

Risk metrics for climate change

Climate change risk monitoring: Which metrics and why?

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Firms are increasingly required to focus on the management of climate change risks by their regulators, whilst wider engagement and awareness in the economy and by the general public is continuing to drive the emergence of transition risks. This white paper aims to explore what metrics are most useful to insurance companies when considering the risks and impacts of climate change.

This white paper will consider regulatory activities, current market practice and metrics for monitoring life and health insurance risks, general insurance risks, and risks to asset values.

Background

REGULATORY AND ADVISOR ACTIVITIES

The European Insurance and Occupational Pensions Authority (EIOPA), the G20-supported Task Force on Climate-related Financial Disclosures (TCFD) and the United Kingdom's Prudential Regulation Authority (PRA) have all published various papers and statements aiming to encourage companies to disclose the impact of climate change on their business. This emphasis is felt across the board, with regulators aiming to ensure that both firms and individuals are able to take into account the risks of climate change when making financial decisions.

Within the paper "Opinion on Sustainability Within Solvency II"¹ released in September 2019, EIOPA responds to a request from the European Commission to integrate climate-related developments into the scope of the Solvency II framework, and also present the findings of its public call for evidence. The call

for evidence was conducted between January and March 2019, and found that at least one firm was developing a "Climate Value at Risk (VaR)" metric to test the impact of climate risks and opportunities under various scenarios. The firm stated that it planned to consider the output of this model within its Own Risk and Solvency Assessment (ORSA) and economic capital model in the future. Respondents also indicated that environmental, social and governance (ESG) criteria monitoring is carried out with respect to investment management, with firms using external ESG metrics to inform investment strategy, and ESG committees setting target tools to manage and monitor sustainability risks.

However, EIOPA's survey also revealed that difficulties associated with monitoring climate change risks are a "main obstacle" for firms wishing to invest sustainably, given that risks arise from changes to migration and impacts on health and biodiversity. Work is particularly required with respect to transition risks, given that many firms "cannot specify to what extent this (transition risk) would affect their portfolio." Transition risk is the risk associated with transitioning to a lower carbon economy, or helping the world to adapt, or to mitigate the effects of climate change².

A more recent paper published by the EIOPA, the "Discussion Paper on methodological principles of insurance stress testing,"³ invites firms to provide their views on appropriate metrics to assess transition risks in assets' as well as the required level of 'granularity'. The consultation period closed in October 2019 and feedback from respondents is outlined within the paper "Methodological principles of insurance stress testing – Comments and Resolutions."⁴ Respondents suggested that appropriate metrics to monitor could include a shock to investment returns depending on the sensitivity of the underlying asset to climate risk impacts, or use of existing market metrics. Two respondents specified that they did not think separate metrics were necessary, given that the risk of shocks to market values are already reflected in existing, more severe, stress testing.

¹ EIOPA (30 September 2019). Opinion on Sustainability Within Solvency II. Retrieved from https://www.eiopa.europa.eu/sites/default/files/publications/opinions/2019-09-30_opinionsustainabilitywithinsolvencyii.pdf.

² IFOA Climate change working party (25 March 2019). Climate Change for Actuaries: An Introduction, p. 5. Retrieved from <https://www.actuaries.org.uk/practice-areas/resource-and-environment/research-working-parties/climate-change-working-party/>

³ EIOPA (22 July 2019). EIOPA publishes Discussion Paper on Methodological Principles of Insurance Stress Testing. Retrieved from https://www.eiopