have proved in the recent past to be vulnerable to extreme weather events. The Stern Review (Stern, 2007) gives several examples, including the 1991–1992 drought in Zimbabwe, which led to a doubling in the country's current account deficit and in its external debt. Another is Hurricane Mitch, which caused devastation in Central America in 1998 – Honduras, for example, faced reconstruction costs in excess of national GDP.

But perhaps the most important issue that is not reflected in the analysis is the impact of climate change in the longer run. Studies from the level of particular sectors, such as agriculture and health through to global economic costs, virtually all agree that impacts would become predominantly negative and increase rapidly in magnitude after 2050. Yet since many of the greenhouse gases emitted today will still reside in the atmosphere until 2100 and beyond (particularly CO_2), emission reductions are required in the short term in order to avoid them. Figure 10 makes the point about long-run impacts, presenting the market impacts of climate change for the period 2050–2200, as estimated by the PAGE2002 model in the Stern Review (Stern, 2007). Notice that 2050 is the origin in this chart. The cost of climate change rises rapidly after 2050.

Figure 10



Source: Stern 2007, Grantham LSE/Vivid Economics

Commodity prices

Commodities could be affected by a number of factors, including changes in supply and demand due to mitigation policies, and changes in supply due to physical impacts.

Fossil fuels

Two things can be expected to happen to fossil-fuel prices under an ambitious mitigation scenario. First, demand for fossil fuels would be lower than in the climate breakdown scenario, depressing prices received by fossil-fuel owners (with the carbon price acting as a wedge between the prices received by producers and the prices charged to customers). Second, the cost to customers of the most carbon-intensive fuels would increase the most following the imposition of a carbon price, causing a relatively greater drop in demand and lowering prices to the owners of those fuels to a greater extent.

In the case of Regional Divergence, the geopolitical situation is most likely one where individual countries or regions don't want to be dependent on the supply from other regions. This would trigger a drive to self-sufficiency that should decrease the fossil fuel demand by the western world.

Agricultural commodities

Crop yields are expected to be higher in many temperate regions, but lower in most tropical regions. We would therefore expect, all else being equal, to see corresponding price increases (decreases) for crops grown in the relevant regions as supply is reduced (raised), with these two effects on commodity price indices counteracting each other to some extent. The regions that would see a crop yield increase (North America, Russia) are also important for global food production. However, population is also expected to rise, increasing the demand for food and exerting an upward pressure on prices under both scenarios. That could be offset to some extent by improved crop varieties and agricultural practices increasing yields. The price impact attempts to separate the effects of climate change from other factors driving price changes, based on forecasts from the studies of Fischer et al (2002) and Parry et al (2004). Commodity prices are expected to be higher under climate breakdown, but not significantly so until mid-century. That is due to the fact that physical impacts under the two scenarios do not start to diverge appreciably until mid-century.

Carbon price

The climate models examined for this study show that the key factors determining the carbon price are:

- The ambition of attempts to mitigate climate change (the ultimate atmospheric concentration for which policymakers aim)

- The flexibility with which emissions reductions can be made, the extent and timing of coordinated global mitigation policies, and the inclusion of as many sectors as possible under a single carbon pricing regime

- The availability of different technological options, which may be constrained by either political or physical feasibility; rates of technological innovation and the possibility of breakthrough technologies; the degree of foresight economic actors have about future abatement options and costs

- Fossil-fuel prices and an offsetting effect, whereby reduced demand for fossil fuels (for example, due to recession) lowers the cost of emitting and dampens carbon prices

- The ease with which energy inputs to production can be substituted

- The existence of major policies other than carbon pricing – for example, large-scale renewables quotas, as in the EU, could reduce demand for carbon credits by forcing certain mitigation actions

Flexibility in emission reductions is vital for maintaining low costs, through taking advantage of cheaper emission reductions wherever and whenever they can be made.[68] Policy regimes that do not achieve this flexibility because they segment the carbon regime, either regionally or sectorally, see higher carbon prices.

Unsurprisingly, therefore, the carbon prices that emerge from analyses are highly sensitive to any

[68] And reductions of the greenhouse gases that are cheapest to abate at the margin. "Carbon pricing" is a convenient shorthand for pricing greenhouse gas emissions in general, with each GHG emission price having an "exchange rate" with the literal carbon price.

barriers to flexibility that are imposed. Estimated carbon prices at different points in time vary hugely between models but are typically in the range of a few tens to a few hundreds of dollars by 2030 for scenarios with the ambition of Stern Action.

The price estimates provided in Table 20 for 2030 are derived by Grantham LSE/Vivid Economics from the WITCH model of the RECIPE study and are based on a global carbon trading regime. They are in the middle of model estimates in the RECIPE study over the time period, but increase rapidly after 2030, while the other estimates increase more steadily with time. Prices accelerate because the model's agents have perfect foresight; they require a relatively modest carbon price to take early action (given their expectation of higher rises subsequently), but they expect limited technological options and substitution possibilities within the energy sector later, because cheaper options are exhausted earlier on. Nearly all projections of carbon prices entail a period-by-period increase for several years, often well into the second half of the century or beyond.

Table 20
Commodity price impact to 2030

Scenarios	Carbon price ($/t$CO_2$)	Oil price (% price change)	Coal (% price change)	Gas (% price change)	Agriculture (% price change)
	2030	2030	2030	2030	2030
Regional Divergence	110	N/A	N/A	N/A	N/A
Delayed Action	220	N/A	N/A	N/A	N/A
Stern Action	110	-2.0	-36.6	10.4	+37
Climate Breakdown	15	25.2	60.0	35.4	+38

Source: Grantham LSE/Vivid Economics estimates

Agriculture refers to percentage difference versus 1990 levels due to climate change rather than other effects on agricultural prices.
Oil, coal and gas prices refer to 2008 dollars per GJ energy provided.

Technology investment

Energy supply and the fuels and technology mix that deliver it would be driven by many interacting factors, key among which are economic growth, new innovations related to research and development expenditure, population growth, fossil-fuel prices and any policies put in place to reduce both energy demand and the carbon intensity of energy supply. All of the models examined in this study show profound switches away from fossil-fuel production in ambitious mitigation scenarios.

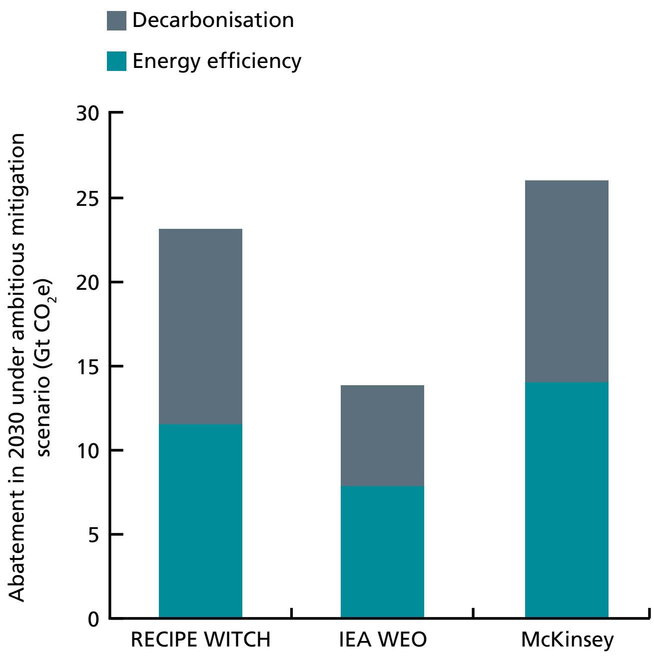
In 2030, about two-thirds of the shift in fossil-fuel use is attributable to lower overall energy demand, while the remaining third results from supply-side changes. Supply-side differences result from the growth of renewables, biomass and nuclear power, as well as the entry of CCS as a viable technology, under Stern Action. The greatest differences across the scenarios are observed in CCS (which has no economic justification under a "no mitigation" scenario) and non-biomass renewables (wind, solar and hydro-electric power).

Energy efficiency and decarbonisation

Energy efficiency could have as much, or even more, potential to abate emissions than switches to low-carbon technologies. Figure 11 illustrates the potential abatement in 2030 attributable to energy efficiency and decarbonisation of the energy supply, according to the RECIPE WITCH model that was built by a team from the FEEM research institution, the International Energy Agency's (IEA) World Energy Outlook 450 ppm mitigation scenario and the McKinsey global abatement cost curve. In all three, abatement from energy efficiency is as great, or slightly greater, than from decarbonisation of energy supply.

Figure 11

Energy efficiency accounts for at least half of potential abatement



Source: Grantham Research Institute LSE and Vivid Economics, based on Edenhofer (2009), IEA (2009) and McKinsey and Company (2009)

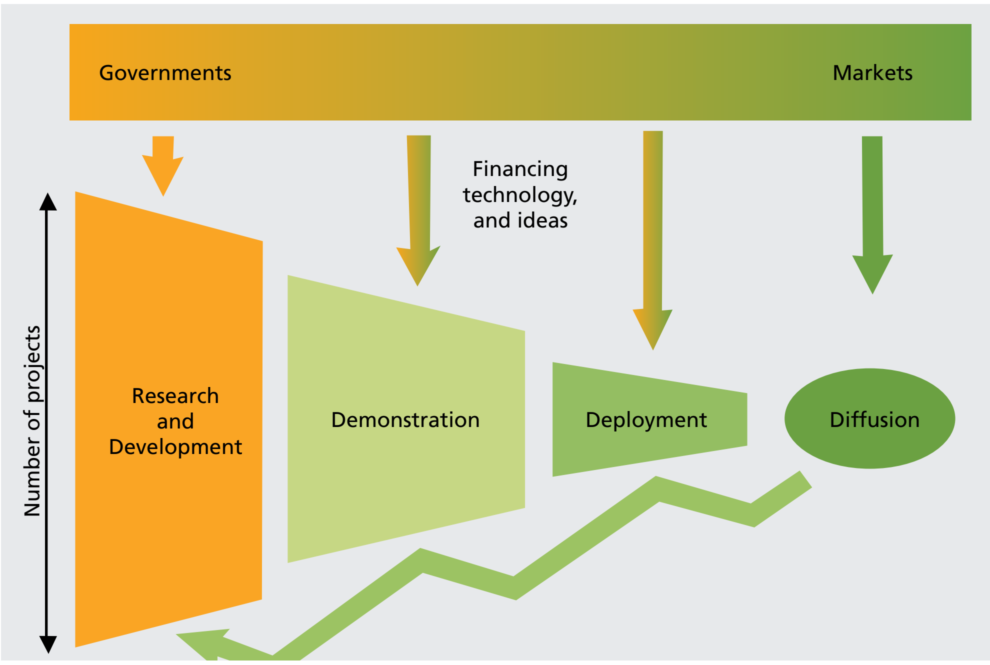
Technology deployment

It is widely understood that a carbon price would be insufficient in itself to bring about the large-scale development and deployment of low-carbon technologies, because of the existence of other barriers in this area (for example, see Stern 2007). These barriers include the spillovers to innovation of new technologies, which the innovating firms cannot capture, as well as problems of “lock in” of existing technologies, due in large part to returns to scale. These barriers are particularly acute in key sectors for climate change, such as energy supply and transport.

Therefore, public support and regulatory measures are required to support technology development and deployment. To understand the set of measures likely to be necessary, Figure 12 depicts the innovation process. Governments have a role to play in the early stage R&D of low-carbon technologies, in particular through public subsidies. As technologies move closer to the market (especially the diffusion stage), private returns increase, as do the required flows of finance. Here, private-sector investment takes the lead, but governments still have a role to play in providing a credible, long-term policy framework. In between, during demonstration and deployment, the picture is more complex and a variety of regulatory measures might be applied – as will be discussed further in the next section.

Figure 12

Governments push innovation of new technologies, markets pull them



Source: Grantham Research Institute/Vivid Economic, base on World Bank (2009b)

Sector impacts

Mitigation

The costs of mitigation may not be evenly distributed across sectors of the economy. In general, those sectors with fossil fuels for output or with the highest carbon intensity of production, and those whose output can be most readily substituted for, would suffer the most from the introduction of carbon pricing. Sectors with high-carbon intensities would face higher costs, while sectors whose goods can easily be substituted for tend to have a demand that is very responsive to increases in price.

Using Goettle and Fawcett (2009) to make a qualitative ranking of the sectoral impacts of mitigation policy (Table 21), we find that sectors with very high sensitivity are, unsurprisingly, those with fossil fuels as their output – that is, coal mining, petroleum refining and gas utilities. These sectors face a significant decline in output, because a carbon constraint makes the goods that these industries provide more expensive than low- or zero-carbon alternatives, while consumers can easily substitute a joule of energy from renewable sources for a joule of energy from fossil-fuel sources. Electricity utilities are also highly sensitive, as the overall cost of supplying electricity increases and demand correspondingly falls.

Sectors that are highly sensitive to mitigation policy include agriculture, forestry and fisheries, chemicals, primary metals, crude oil and gas extraction, and metal mining. Their vulnerability derives from the fact that these sectors face a direct cost due to their own greenhouse gas emissions, and an indirect cost due to their high energy consumption.

Sectors with medium sensitivity to mitigation include the bulk of manufacturing: motor vehicles, glass and minerals, pulp and paper, machinery manufacturing and so on. Some of these sectors are relatively energy-intensive, but there may be relatively few or imperfect substitutes for their products.

Sectors with low sensitivity to mitigation policy are those with low energy use, low consumption of carbon-intensive inputs, and little in the way of direct combustion. Services dominate this category, but it also includes some less energy-intensive manufacturing. Indeed, any declines in output among these sectors are generally not a result of an increase in the cost of production, but rather the effect of a decline in real incomes, which leads consumers to consume less of all goods in the economy.

Table 21
Energy- and carbon-intensive primary and manufacturing industries would suffer the biggest impact of a carbon constraint

Sensitivity category	Sectors
Very high	Coal mining; petroleum refining; gas utilities (services); electric utilities (services)
High	Agriculture, forestry and fisheries; chemicals and allied products; primary metals; crude oil and gas extraction; metal mining; non-metallic mineral mining
Medium	Stone; clay and glass products; fabricated metal products; non-electrical machinery; paper and allied products; electrical machinery; motor vehicles; rubber and plastic products; furniture and fixtures
Low	Lumber and wood products; transportation and warehousing; wholesale and retail trade; construction; other transportation equipment; leather and leather products; instruments; miscellaneous manufacturing; printing and publishing; government enterprises; apparel and other textile products; finance; insurance and real estate; personal and business services; communications; textile mill products; food and kindred products; tobacco manufacturers

Source: Grantham Research Institute/Vivid Economics, based on Goettle and Fawcett (2009)

There would, of course, also be winners from mitigation policy. Analyses of industrial sectors are generally not able to detect these winners, because they tend to be types of business that fall within, or cut across, traditional sectoral classifications. While different studies make different assumptions about technological possibilities, it seems clear that winners would include renewable and nuclear power supply firms, the part of the agriculture sector that specialises in biofuels, and firms supplying CCS and energy efficiency technologies (for example, smart-grid components and energy-use auditing methods). These are discussed further in the Listed Equities and Renewable Energy investment impacts in this report.

Impacts of physical climate change impacts

There may also be winners and losers from the impacts of climate change itself. To a first order, the sectors that stand to gain and lose the most from physical climate change are those sectors whose output most depends on prevailing weather conditions, such as agriculture, forestry and water. Coastal-zone economic activity is vulnerable to sea-level rises, especially floods and storms.

As with mitigation, it is also to be expected that the impacts of climate change would trigger second-round effects on the performance of other sectors of the economy that demand goods and services from sectors directly affected. However, there has been little or no research on these second-round effects, and we are limited to considering the first-round impacts only.

Table 22 summarises the present state of knowledge about positive and negative impacts of up to 3°C global warming on different sectors. The evidence is drawn from the synthesis report of the Intergovernmental Panel on Climate Change (Parry et al, 2007). The pattern is mixed and region-specific, except for coastal zones, where the costs of protection and residual damage are always negative.

Table 22
Initial climate change has both positive and negative consequences for economic sectors

Sector	Sectoral impacts of climate change for up to 3°C warming	
	Positive impacts	Negative impacts
Agriculture	Increasing crop productivity in the mid to high latitudes, e.g. northern North America, northern Europe, Russia	Decreasing crop productivity in the low latitudes, e.g. Africa
Forestry	Increasing global timberland production overall Increasing production potential in South America	Decreasing production in northern North America
Water	Increasing water availability at high latitudes and in the moist tropics	Decreasing water availability in the mid latitudes and in semi-arid, low-latitude regions
Health	Decreased morbidity and mortality from cold stress, primarily at mid to high latitudes	Increased impact from malnutrition, heat stress, extreme events, diarrhoea, and some other vector- and water-borne diseases; burden concentrated on low-latitude developing regions
Coastal zones		Increased adaptation costs in all regions to protect against flood risk
Energy	Decreased requirement for space heating at mid to high latitudes	Increased requirement for space cooling
Tourism	Increased tourism in mid- to high-latitude regions	Decreased tourism at low latitudes

Source: Grantham Research Institute/Vivid Economics

Climate policy

The climate change modelling literature assumes that reductions in greenhouse gas emissions are made efficiently. The cheapest emissions abatement options are always chosen in these models, so that the marginal costs of abatement in different sectors and regions are equal, as they are across time.[69] Modelling studies also make assumptions about the feasibility of particular emissions reduction techniques (for example, efficiency gains) and technologies (for example, renewable energy and CCS).

The reality investors face is that policy is very unlikely to be implemented efficiently the way the studies assume. That was one of the primary aims behind considering some of the wider policy factor risks associated with each climate scenario, as the risk of slippage or inefficient or unanticipated policy action could create new opportunities and pose risks for long-term institutional investors.

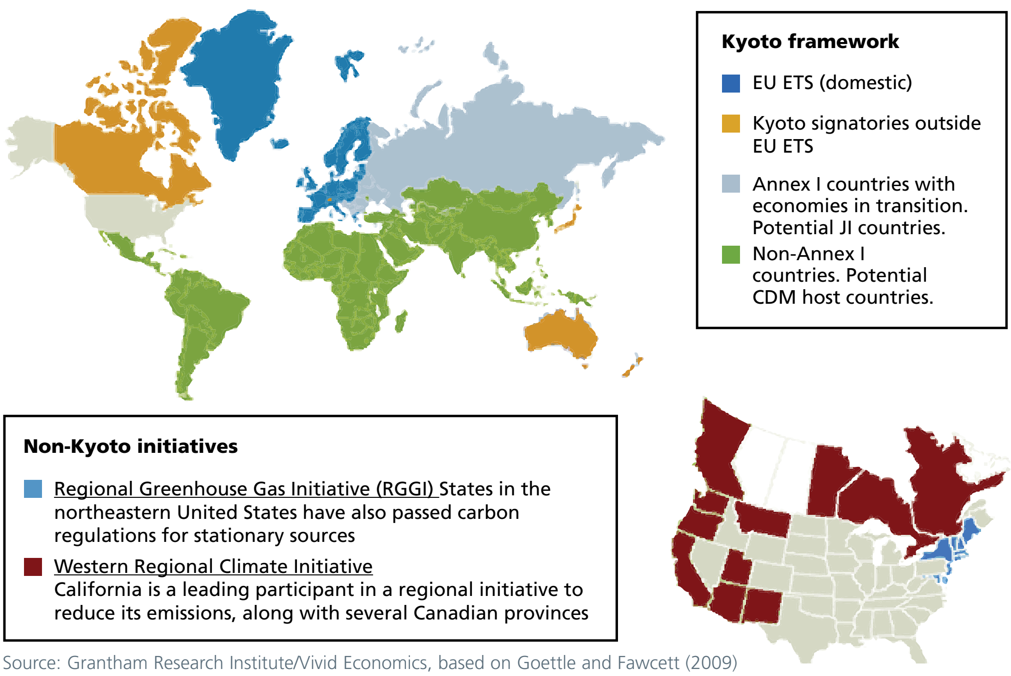
Three types of regulatory interventions that may feature in policy design have been examined in this study. The first involves the introduction of a price on emissions of carbon, the second is focused on promoting technology development, and the third relates to requirements to comply with performance standards.

Carbon price instruments

A foundation of the Stern Action scenario is a coordinated global incentive to abate emissions (for example, see Stern 2007) either in the form of an internationally harmonised system of carbon taxes or in the form of a global market for tradeable carbon allowances.

Figure 13 illustrates the state of the global carbon market today. The most well-known ETS is in the EU. Established in 2005, it now covers around half of all EU CO_2 emissions and involves trading between firms. In addition, governments signed up to the Kyoto Protocol and facing binding emissions targets can also trade emissions between themselves. Kyoto signatories outside the EU include Australia, Canada and Japan.[70] Developing countries can sell carbon credits, generated by emissions reduction projects such as renewable energy, to governments with Kyoto targets or to firms regulated by the EU ETS through the CDM, while transition countries can do the same under JI.

Figure 13
The carbon market already has a global reach



Source: Grantham Research Institute/Vivid Economics, based on Goettle and Fawcett (2009)

[69] There are occasional exceptions to this rule, such as when studies explicitly investigate delayed participation by the developing world in global efforts to reduce emissions.

[70] EU member states can trade emissions both at the government level and at the firm level through the EU ETS to meet their Kyoto targets.

In the US, emission trading has commenced on a small scale with the Regional Greenhouse Gas Initiative (RGGI), involving states in the northeast of the country, and there is also a proposal to trade allowances between a group of Canadian provinces and US states, largely on the western seaboard, called the Western Climate Initiative. Indeed, there are further proposals in several countries that are not included in Figure 13, including Mexico, Japan, South Korea, Australia, New Zealand, in Midwestern states of the US, and at the federal level in the US and Canada.

For emissions trading to take place at the scale necessary to realise Stern Action, current schemes would have to be expanded, deepened and better integrated, so that by 2030 at the very latest, there would effectively be a single global carbon market. The signal of a transition compatible with Stern Action is a rapid geographical spread of carbon prices, accompanied by designs capable of delivering substantial emissions reductions. This could either come about through emissions trading or through harmonised carbon taxes.

Other policy instruments

A wide variety of measures have been taken around the world to support the initial deployment of new, low-carbon technologies. Box 2 gives some examples, ranging from direct fiscal instruments, such as tax breaks and subsidies, through to quantity-based schemes like renewables certificates. As recent research from Deutsche Bank Climate Change Advisors (2009) has shown, deployment support measures for low-carbon technologies are proliferating across the world, in many different forms. This would continue under the Stern Action scenario, although measures might be progressively withdrawn as technologies mature and are deployed at ever-increasing scales.

Box 2:
Examples of deployment support measures for low-carbon technologies

Capital subsidies for demonstration projects and programmes, such as for rooftop solar photovoltaic panels in the US, Germany and Japan.

Tax credits and exemptions, such as the Production Tax Credit in the US, which is given to renewable electricity generators in their first 10 years of operation, and tax breaks on biofuels in the UK and US.

Feed-in tariffs, which are price premiums paid to electricity generators to feed renewable energy into the grid, have enjoyed notable success in, for example, Germany and Spain. To be successful, they are usually combined with a regulatory requirement that eligible renewable electricity generators are connected to the grid.

Quota-based schemes, such as the Renewable Portfolio Standards in use in many US states, which require electric utilities to source a specified proportion of their electricity from renewable sources. Such schemes sometimes allow the quotas to be traded, as is the case with the Renewables Obligation Certificate (ROC) in the UK.

Tendering for tranches of output, which has been used in, for example, China and Canada to ensure renewables make up a certain portion of energy supply.

Government procurement policies, ranging from demonstrator projects on local-government buildings to the use of fuel cells and solar technologies in national defence and aerospace industries.

Source: Grantham Research Institute LSE/Vivid Economics, based on Deutsche Bank Climate Change Advisors (2009) and Stern (2007)

Overcoming barriers to increasing energy efficiency

Another pillar of climate policy necessary to deliver the most optimistic mitigation scenario in this study – Stern Action – is a set of regulatory measures to promote energy efficiency. There are particular barriers to increasing energy efficiency that are not overcome by carbon pricing or technology support alone. McKinsey and Company (2009) suggests the existence of abatement options in energy efficiency, which saves money.[71] Without the presence of barriers, these options should already have been taken up, irrespective of climate change.

These barriers include hidden and transaction costs, such as the cost of the time needed to plan new investments, the cost of information about available options, capital constraints, misaligned incentives such as the landlord-tenant problem,[72] as well as behavioural and organisational factors.

While a variety of measures exist to counter such barriers, including information-provision techniques such as energy performance labelling and smart energy metering, perhaps the most important category of measure to promote energy efficiency is the traditional regulatory standard – for example, mandating the use of particular technologies, banning the use of others, or mandating minimum efficiency performance.

Such regulatory standards relevant to climate-change mitigation are widely used across the world, including in transport (for example, fuel efficiency standards for road vehicles). Expect to see the further proliferation of such standards under Stern Action, and an increase in their stringency.

Standards and process controls

Carbon prices and technology policies are unlikely to be sufficient to deliver the Stern Action emissions scenario in areas where the market is unresponsive to price signals. The reasons behind price unresponsiveness can be complex. They include a small cost share for energy, among other costs; a split between the owner and operator of an energy-consuming asset (for example, a building); and a low weight placed on the value of future energy cost savings (evidence in consumers' purchasing of domestic appliances and personal transport). The introduction of energy performance standards has already begun in a few areas and might be used to complement carbon pricing in many product areas, including vehicles (air, road and sea), lighting, boilers, motors and drives, buildings and electrical appliances.

Public attitudes, politics and business

Public support for climate-change mitigation in all major emitting nations is a precondition for the Stern Action scenario, given the depth of emissions reductions required. While a portion of the required emissions reductions may provide co-benefits to, for example, energy security and local air quality, and may thus garner support irrespective of climate-change goals, the majority of the required reductions would need support in their own right.

Mounting scientific evidence (for example, on melting ice caps) is one potential basis for a rise in public concern, but there has been a recent upturn in climate scepticism in countries such as the UK (BBC, 2010), which has happened in spite of the continuing consensus message from climate scientists.

It is possible that local weather events, which are not conclusively linked to climate change, are a source of concern, as they have been in the recent past (Jordan and Lorenzoni, 2007). In all nations, rising affluence might lead to an increase in environmental concerns more generally (for example, see Kristroem and Riera, 1996), while periods of economic crisis or stagnation could divert attention from the environment.

In contrast to Stern Action, the Climate Breakdown scenario is founded on a failure to win widespread public support. In the immediate future, this is most likely to be due to a preoccupation with jobs and disposable income, in the wake of the global economic downturn, as well as the way in which scientific uncertainty plays out in the media and public realm. High costs of mitigation, as experienced with some renewables and CCS demonstrations, might deter some members of the public.

[71] On the other hand, analyses such as Joskow and Marron (1992) contest the idea of negative-cost abatement.

[72] The landlord faces the capital cost of an investment in energy efficiency, but the benefit is reaped by the tenant in the form of lower fuel bills.

Physical impacts

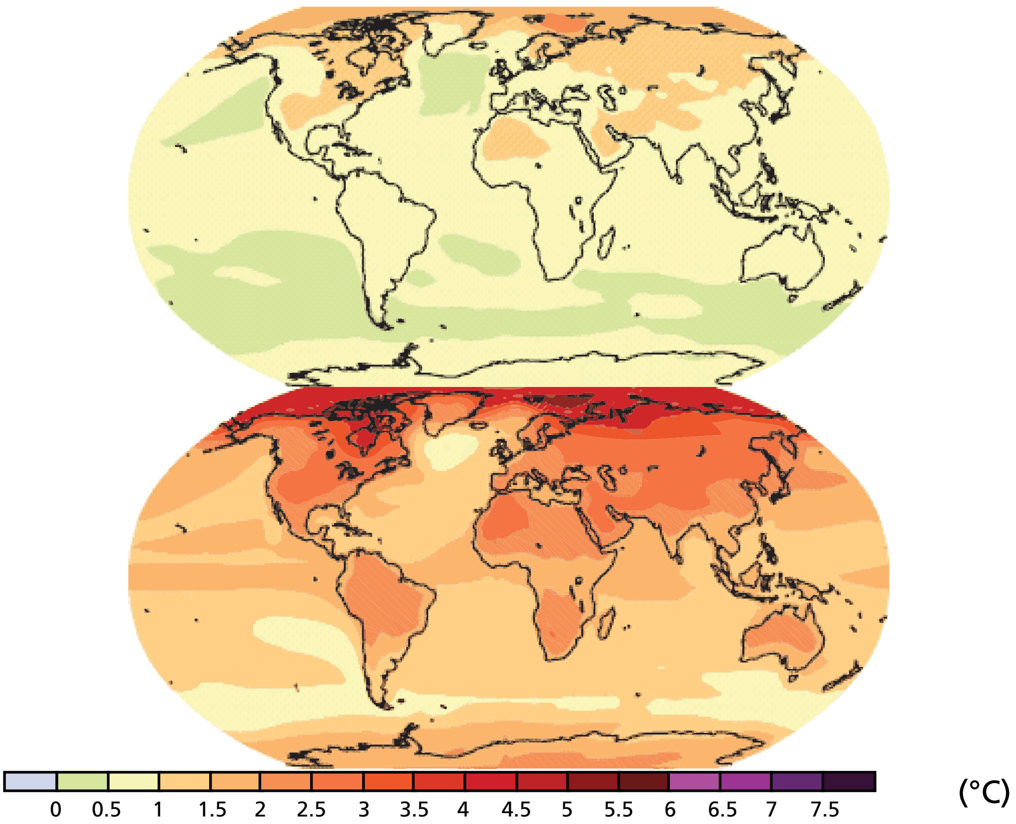
Taking the two most extreme scenarios in terms of climate change impacts, the Climate Breakdown scenario involves 3°C warming above the pre-industrial level by 2050, with the Stern Action scenario involving warming f 1.8°C. While this difference in temperature is significant, many of the major differences in climate impacts between the scenarios arise after 2020, and most of them after 2030.

Sea-level rise

One of the main consequences of rising global temperatures is a rise in sea levels, which increases the risk of coastal flooding unless adaptation is undertaken to boost sea defences. The sea-level rise from 1990 to 2050 under Climate Breakdown is 0.38 m; under Stern Action, it is 0.24 m, with little difference between the scenarios until after 2030. Table 23 (on page 90) shows Grantham LSE/Vivid Economics headline estimates of the global mean sea-level rise for the two most extreme scenarios in terms of climate impacts – Climate Breakdown and Stern Action. For this study, the Rahmstorf (2007) projections are used, because they appear to provide a better fit of the observational record of sea-level rises over the past few decades. These projections are also used by the World Bank Economics of Adaptation to Climate Change study (World Bank 2009a).[73]

Figure 14

Regional temperature change in 2020 (top) and 2050 (bottom) for BAU



Source: Meehl G. et al. "Global Climate Projections" in Solomon S. et al. (eds.) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* (Cambridge and New York: Cambridge University Press, 2007)

[73] Unfortunately, the Rahmstorf projections are only available for the IPCC's business-as-usual emissions scenarios. In order to estimate sea-level rises under Stern Action, the data are used to estimate a linear relationship between sea-level rises and global mean warming that can be used to extrapolate to Stern Action. This is likely to be a reasonable approximation, since Rahmstorf himself fits a linear relationship.

Table 23

Little difference in sea-level rises until after 2030

	Sea-level rise (metres above 1990)			
	2012	2020	2030	2050
Climate breakdown	0.08	0.12	0.19	0.38
Stern Action	0.08	0.12	0.17	0.24

Source: Grantham Research Institute/Vivid Economics

Water availability

Changes in the availability of water have been identified as perhaps the most important type of physical change resulting from greenhouse gas emissions (Stern, 2007). Unfortunately, they are also among the more poorly understood outcomes of climate change. At the regional level, climate models continue to disagree about the direction of changes in precipitation over many regions, with some predicting increases and some predicting decreases.

At the same time, most models predict a decrease in precipitation at subtropical latitudes (20–40 degrees), especially at the poleward margin of this belt. Precipitation is expected to fall over Central America, with the southern states of the US falling in a more uncertain transition zone. Precipitation is also expected to fall in southern Europe and North Africa. This drying would be particularly strong in the summer months, due to greater relative reductions in precipitation and to increased evaporation in the heat.

In the Southern Hemisphere, very little land in the subpolar belt is set to experience increased precipitation. Instead, areas such as the southernmost countries of Africa and southern Australia may see decreases in precipitation. Changes in precipitation in the tropical belt are the least well-understood, due to the complex climate processes in this zone. Most models predict precipitation increases in the summer monsoon season in South and Southeast Asia, as well as in East Africa.

Extreme events

Another important way in which climate change can affect human and economic systems is through changes in the frequency and severity of extreme weather. Unfortunately, like changes in water availability, this aspect of climate change is generally poorly understood. Extreme weather events related to temperature – that is, heat waves and cold snaps – are better understood than storms. The IPCC expects the frequency, severity and length of heat waves to increase globally (Solomon et al, 2007), with very few exceptions. At the same time, a reduction is expected in the number of cold snaps affecting the Northern Hemisphere. This, in turn, is expected to reduce morbidity and mortality due to cold and increase the length of the growing season for agriculture.

Changes in the frequency and intensity of typhoons and hurricanes are very uncertain and forecasts have been the source of controversy. The IPCC tentatively expects an increase in the intensity of typhoons and hurricanes but a reduction in their frequency (Solomon et al, 2007).

Crop yields and arable land supply

Agriculture is one of the most sensitive economic sectors to climate change. Crop yields are critically dependent on prevailing temperatures and water availability, and can increase as a function of the atmospheric concentration of CO_2 (CO_2 is an input to plant growth).[74] Based on Parry et al (2004), the chart below maps the global change in crop yield due to climate change in 2020 and 2050 on a BAU scenario similar to the Climate Breakdown scenario.[75] Crop yields are defined as the aggregate yield of wheat, rice, maize and soybean.

[74] Climate change is also expected to affect crop yields indirectly through, for example, plant and insect pests.

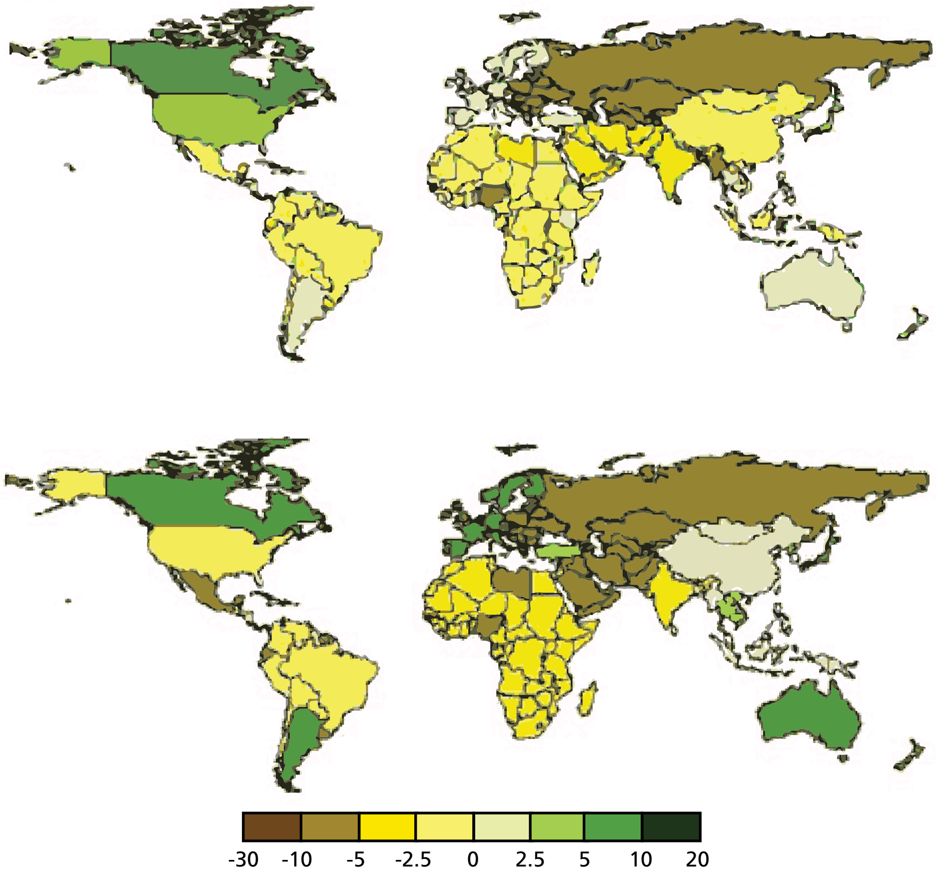
[75] Parry et al use the AOGCM of the UK's Hadley Centre. When run with the IPCC's high emissions A1FI scenario, the Hadley Centre model forecasts an increase in the global mean temperature of approximately 3°C by 2050. Figure 15 includes the fertilisation effect of increased atmospheric CO_2.

The key message for investors from this chart is the significant variation across regions in terms of crop yield impacts. According to Parry et al's (2004) projections, under a Climate Breakdown scenario, yields would increase in North America, northwestern Europe, Australia, Argentina, and in parts of Asia. Conversely, they would decrease throughout Africa and the Middle East, in Russia and in most of Central and South America.

Caution should be exercised in interpreting yield projections in particular regions, due to the greater uncertainties at this spatial resolution. Nevertheless, a general conclusion is that climate change under the "no mitigation" scenario causes yields to increase in most of the currently industrialised world in the period to 2050, and decrease in most of the developing world.

Fischer et al (2002) provide estimates of the effect of climate change on the availability of land with potential for cultivating major fruit and fibre crops. These are available for major world regions on a business-as-usual scenario compatible with climate breakdown and are reported for the year 2080.
In brief, climate change is forecast to slightly reduce the availability of good and prime cropland in 2050, but to increase the availability of marginal cropland. The beneficial effects are experienced in North America and Russia, with the biggest losses experienced in Africa and Latin America. These estimates are in line with the data for crop yields presented earlier, but once again caution should be exercised in interpreting regional results, given the differences between studies.

Figure 15
Percentage change in crop yield in 2020 and 2050 under climate breakdown



Source: Parry M., Rosenzweig C. et al. (2004). "Effects of climate change on global food production under SRES emissions and socio-economic scenarios". Global Environmental Change 14: 53-67.

Top indicates 2020, bottom 2050.

Health impacts and population migration

For institutional investors, health impacts and population migration can potentially have an impact on long-term liabilities and affect assumptions around mortality rates. At present, the evidence available to consider changes to such assumptions is not sufficiently strong (as discussed later). The health effects would be both positive and negative; the period in which they would become pronounced is also uncertain. The research on population migration impacts is sporadic and qualitative, with further research required to evaluate the potential impact on pension fund liabilities.[76] Grantham LSE/Vivid Economics highlight that the studies omit potentially important sources of mortality, including malnutrition and deaths from extreme events. So they are likely to be an underestimate of the increase in illness and death in the period to 2050.

Few studies have quantitatively analysed the effect of future climate change on global mortality across multiple diseases. The most comprehensive and up-to-date study that could be used for this purpose is Bosello et al (2006). The data show that climate change would have both health benefits and health costs, and that these would vary by region. Perhaps surprisingly, the largest absolute change is a decrease in all regions, except the EU, in mortality due to cardiovascular diseases from heat and cold stress. That is, a decrease in the number of winter cold periods due to climate change has significant health benefits. Largely on the strength of this benefit, total global mortality as a result of climate change falls. On a region-by-region basis, significant benefits are forecast for China and India, due entirely to reduced mortality from cardiovascular diseases (cold stress), as well as eastern Europe and the former Soviet Union, as well as the US. Mortality is forecast to increase in Europe and Japan, but by far the greatest absolute increase is forecast for the "rest of the world" category, which comprises much of the developing world. This is due, in large part, to diarrhoea, but respiratory diseases caused by heat waves play a role, as does malaria.

[76] Brown O. (2008).

Methodology

The focus of this study is on the period to 2030, although the implication of the scenarios out to 2050 was also considered.

The scope of the study in terms of asset classes and geographies is summarised below.

- **Asset classes:**
  - Listed equities (global, emerging, sustainability, efficiency/renewables)
  - Bonds (government, emerging debt, investment-grade credit)
  - Real estate (core unlisted)
  - Infrastructure (core unlisted, efficiency/renewables)
  - Private equity (LBO, venture capital, efficiency/renewables)
  - Commodities (agriculture, timberland and carbon)
- **Geographies:**
  - EU
  - US
  - Japan
  - China/East Asia
  - Russia
  - India/South Asia

To answer these questions a multi-layered, collaborative approach was taken with the following features:

- Collaboration
- Scenario analysis
- Factor risk framework
- Climate-change factors – TIP™ framework

Collaboration

The project required a lot of new research that would be costly and onerous for one institution to undertake independently. Collaboration brings the benefit of combining different geographies and perspectives, increasing the global applicability of the findings. Successful examples of collaboration should encourage institutional investors to work together, pooling knowledge and finding solutions to market shortcomings, especially when dealing with systemic issues that investors cannot influence individually.

This project is part of an increasing trend towards pension funds and institutional investors working together in a collaborative way to address systemic issues that may affect their ability to meet their long-term objectives.[77] Research institutions have examined the merit of collaboration among financial professionals, fuelling further interest and collaborative activities among institutional investors on a range of investment issues (Guyatt, 2008; 2009).[78]

The core project group

- All the members of the group shared a common goal – namely, to examine the implications of climate change for strategic asset allocation (SAA) decision making.
- The group included 14 institutional investors spanning Asia, Australia, Europe, the UK, the US and Canada.[79] Of these 14 institutional investors, a range of different types is represented with national (wealth) funds, public pension funds (or linked to public sector agency), industry funds (that represent members for particular industries) and a company pension fund.
- The group included two industry groups with a special interest in climate change and mobilising private-sector finance.
- The project was put together and managed by Mercer, with representatives from the Responsible Investment and the Financial Strategy Group teams,[80] as well as financial analysts, asset-class experts and asset-allocation specialists around the globe.

Outside experts

- The Grantham Research Institute on Climate Change and the Environment at the London School of Economics, jointly with Vivid Economics, were engaged as specialists on the economic impact of climate change, with some of the team members having been part of the Stern Review (2007). The team provided research input on the first two stages of the project – namely, designing the climate scenarios and evaluating the outcome of the scenarios on key macroeconomic and micro variables. This involved the delivery of two (non-public) reports, one on building the climate scenarios and the second on mapping the evidence to the scenarios. The team also provided ongoing support and feedback on Mercer's interpretation of the research outputs for investments.
- A Research Group was established to provide expert input and commentary on the methodology and draft reports.[81] This group met three times in person to debate and discuss the project outputs during the course of the project. Interaction with the research group also took place outside of these meetings, including through their involvement in some of the workshop events hosted during the project, informal meetings, discussions and written feedback on the draft reports. Group members include:
  - Alan Miller (Principal Climate Change Specialist Environment Department, IFC)
  - Dr. Monica Araya (Senior Associate, E3G, Third Generation Environmentalism, UK)
  - Ingrid Holmes (Programme Leader Low Carbon Finance, E3G, Third Generation Environmentalism, UK)

[77] The Principles for Responsible Investment (PRI), the Institutional Investors Group on Climate Change (IIGCC) in the UK/Europe, Ceres and the Investor Network on Climate Risk (INCR) in the US and the Investor Group on Climate Change (IGCC) in AsiaPac, to name a few.

[78] For more information, see http://www.rotman.utoronto.ca/icpm/, including sponsored research and workshops on collaboration http://www.rotman.utoronto.ca/icpm/details.aspx?ContentID=88.

[79] For more information, see http://www.mercer.com/summary.htm?idContent=1374855.

[80] For more information on Mercer's Responsible Investment team, see http://www.mercer.com/ri.

[81] The Research Group included representatives from the IFC, The Carbon Trust, Oxford University Centre for the Environment, HSBC Bank, E3G – Third Generation Environmentalism and the Institutional Investors Group on Climate Change (IIGCC).

– Professor Gordon Clark (Halford Mackinder Professor of Geography, Oxford University)
– Nick Robins (Head of Climate Change Centre of Excellence, HSBC)
– Joaquim de Lima (Global Head of Equity Quantitative Research, HSBC)
– Bruce Duguid (Head of Investor Relations, The Carbon Trust)
– Garrie Lette (Chief Investment Officer, Catholic Super, Australia)
– Stephanie Pfeifer (Executive Director, Institutional Investor's Group on Climate Change)

Regular communication and meetings

- Mercer established an online platform, called the Connect site, which granted access to all the project group members. This password-protected site gave the group the ability to interact through the portal as well as provide access to all the reports delivered during the project, relevant research documents on the economic and investment impact of climate change, and scenario analysis and factor risk for asset allocation.

- Regular conference calls took place between the project group members (typically every six weeks) to discuss key stages of the project and the next steps. During the first half of the project (October 2009 through May 2010), Grantham LSE/Vivid Economics also participated in these conference calls to discuss the draft reports that were delivered to the group.

- One-on-one interactions took place between Mercer and the project group members at critical points during the project, such as establishing the goals of the tailored reports and discussion about the proposed methodology and preliminary findings.

- Two in-person meetings with the project group were held to provide the opportunity for face-to-face interaction and exchange between the project group members on the outputs and next steps. Mercer hosted a London event in January 2010 and the IFC hosted a Washington event in October 2010.

- Two workshops were hosted by Mercer as part of the process of building the scenarios and evaluating the investment outcomes of the scenarios. The workshops were jointly facilitated by Grantham LSE/Vivid Economics and Mercer and included representatives from the academic community with expertise in climate-change science and economics, the finance industry (including climate change experts and mainstream investors), as well as the project group members.

Project stages and deliverables

The project consisted of three major stages:

- Stage 1 – design of the climate scenarios: led by Grantham LSE/Vivid Economics, guided by Mercer with input from the project group and the research group. A (non-public) report was delivered to the project group by Grantham LSE/Vivid Economics out of this process.

- Stage 2 – mapping the evidence of the climate scenarios to key macroeconomic and microeconomic outcomes: led by Grantham LSE/Vivid Economics, guided by Mercer with input from the project group and the research group. A (non-public) report was delivered to the project group produced by Grantham LSE/Vivid Economics out of this process.

- Stage 3 – evaluating the impact of the scenarios and the evidence, as defined in Stages 1 and 2, to consider the impact for investments across asset classes and regions. This stage was led by Mercer, with input from the project group and the research group. A series of (non-public) reports, produced by Mercer, on each asset class and the overall implications were discussed with the project group.

The primary deliverables include a Public Report and a Tailored Report for each of the asset owner partners:

- Public report – The aim of the public report is to provide a synthesis of the key findings from the study, incorporating the highlights from each of the three defined stages.

- Tailored reports – Each asset owner member received a confidential report specific to the organisation's asset mix to examine the impact of the scenarios, including recommendations on possible actions to take.

- Communication and outreach – The project group sought to share the broad findings with the industry, such that other institutional investors and policymakers could consider the possible implications for their organisations and/or policy frameworks.

Expanding the asset-allocation toolkit

Traditional modelling approaches do not adequately capture the nature of the economic transformation process and the potential sources of risk associated with climate change. As such, the tools to integrate climate change into the way we think about sources of risk for SAA need to be expanded along the following lines:

- **Climate change increases uncertainty:** Climate change increases the uncertainties for institutional investors that can potentially have a significant impact on the performance of a portfolio mix over the long term, with the primary source of risk coming from uncertainty around policy and its associated adjustment costs. Prudent risk management processes should build climate change considerations into long-term strategic decision-making processes to help manage these uncertainties.

- **Need to look beyond macroeconomic impacts:** The Grantham LSE/Vivid Economics analysis showed that the potential impact of climate change on GDP, interest rates and inflation across the scenarios magnifies beyond 2050, but may not be the driving force behind investment risks before then. Mercer's analysis concluded that the source of investment risk over the coming 20–30 years will come through the increased uncertainty around new technology, physical impacts and climate policy.

- **Need to think about diversification across sources of risk:** To varying degrees, traditional asset-allocation techniques optimise portfolio exposure based on assumptions about the risk, return and correlation between asset classes where diversification across assets is sought. An additional tool in this analytical framework is to think of SAA in terms of diversifying across sources of risk, rather than via asset classes per se. This means utilising a factor risk approach to supplement asset allocation decision making.

- **Need to be more forward looking:** Climate change requires forward-looking analysis and cannot rely on modelling historical asset-class relationships that traditional modelling analysis techniques predominantly rely on. This means utilising tools such as scenario analysis.

- **Need to go beyond quantitative analysis:** Qualitative factors need to be embedded into the decision-making process. SAA decision-making processes rely heavily on quantitative analysis, whereas much of the source of investment risk around climate change requires the exercise of judgement about how things might develop in terms of the science of climate change, the policymakers' response and the type of technologies that may/may not prosper.

- **Need to review assumptions regarding market risk:** Past periods of positive and negative economic transformation have been associated with a significant change in the realised ERP[82] over time, ranging from destructive wartime periods to positive periods of substantial efficiency improvements arising from a growing service sector and innovations in IT. Assumptions regarding the ERP should therefore be reviewed in light of the potential impacts of climate change on the process of economic transformation that may take place in the transition to a low-carbon global economy.

[82] Broadly defined, the ERP represents the compensation for taking on equity risk versus a risk-free rate. The notion of the ERP is widely used in finance models and also features as an input into the way Mercer develops some of its asset-class assumptions. Hence, it is important to consider if the climate change scenarios might affect the ERP and, if so, in what way and by how much. The ERP discussion in this study focuses on realised returns for an existing portfolio of assets at a future point in time. This is because the study is evaluating the outcome/consequence of different climate scenarios for an existing portfolio of assets, starting from today and looking at a future end date (in this case 2030).

Scenario analysis

It was against this backdrop that scenario analysis emerged as a potentially useful tool to utilise for this project. Scenarios have been widely used, and have proved to be a powerful tool in informing strategic decisions in the face of deep uncertainty about the future. Shell, for example, has pioneered the use of scenarios of future energy supply and demand, in order to consider the risks and opportunities to its business (Shell, 2008). Governments are also turning to scenarios to understand how future events might affect areas of national interest. The UK government, for example, launched the Foresight programme in 1993, in order to identify risks and opportunities for the national science, technology and engineering sectors. Scenario planning is a key element of the Foresight approach.

In the context of climate change, scenarios have been used to map the evolution of greenhouse gas emissions, temperatures and impacts, both under BAU and with policy intervention. Perhaps the best-known example is the IPCC's *Special Report on Emissions Scenarios* (Nakicenovic and Swart, 2000).

Scenario analysis is ideally suited to exploring extreme events and searching for "black swans" (Taleb, 2007). It is "the methodical thinking of the unthinkable" (Van der Heijden, 1996). In doing so, its particular strength lies in identifying storylines or sequences of events and their consequences. This can reveal unexpected futures, but at the same time it can also reveal inevitable futures, both of which constitute valuable knowledge.

Not only has scenario analysis been the method utilised by the research community on climate change science and economics, it is also a tool that can potentially improve risk management and SAA processes to incorporate more qualitative factors into the mix that are generally overlooked.

While the future holds many uncertainties that we may not always be able to fully prepare for, it is beneficial for long-term investors to utilise processes that help them to better consider systemic risks such that they respond in a more measured way if/when events do unfold. Scenario analysis can help fiduciaries to fulfil their obligations in a number of ways:

- Increase knowledge and awareness about where major risks might lie across investments
- Become better prepared for turbulent times, minimising the risk of making bad (short-term) decisions at the wrong time in response to unforeseen events
- Recognise early warning signs if developments move towards a certain scenario outcome

Factor risk framework

The next feature of our approach was to look at SAA through a factor risk framework, as climate change and scenario analysis supported a more forward-looking approach to better inform the assumptions made within traditional modelling techniques that rely heavily on historical data. In its most extreme form, thinking about asset allocation in terms of factor risks means that the decision-making framework is not divided up along asset-class lines but by sources of risk. The asset classes are then thought of in terms of how they will be affected by those sources of risk, with the ultimate goal being to achieve diversification across them.

Scenario analysis and a factor risk framework are particularly helpful in considering how climate change might affect a portfolio's asset mix, since the sources of risk might not always come through financial variables that traditional portfolio optimisation models rely on. Moreover, historical data are not always available for risks such as climate change, since it is more about looking into the future and less about modelling the past. It involves an element of judgement and discussion about the assumptions as part of the SAA process to test and challenge the quantitative assumptions that underpin modelling analysis.

Defining the sources of investment risk

The sources of risk that have been examined in this study are summarised in Table 24. The fundamental and market risks draw from Mercer's analysis within the Growth Portfolio Toolkit (GPT).[83] The climate change risks (TIP™) are an additional set of factors that have been developed for this project to provide a framework to translate the climate scenarios and their outcomes into sensitivities across asset classes and regions.

Table 24
Source of investment risk

Fundamental factors	Market factors	Climate change factors
Economic cycle sensitivity	Equity risk premium	Technology (low carbon)
Inflation sensitivity	Volatility	Impact (physical)
		Policy (climate)

Source: Mercer

Interpretation of the sources of investment risk

Thinking about SAA in terms of the potential source of investment risk is a relatively new approach for institutional investors – hence, a few observations on how a factor risk framework can be used for SAA decision making might be helpful at this point.

First, diversification across the different sources of risk is preferable to ensure that the portfolio is resilient to a number of different potential factors that might affect performance and is not overly exposed to each one. The objective is not to maximise exposure to one factor or minimise it to another, but rather to have an asset mix that is broadly dispersed across the sources of risk. Put simply, this means having a spread of high and low exposure across the portfolio mix to fundamental risks, market risks, asset-specific risks and climate change risks.

Second, a high *sensitivity* to a source of risk does not necessarily indicate that it will be negative (or positive) for investments. For example, listed equity has a high sensitivity to the economic cycle, but this relationship can be either positive or negative depending on the different stages of the economic cycle. Likewise, assets that are highly sensitive to regulatory or political change, such as real estate and infrastructure, may benefit from favourable policies or suffer from unfavourable ones. In summary, it need not be that a higher sensitivity to a factor means lower returns or higher risk; the objective is to disperse the source of risk across the factors as far as possible and to consider these as part of a fiduciary's regular strategic review discussions.

Finally, interpreting the *direction* of the potential risk (whether it will be positive or negative) requires an element of judgement and discussion about the changing investment conditions. This is one of the primary benefits of integrating factor risk analysis into asset-allocation discussions, as it encourages decision makers to step back from quantitative model assumptions and ask questions to test their thinking. This might be in the form of stress testing for the impact of extreme situations, or combined qualitative and quantitative scenario analysis, the latter of which is the method adopted for this study.

[83] See "Diversification: A Look at Risk Factors", available at http://www.mercer.com/referencecontent.htm?idContent=1378620.

Climate change risks – TIP™ framework

Recognising the limitations of existing approaches to SAA and the need to integrate a plethora of new data into the decision-making process around the science and economics of climate change, Mercer developed the TIP™ factor risk framework, defined as:

- **Technology** (T) – broadly defined as the rate of progress and investment flows into technology related to low carbon and efficiency, which are expected to provide investment gains

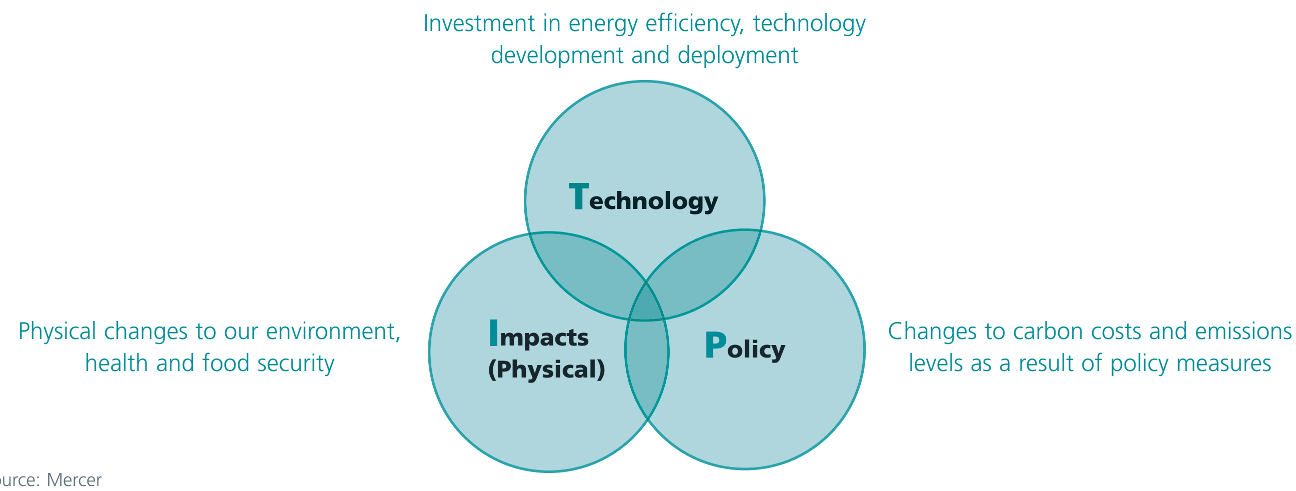
- **Impacts** (I) – the extent to which changes to the physical environment will affect (negatively) on investments

- **Policy** (P) – the cost of climate policy in terms of the change in the cost of carbon and emissions levels that result from policy depending on the extent to which it is coordinated, transparent and timely

The factors are all interdependent, as policy will be a key for mobilising technology, both of which will be important for minimising physical impact risk. For this reason, the framework cannot be viewed in a linear way. Each factor is designed to provide insight into a different part of the climate change transformation process. These changes may be positive or negative for investments; hence, the direction of the investment impact is determined through interpretation of the sensitivities of each asset class to these factors across the scenarios.

The TIP™ framework was formulated to examine the process of economic transformation due to climate change, inspired by Schumpeter's work (1947) on the process of economic change and the role of innovation and disruptive technologies. The framework is designed to look beyond the macroeconomic impacts to understand the process of transformation associated with climate change and what this means for investments, such as capital flows in low-carbon technology and energy efficiency, the sensitivity of investments to physical changes to the environment, the policy measures used and how this varies by region, the market sensitivity to policy measures, and the degree to which investors anticipate (or do not anticipate) the climate policy measures.

Figure 16
TIP™ = Technology, Impacts and Policy
Factor risk approach to evaluate climate change investment impacts



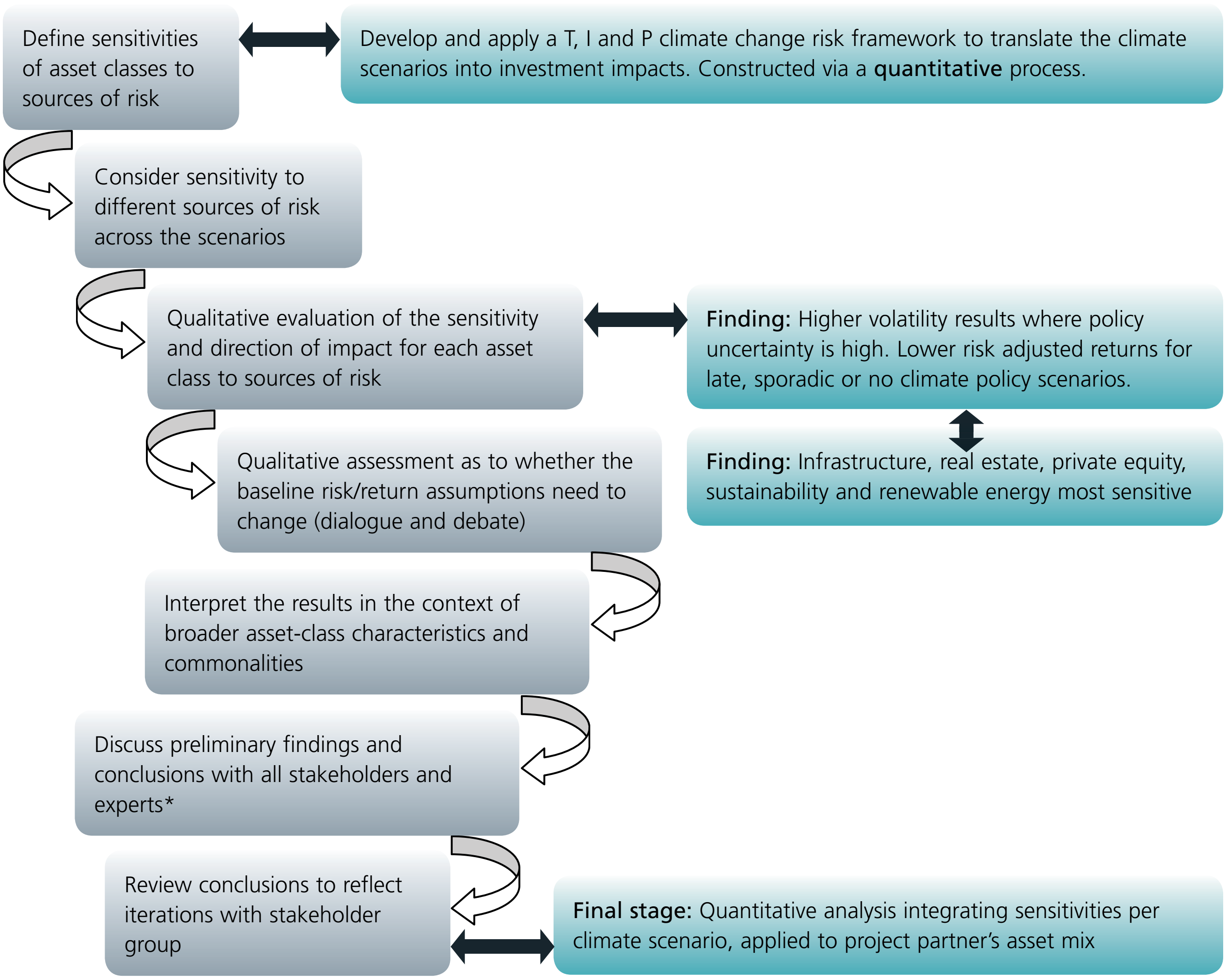
Source: Mercer

As Figure 17 describes, the initial process of aggregating the relevant data to measure the TIP™ values across the scenarios was largely a *quantitative* process. The next stage involved evaluating the sensitivities of each asset class and region to the sources of investment risk, which was largely a *qualitative* process.

This combination of quantitative and qualitative techniques allowed some degree of numerical estimation to gauge the possible magnitude of impacts and how they vary across the scenarios (such as capital flows due to technology, the costs of physical damage to the environment and the outcome of policy measures). However, the forward-looking nature of the process also necessitated a high degree of judgement regarding the sensitivity of each asset class and region across the scenarios.

Figure 17

Framework linking the climate scenarios to sources of investment risk



Source: Mercer

* Where the stakeholders and experts consulted include: All members of the project group, Mercer asset-class experts for equities, bonds, private equity, infrastructure, real estate and factor risk specialists on asset allocation. The Research Group and Grantham LSE/Vivid Economics were also consulted.

Figure 18 sets out the TIP™ factor risk framework. While each of the T, I and P factors have been quantified to provide a sense of scale and magnitude in terms of capital flows, the framework is largely a qualitative one that requires judgement in interpreting the impact for investments.

A higher T, I or P value of one scenario versus another indicates a higher value associated with the transformation process. The variability across the scenarios is also of interest as it shows the potential range of outcomes where a higher range suggests a higher degree of uncertainty for investors in predicting the factor. Needless to say it will not always be the case that a higher T, I or P value will be positive for investments, and vice versa for lower values. Hence in the second stage of the analysis the sensitivity of each asset class to these T, I and P factors is evaluated to determine the overall impact for investments in terms of the magnitude and direction across the scenarios.

The T, I and P factors are all interdependent (as policy will be key for mobilising technology, both of which will be important for minimising physical impact risk), hence the framework cannot be treated in a linear model way. Each factor is designed to provide insight into a different part of the climate change transformation process, some of which will be positive or negative for investments; hence, the direction of the impact is determined through interpretation of the sensitivities of each asset class across the scenarios.

Figure 18

Climate change risks – **TIP™** framework formulation

Technology: \$ size of additional low carbon investment flows by 2030	**Impacts:** \$ cost of physical climate change impacts by 2030	**Policy:** \$ change in cost of emissions to 2030 as a result of climate policy
Cumulative additional investment in efficiency improvements, renewable energy, biofuels, nuclear and CCS to 2030 (Source: derived by Mercer from IEA WEO 2009)	Cumulative economic cost of changes to the physical environment, health and food security to 2030 (Source: estimates by Grantham LSE/Vivid Economics)	Change in cost of emissions = [2030 Emissions x \$ / tCO_2e] – [2010 Emissions x \$ / tCO_2e] (Source: CAIT and Grantham LSE/Vivid Economics)
IEA estimates modified according to different degree of mitigation across scenarios. Climate Breakdown is baseline investment flows that would happen without additional mitigation	Calculations by Grantham LSE/Vivid Economics, using Hope's PAGE2002 model estimates and data on adaptation costs from the World Bank/United Nations Framework Convention on Climate Change (UNFCCC)	Carbon price derived by Grantham LSE/Vivid Economics from the WITCH model; emissions derived by Grantham LSE/Vivid Economics based on Bowen & Ranger, 2009 and IEA 2009
Result: The value of additional investments in these assets will grow by between \$180 bn to \$260 bn pa to 2030 for all mitigation scenarios, with Stern Action at the upper end	Result: The costs range in the order of \$70 bn to \$180 bn pa globally in terms of adaptation and residual damage costs, with Climate Breakdown the highest cost	Result: The increase in the cost of emissions from 2010 to 2030 ranges between \$130 bn and \$400 bn pa globally, with Delayed Action the most costly due to late and unanticipated policy

Source: Mercer. The factors have been discounted to the net present value using a 3% discount rate. This was chosen based on a composite of global 10Y bond yields as at October 2010.

Technology – Size of future investment flows

- This factor measures the cumulative additional investment in low-carbon technology that takes place under the different climate scenarios to 2030 as a result of mitigation policies. This includes investment in efficiency improvements, renewable energy, biofuels, nuclear and CCS.

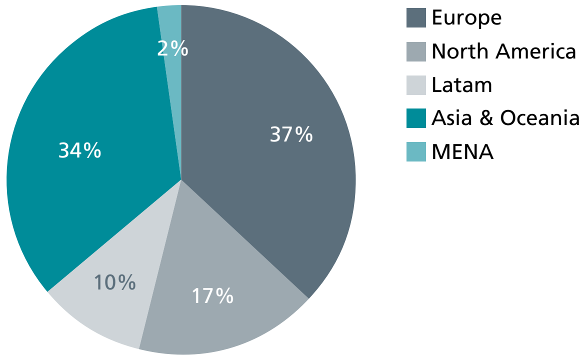
- The variability in Technology across the scenarios has been calculated based on the expected size of the investment for each scenario, rather than on making explicit assumptions about the rates of return for each type of technology, as the information available is too sporadic to make any IRR assumptions sufficiently robust. The estimates for technology therefore err on the side of caution and are likely to underestimate the future value of technology investments, depending on the rate of return earned.

- Technology estimates for Climate Breakdown are zero, as the data are based on the IEA World Energy Outlook (2009) computations on the additional investment under the 450 Scenario used as the proxy for Stern Action versus the Reference baseline scenario as the proxy for Climate Breakdown. In Regional Divergence, we have assumed 25% less investment spending than Stern Action, as emissions levels are higher and policy is less efficient globally. Delayed Action only includes the 2020–2030 of the IEA estimates of investment flows, as we assume BAU until after 2020.

- By region, the estimates are also based on the IEA World Energy Outlook (2009) data together with Mercer assumptions. The same estimation process as defined above was applied, with the only modification being a clustering of countries into leaders (the EU and China/East Asia), mature but contracting (the US), improvers (Japan and India/South Asia) and laggards (Russia). This classification was based on the rate of change in the investment into clean energy and energy efficiency, as reported by UNEP, SEFI and Bloomberg New Energy Finance (2010). Figure 19 summarises the new investment flows by region in 2009, with China representing a substantial $33.7 bn and India $2.7 bn of the Asia and Oceania category.

Figure 19

New investment by region 2009 (total investment = $19 bn)



Source: *Global Trends in Sustainable Energy Investment 2010 Analysis of Trends and Issues in the Financing of Renewable Energy and Energy Efficiency.* UNEP, SEFI and Bloomberg New Energy Finance

- On the basis of these trends, the Regional Divergence scenario applied a percentage reduction in investment in some regions versus Stern Action, which assumes global participation and, hence, represents the best-case outcome in terms of investments. For Regional Divergence:

  – The leaders were assumed to be 100% of the Stern Action investment levels. This applied to the EU and China/East Asia.
  – The mature but contracting was assumed to be 50% of the Stern Action investment levels. This applied to the US.
  – The improvers were assumed to be 50% of the Stern Action investment levels. This applied to India/South Asia and Japan.
  – The laggards were assumed to be 20% of the Stern Action investment levels. This applied to Russia.

Impacts – Cost of physical climate change impacts

- This factor measures the economic cost of changes to the physical environment, health and food security owing to climate change. It was estimated by Grantham LSE/Vivid Economics on the basis of two components – adaptation costs and residual damages. The impact on adaptation costs and residual damage in terms of GDP effect over the scenarios out to 2030 is presented in Table 25. The costs of adapting to climate change include costs related to infrastructure, coastal zone protection, extreme weather, human health, fisheries, agriculture and water supply/flood protection. Adaptation costs also incorporate the financial transfers required to assist adaptation from developed to developing economics.

- Adaptation costs were estimated by Grantham LSE/Vivid Economics based on a World Bank (2009a) study, which takes a sectoral approach to estimating adaptation costs but provides estimates disaggregated to the level of large regions in the developing world, and shows how these change over time, implicitly as a function of climate change and socioeconomic development. Appendix F provides further explanation of the methodology used by Grantham LSE/Vivid Economics.

- As Table 25 shows, the estimated difference between adaptation costs between the Climate Breakdown and Stern Action scenarios across the countries is low in terms of percentage GDP by 2030 (the focus of this study). However, the differences in adaptation costs between the scenarios become more pronounced over time. This is because the change in temperature and sea-level rise escalates by 2050 and beyond. The focus of this study is based on the estimates to 2030 – hence, the differences in temperature are comparatively small (as illustrated in Figure 20 on page 105).

Table 25

Adaptation costs are higher under Climate Breakdown, and increase more than proportionately over time

	Adaptation costs in US$ billion and % GDP (in parenthesis)			
	2012	2020	2030	2050
Climate Breakdown				
Europe	7.3 (0.1)	10.5 (0.1)	17.1 (0.1)	38.4 (0.2)
US and Canada	27.4 (0.3)	39.3 (0.3)	63.7 (0.4)	143.5 (0.7)
OECD Pacific	3.5 (0.0)	5.0 (0.1)	8.1 (0.1)	18.2 (0.1)
China and East Asia	22.3 (0.4)	23.6 (0.2)	25.7 (0.1)	32.2 (0.1)
Russia and the former Soviet Union	6.4 (0.5)	8.3 (0.4)	11.6 (0.3)	22.2 (0.3)
Latin America and the Caribbean	18.4 (0.7)	19.6 (0.5)	21.8 (0.4)	28.1 (0.3)
Middle East and North Africa	1.8 (0.1)	2.8 (0.1)	4.4 (0.1)	9.7 (0.1)
India and South Asia	10.0 (0.4)	11.3 (0.4)	13.6 (0.2)	20.7 (0.1)
Sub-Saharan Africa	12.6 (0.7)	15.7 (0.6)	21.2 (0.8)	38.7 (1.0)

Table 25

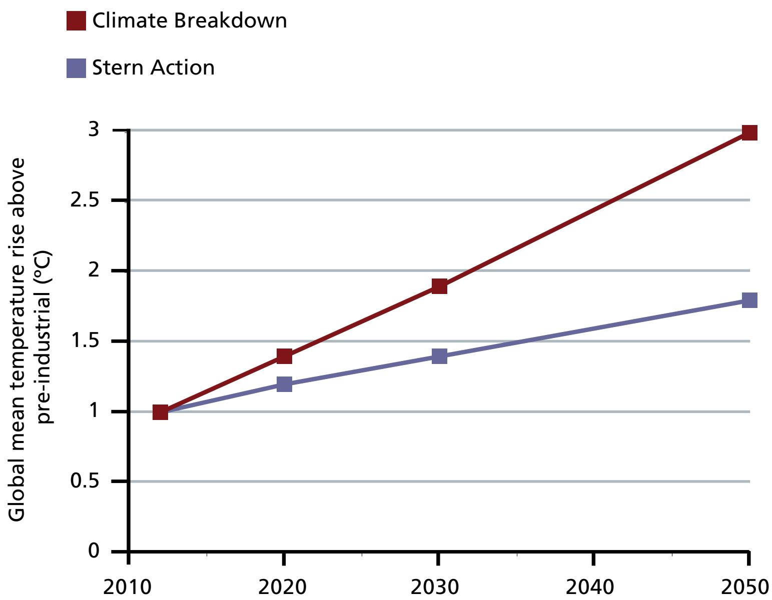
Adaptation costs are higher under Stern Action, and increase more than proportionately over time *(cont'd)*

	Adaptation costs in US$ billion and % GDP (in parenthesis)			
	2012	2020	2030	2050
Stern Action				
Europe	7.3 (0.1)	9.2 (0.1)	11.5 (0.1)	17.1 (0.1)
USA and Canada	27.4 (0.3)	34.5 (0.3)	43.0 (0.3)	63.7 (0.3)
OECD Pacific	3.5 (0.0)	4.4 (0.0)	5.4 (0.0)	8.1 (0.1)
China and East Asia	22.3 (0.4)	23.2 (0.2)	24.3 (0.1)	26.1 (0.1)
Russia and the former Soviet Union	6.4 (0.5)	7.4 (0.3)	8.5 (0.3)	11.1 (0.2)
Latin America and the Caribbean	18.4 (0.7)	19.4 (0.5)	20.5 (0.4)	22.5 (0.2)
Middle East and North Africa	1.8 (0.1)	2.3 (0.1)	2.9 (0.1)	4.2 (0.1)
India and South Asia	10.0 (0.4)	10.7 (0.2)	11.5 (0.1)	13.2 (0.1)
Sub-Saharan Africa	12.6 (0.7)	14.2 (0.6)	16.2 (0.6)	20.6 (0.5)

Source: Grantham LSE/Vivid Economics calculations, based on World Bank (2009a)

Figure 20

Rapid warming under Climate Breakdown, lower under Stern Action



Source: Grantham LSE/Vivid Economics

- Another variable that could change between the scenarios by 2030 is residual damage costs. Adaptation will not eliminate all of the damage costs of climate change (Fankhauser, 2010). Even if it were technically feasible to do so, it would be highly unlikely to be cost-effective, as adaptation costs at the margin are likely to exceed damage costs when near total climate proofing is achieved. Therefore, the residual damage costs of climate change must still be determined.

- The residual damage cost estimates were based on the PAGE2002 model that was built by Dr. Chris Hope from the University of Cambridge and used by the Stern Review (Stern, 2007). It captures sub-factors such as changes in temperature, increased propensity for drought, increased flood risk, increased risk of extreme weather events, changes in health and disease across regions, and changes in crop yields and food security.

- PAGE2002 has eight world regions and a time horizon of 200 years, from 2000 to 2200. Like other integrated assessment models, PAGE2002 contains a set of equations to represent all links in the chain between economic and population growth and associated greenhouse gas emissions on one side and economic damages of climate change on the other. The section "Estimating Residual Damages" (on page 11) provides further explanation of the methodology used by Grantham LSE/Vivid Economics.

- Table 26 estimates residual damage costs between the Stern Action and Climate Breakdown scenarios. Residual damages are higher under Climate Breakdown than under Stern Action – even by 2030. This is because of the temperature differences between the two scenarios (see Figure 20) as well as using PAGE2002 to assume that a given amount of warming produced more damage in Climate Breakdown than in Stern Action to reflect the longer-term policy trajectory. Furthermore, it is again the case that residual damage costs increase over time – hence, this difference between the scenarios increases considerably by 2050 and beyond.

Table 26
Residual climate damages are steeply rising under Climate Breakdown and are highest in the developing world

	Residual damage costs in US$ billion and % GDP (in parentheses)			
	2012	2020	2030	2050
Climate Breakdown				
Europe	0.0 (0.0)	0.0 (0.0)	1.3 (0.0)	10.3 (0.1)
USA and Canada	0.0 (0.0)	0.0 (0.0)	0.7 (0.0)	5.9 (0.0)
OECD Pacific	0.1 (0.0)	0.0 (0.0)	1.9 (0.0)	4.8 (0.0)
China and East Asia	0.0 (0.0)	0.1 (0.0)	4.4 (0.0)	44.0 (0.1)
Russia and the former Soviet Union	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	1.2 (0.0)
Latin America and the Caribbean	6.1 (0.2)	20.3 (0.5)	70.1 (1.2)	285.4 (2.8)
Middle East and North Africa	6.3 (0.3)	20.9 (0.6)	45.8 (1.3)	154.2 (3.1)
India and South Asia	4.0 (0.2)	12.5 (0.3)	57.4 (0.7)	288.2 (1.5)
Sub-Saharan Africa	4.8 (0.3)	16.1 (0.3)	35.3 (1.3)	116.4 (3.1)

Table 26

Residual climate damages are steeply rising under Stern Action and are highest in the developing world *(cont'd)*

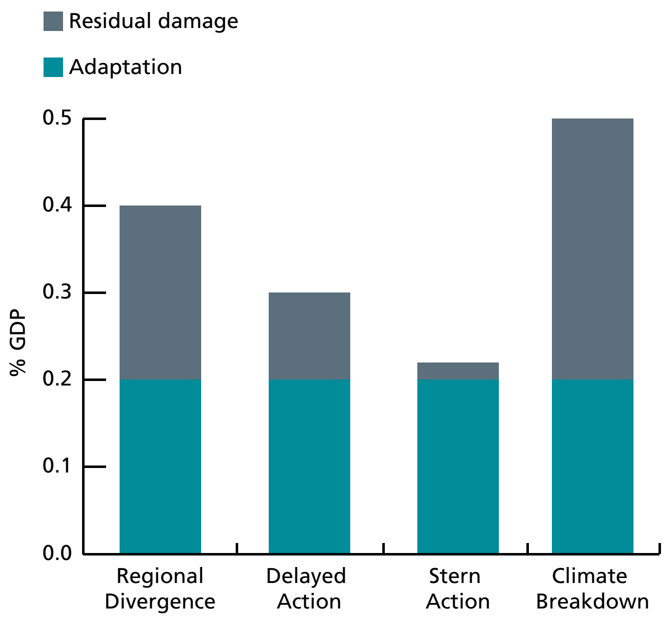
	Residual damage costs in US$ billion and % GDP (in parentheses)			
	2012	2020	2030	2050
		Stern Action		
Europe	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.4 (0.0)
USA and Canada	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)
OECD Pacific	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.0)
China and East Asia	0.0 (0.0)	0.0 (0.0)	0.2 (0.0)	2.0 (0.0)
Russia and the former Soviet Union	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	-0.1 (0.0)
Latin America and the Caribbean	1.1 (0.0)	2.9 (0.1)	8.7 (0.2)	33.0 (0.3)
Middle East and North Africa	2.1(0.1)	8.1 (0.2)	5.7 (0.2)	17.9 (0.4)
India and South Asia	0.8 (0.0)	2.1 (0.0)	7.6 (0.1)	33.8 (0.2)
Sub-Saharan Africa	1.6 (0.1)	6.2 (0.2)	4.4 (0.2)	13.5 (0.4)

Source: Grantham Research Institute/Vivid Economics

- On the basis of these estimates for Climate Breakdown and Stern Action, the following assumptions were made for the remaining scenarios:
  - For adaptation costs, as Figure 21 shows, both scenarios are the same as for Climate Breakdown and Stern Action at around 0.2% of global GDP in 2030. This is because policy cannot change the course of the physical impacts of climate change within that period.
  - For residual damage costs, based on the emissions trajectory for each scenario, the Delayed Action scenario was assumed to cost 1.5x that of Stern Action in terms of residual damage. Similarly, Regional Divergence was assumed to be 2x the cost of Stern Action. This is because the residual damage cost estimates take into account the emissions trajectory, with Regional Divergence producing higher emissions levels than under Delayed Action (see Table 27, on page 108, for emissions levels for each scenario).

Figure 21

Residual damage costs + Adaptation costs as a percentage GDP to 2030



Source: Grantham LSE/Vivid Economics

Policy – Change in cost of emissions

- This factor measures the change in the cost of carbon emissions as a result of climate policy measures in 2030 under each scenario. It is derived from the change in the expected level of emissions and the future carbon price in 2030 compared to 2010. More specifically, it represents the change in future emissions level x future carbon price between the two periods. The carbon price could be a market-based trading system or an implied cost of carbon due to policy measures and/or relative changes in commodity prices.

- The estimates are based on the outcomes of the climate scenarios within the Grantham LSE/Vivid Economics scenarios and mapping evidence reports produced as part of this project. The assumptions are set out in Table 27. In brief:

  – The carbon price estimates were derived by Grantham LSE/Vivid Economics from the WITCH model of the RECIPE study, built by a team from the FEEM research institution.
  – The emissions levels were derived by Grantham LSE/Vivid Economics based on data from Bowen and Ranger (2009) and the IEA (2009), in which the 450 Scenario was used as a proxy for Stern Action and the Reference scenario as a proxy for Climate Breakdown.

- According to Grantham LSE/Vivid Economics, the carbon price estimates are in the middle of model estimates in the RECIPE study over the time period, but increase rapidly after 2030. Prices accelerate because the model's agents have perfect foresight – they require a relatively modest carbon price to take early action (given their expectation of higher rises subsequently), but they expect limited technological options and substitution possibilities within the energy sector later, because cheaper options are exhausted earlier on. Nearly all projections of carbon prices entail period-by-period increases for several years, often well into the second half of the century or beyond.

Table 27
Cost of carbon and emissions levels in 2030

Scenario	Cost of carbon in 2030	Emissions in 2030
Regional Divergence	\$110/tCO_2e only in participating regions, including all countries in this study except India/ South Asia and Russia	50 Gt CO_2e per year
Delayed Action	\$15/tCO_2e to 2020 then dramatic rise to \$220/ tCO_2e	40 Gt CO_2e per year
Stern Action	\$110/tCO_2e	30 Gt CO_2e per year
Climate Breakdown	\$15/tCO_2e	63 Gt CO_2e per year

Source: Grantham LSE/Vivid Economics estimates

- Across regions, the same methodology and source of data were used for the regions examined in this study for each scenario, with the future carbon emissions in each respective region/country in 2030 using IEA WEO (2009) data for the 450 Scenario as a proxy for Stern Action and the Reference scenario for Climate Breakdown. The Delayed Action scenario was estimated based on a shortfall in reducing emissions at the global level as a result of the delay compared to Stern Action – that is, emissions stay higher by a factor of 40 Gt/30 Gt (see Table 27). The Regional Divergence scenario applied the same factor weighting based on comparative emissions levels to Stern Action of 50 Gt/30 Gt.

- The cost of carbon for the non-participating countries in the Regional Divergence scenario – namely Russia and India/South Asia – was assumed to be \$15/tCO_2e. The other countries examined in this report that are assumed to incur a cost of carbon of \$110/tCO_2e include the EU, the US, China/East Asia and Japan. For all other scenarios the carbon cost was applied consistently across the countries and analysed against their future emissions levels.

Estimating the costs **of adaptation**

This section was produced by Grantham LSE/Vivid Economics.

Estimates from the literature of the costs of adaptation, in particular from the World Bank (2009) and from the United Nations Framework Convention on Climate Change (UNFCCC) (2007), are reported with respect to a particular scenario of greenhouse gas emissions and associated climate change. The UNFCCC estimates have the added limitation of only being available for one future year, 2030. In their case, the dependency of costs on climate change cannot be deduced.

In order to produce estimates of adaptation costs that are both dynamic and consistent with our scenarios, a series of adaptation cost functions were constructed that show how the costs of adaptation in particular regions and sectors depend on a changing climate.

The following functional form was used:

$$C_{r,s,t} = \alpha_{r,s} + \beta_{r,s} TE_t^{\,2} \qquad \text{(AX1)}$$

Where C is the cost of adaptation in region *r*, sector *s*, and at time *t*, $\alpha_{r,s}$ and $\beta_{r,s}$ are constants, and TE is the increase in global mean temperature above the pre-industrial level.

One exception is the cost of enhancing coastal zone protection, in which costs were set as a function of sea-level rise directly:

$$C_{r,s,t} = \alpha_{r,s} + \beta_{r,s} SLR_t^{\,2} \qquad \text{(AX2)}$$

Where *SLR* is sea-level rise.

Costs are assumed to be a quadratic function of warming/sea-level rise, meaning that they increase more than proportionately. That costs increase more than proportionately with increasing adaptation requirements is a common finding, while the quadratic functional form is convenient and is frequently used in the economics of climate change to represent cost functions of all types.

Given this assumption, the constants $\alpha_{r,s}$ and $\beta_{r,s}$ can be solved by simultaneous equations to calibrate the curve on data from the World Bank (2009) study. The resulting adaptation cost curve thus delivers the same estimate of the cost of adaptation as the World Bank (2009) study using its warming scenario, but it can also be extrapolated and interpolated to different amounts of warming.

Adaptation cost curves are constructed for three sectors: (i) infrastructure, (ii) coastal zone protection and (iii) all other adaptation costs. The third category includes the following sectors: industrial and municipal water supply and riverine flood protection, agriculture, fisheries, human health, and extreme events. There is insufficient information in the World Bank (2009) study to estimate adaptation cost functions for these sectors separately. However, data are available on the share of these sectors' costs in (iii), averaged over the period 2010–2050, and so a rough estimate of costs to these sectors can be made by assuming they command a constant share of (iii) for all amounts of warming.

Estimating residual **damages**

This section was produced by Grantham LSE/Vivid Economics.

To estimate the residual damages of climate change, the PAGE2002 model was used. This model was built by Chris Hope (2006) and used by the Stern Review (Stern, 2007). PAGE2002 has eight world regions and a time horizon of 200 years, from 2000 to 2200. Like other integrated assessment models (IAMs), PAGE2002 contains a set of equations to represent all links in the chain between economic and population growth and associated greenhouse gas emissions on one side and economic damages of climate change on the other. Figure A1 (on page 113) is a stylistic representation of this process.

PAGE2002 is a stochastic IAM, meaning that each of its parameters can be sampled from a distribution of values in the course of a Monte Carlo simulation, which ultimately produces a distribution of estimates of the cost of climate change (and, if required, of the cost of adaptation and of mitigation). However, since the present study is scenario-based, the model was run in deterministic mode with a set of assumptions consistent with each scenario.

Most of the intricacies of the modelling need not be explored in detail, since not all aspects of the model were used in this study. Rather, the question is: What are the residual damages of climate change for scenarios of global mean warming that are compatible with the scenarios? The equations representing how global mean temperature responds to increases in the atmospheric concentration of greenhouse gases are particularly complex. In short, the so-called climate sensitivity parameter was calibrated – namely, the equilibrium increase in global mean temperature following a doubling in the atmospheric concentration of CO_2 – in order to replicate the temperature trend in Climate Breakdown and Stern Action.

From here, the key assumptions about residual climate damages concern the so-called damage function, which in PAGE2002 is represented by the following equation:

$$D_{r,t} = \alpha_r \left(\frac{TE_{r,t} - ATL_{r,t}}{2.5} \right)^{\beta} \kappa_{r,t} \qquad \text{(AX1)}$$

Where D is residual damage in region r at time t, TE is the increase in regional mean temperature (which PAGE2002 estimates from the corresponding increase in global mean temperature), α sets the cost of 2.5°C warming, and β is the damage-function exponent, determining curvature. Adaptation reduces the cost of climate change in two ways. First, it sets the tolerable level of warming before any residual damage occurs, *ATL*. Second, it reduces damage in excess of that tolerable level by the amount κ. *ATL* is itself a function both of the level of warming *ATP* and the rate of warming *ATR*:

$$ATL_{r,t} = \min[\, ATP_{r,t}, ATL_{r,t-1} + ATR_{r,t} t)] \qquad \text{(AX2)}$$

For warming of up to around 3°C, the key parameter is α, the regional cost of 2.5°C warming. Under the Climate Breakdown scenario, it is assumed that α_r take their maximum value, which is consistent with the scenario's storyline. In Stern Action, it is assumed that they take their central value. In both scenarios, the curvature of the damage function β is set to the central value of 1.8 (that is, almost quadratic). β only becomes an important parameter for warming well in excess of 3°C.

Figure A1
Integrated assessment models capture the whole process of man-made climate change

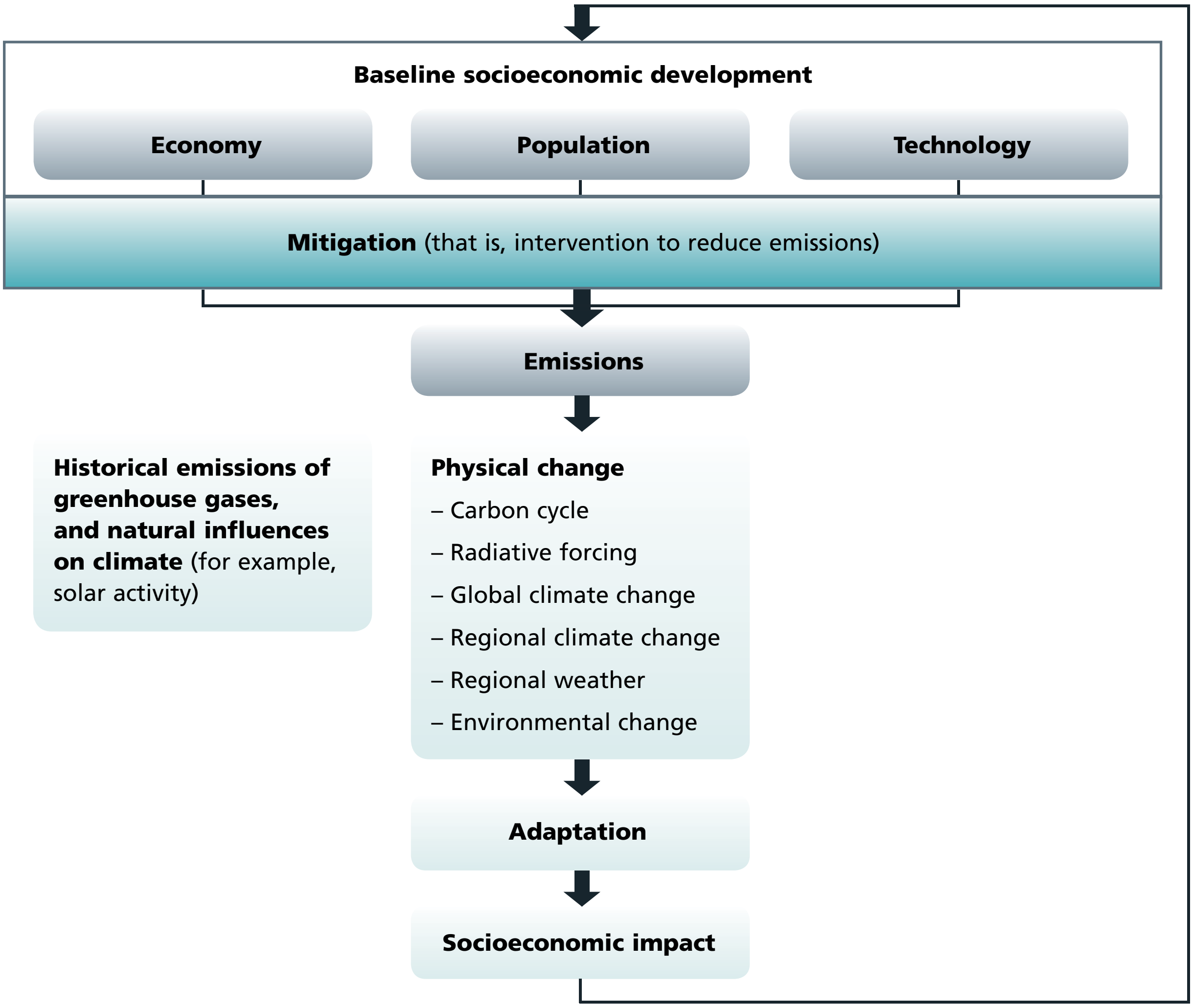


Table listing

Tables

Figures

Glossary

Abatement
Mitigation cost estimates generally comprise abatement costs: the extra resources needed to produce the existing pattern of production, sometimes with an estimate added on for the costs of reducing energy demand.

Adaptation
The process or outcome of a process that leads to a reduction in harm or risk of harm or realisation of benefits associated with climate variability and climate change. Adaptation costs are the added costs of adapting economies to climate change.

Alpha
Excess return to the market return, added by an investment manager through active management. It is often referred to as manager skill.

Asset/liability modelling (ALM)
Projection of future movements in assets and liabilities, and especially, the relationship between the two. ALM is used to provide an insight into the likely effect of different asset-allocation strategies on a pension scheme's future financial position.

Beta
At the asset-class level, beta refers to market return, or the return that would be earned on an asset class independent of manager skill. In its purest form, beta can be obtained through passive investment against an index where this is available (for example, equities, bonds, real estate, infrastructure and some commodities). For assets that embed a component of active management, the separation of alpha (manager skill) from beta (market return) is less straightforward.

Business as usual (BAU)
In the context of climate change and the climate change scenarios laid out in the report, BAU refers to unchanged policy from the current situation. A BAU scenario has been an integral part of most studies into the consequences of climate change. The most well-known and well-used set of BAU scenarios was developed by IPCC in its Special Report on Emissions Scenarios. The Reference scenario (that is, business as usual) of the IEA has also been widely used.

Capital asset pricing model (CAPM)
Economic model for valuing assets. The simplest version states that the expected excess return of a security over a risk-free asset will be exactly in proportion to its beta.

Carbon capture and storage
Carbon capture and storage (CCS), alternatively referred to as carbon capture and sequestration, is a means of mitigating the contribution of fossil fuel emissions to global warming, based on capturing carbon dioxide (CO_2) from large point sources such as fossil fuel power plants, and storing it in such a way that it does not enter the atmosphere.

Clean energy/cleantech
Products, services and processes that are geared towards reducing or eliminating the environmental impact of a means of production. It may include investments in agriculture, energy, manufacturing, materials, technology, transportation and water.

Climate change
A change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

Climate change risk factors
Climate change risk factors have been defined in this report in terms of the TIP™ framework – Technology, Impacts and Policy. They can be used to examine the extent to which asset-class returns are sensitive to climate change.

Climate sensitive assets
Climate sensitive assets refer to assets whose underlying risk/return characteristics are sensitive to the different sources of risk, defined in this study as low-carbon technology (T), physical impact risk (I) and climate policy risk (P). As indicated in Table 2, page 25, we conclude that the assets that are either highly sensitive or very highly sensitive to climate change include real estate, infrastructure, private equity, sustainable equities (listed and unlisted), efficiency/renewables (listed and unlisted) and commodities (including agricultural land and timberland).

Debt/equity ratio
A company's borrowings divided by its issued share capital. It is a measure of the amount of gearing (leverage) of a company and an indicator of financial strength. A company with a higher debt/equity ratio can offer greater returns to shareholders, but these will be more volatile than if the gearing were lower.

Efficiency/renewables listed/unlisted assets
In this report, this term is used to capture listed/unlisted sustainability-themed assets whose core activities are theme-specific and more concentrated in terms of exposure than broad sustainability equity. This includes (but is not limited to) energy efficiency, low energy transport, renewable energy, bioenergy, carbon capture and storage, smart grid, water supply, usage and management, waste management, hydro energy and geothermal, to name a few.

Equity risk premium (ERP)
Broadly defined, the ERP represents the compensation for taking on equity risk versus a risk-free rate. There are different ways to measure and refer to the ERP (Fernández, 2010), including historical equity premium, which measures the historical differential return of the stock market over treasuries. Expected equity premium measures the expected differential return of the stock market over treasuries. Required equity premium measures the incremental return of a diversified portfolio (the market) over the risk-free rate required by an investor. It is used for calculating the required return to equity. Implied equity premium measures the required equity premium that arises from assuming that the market price is correct.

Factor risk framework
A risk management tool that can complement traditional asset-allocation techniques, with the aim being to diversify across different sources of risk and return drivers across assets. The analysis can include factors such as the equity risk premium, small cap premium, unexpected inflation, term premium and credit risk premium. The approach allows for scenario analysis and the inclusion of additional sources of risk that might not otherwise be considered, such as leverage, illiquidity and climate change risk factors.

In its most extreme form, thinking about asset allocation in terms of factor risks means that the decision-making framework is not divided up along asset-class lines but by "sources of risk". The asset classes are then thought of in terms of how they will be affected by those sources of risk, with the ultimate goal to achieve diversification across them. This is the philosophy underpinning Mercer's GPT that has been applied in this report.

Fundamental analysis
Assessment of a company's share value and potential for future cash flows, profit and dividends based on accounting, economic and business information (hence, fundamental factors).

Fundamental risk factors
Fundamental risk factors refer to changes in the macroeconomic backdrop that might have an impact on investment performance, including changes to interest rates, inflation and GDP growth.

Impact risk factor
In this study, the impact risk factor refers to the extent to which changes to the physical environment will have an impact (negative) on investments, representing the I of the TIP™ framework.

Long-horizon assets
Similar characteristics to real assets (defined below), in that they tend to be priced with a long-term horizon (>10-year horizon), such as unlisted infrastructure and real estate, and are illiquid assets that cannot be readily realised.

Market risk factors
Market risk factors refer to the broad market conditions that might have an impact on investment performance, including factors such as the ERP, market volatility and illiquidity risk. It is the level of risk in the market that cannot be fully eliminated by diversification. Also known as systematic risk.

Mean-variance analysis
The process of portfolio selection that assumes that every rational investor, at a given level of risk, will accept only the largest expected return. More specifically, mean-variance analysis attempts to measure risk, correlation and expected return mathematically to help the investor find a portfolio with the maximum return for the minimum amount of risk. It is widely used in finance but also has a number of shortcomings, particularly the assumptions that investors are rational, that correlations are fixed and constant and that returns are normally distributed.

Mercer's Growth Portfolio Toolkit
Refer to "Factor Risk Framework".

Mitigation
Mitigation of climate change involves actions that are designed to limit the amount of long-term climate change. Mitigation costs are the added costs of reducing greenhouse gas emissions.

Modern portfolio theory (MPT)
Modern portfolio theory is a theory of investment that attempts to maximize portfolio expected return for a given amount of portfolio risk, or equivalently minimise risk for a given level of expected return, by carefully choosing the proportions of various assets.

PAGE2002 model
To estimate the residual damages of climate change, Grantham LSE/Vivid Economics used the PAGE2002 model built by Chris Hope (2006) and used by the Stern Review. PAGE2002 has eight world regions and a time horizon of 200 years, from 2000 to 2200. Like other integrated assessment models (IAMs), PAGE2002 contains a set of equations to represent all links in the chain between economic and population growth and associated greenhouse gas emissions on one side and economic damages of climate change on the other.

Policy risk factor
In this study, policy risk is defined as the P of the TIP™ framework, meaning the cost of climate policy in terms of the change in the cost of carbon and emissions levels that result from policy, depending on the extent to which it is coordinated, transparent and timely.

Portfolio risk
Represents the aggregation of risks associated with the assets held in a portfolio. In traditional approaches to mean variance analysis, risk refers to the standard deviation in returns. In this study, the different sources of risk underlying different assets have been examined, including fundamental risks, markets risks and climate change risks. Portfolio risk should be considered in the context of an institution's strategic objectives and the risk of not

meeting these. For example, the objective may be to generate sufficient returns to hedge liabilities, to protect a reserve pool of assets while minimising risk and maximising return, to minimise variations in contribution for sponsors, or to target a certain funding level.

Real assets
Physical/tangible assets such as infrastructure, private equity, real estate, gold, agricultural land, timberland.

Scenario analysis
Analysis of alternative future possibilities as an input into future planning, strategic risk management and, in the context of this study, asset allocation. Scenarios have been widely used and have proved to be a powerful tool in informing strategic decisions in the face of deep uncertainty about the future. In the context of climate change, scenarios have been used to map the evolution of greenhouse gas emissions, temperatures and impacts, both under BAU and with policy intervention. Scenario analysis can help to reveal unexpected futures, but at the same time it can also reveal inevitable futures, both of which constitute valuable knowledge.

Short-horizon assets
Liquid assets that are readily tradeable, such as stocks and bonds, that tend to be priced with a relatively short time horizon (12–18 months) compared to long-horizon assets.

Strategic asset allocation
Broadly defined as the use of optimisation tools to determine long-term asset allocation benchmarks to achieve long-term objectives. The objectives vary, depending on the type of asset owner and its obligations to beneficiaries or other stakeholders. It involves making decisions around allocation to high-level asset classes – that is, equity/fixed split, domestic/international/emerging equity split, duration of fixed income, and the split between nominal and inflation-adjusted fixed income, allocation to unlisted assets and sustainability-themed assets. This is distinct from other considerations such as portfolio structuring (including allocation to capital weightings, styles and sectors, and includes active/passive analysis) and manager selection (the evaluation of manager performance in order to select one suitable for a client’s requirements).

Sustainable investment
Broadly speaking, sustainable investment refers to investments that integrate long-term sustainability issues into core investment-making processes. At its broadest level, sustainable investment seeks to support sustainable economic development, enhance quality of life and safeguard the environment.

Sustainable equity
Sustainable equity refers to broad multi-themed listed equity companies that generate a substantial proportion (typically more than 25%) of their earnings through sustainable activities. Sustainable activities at the broadest level are those that seek to support sustainable economic development, enhancing quality of life and safeguarding the environment.

Technology risk factor
In this study, the technology risk factor is defined as the T of the TIP™ framework, meaning the rate of progress and investment flows into technology related to low-carbon and energy efficiency.

WITCH model
The WITCH (World Induced Technical Change Hybrid) model is one of the main modelling tools developed within the Climate Change Modelling and Policy Research Programme of the Fondazione Eni Enrico Mattei. Grantham LSE/Vivid Economics used this model to estimate the macroeconomic impacts of mitigation costs, adaptation costs and residual damage costs for the Stern Action and Climate Breakdown scenarios, describing it as a “top down” model that has considerable technological detail.

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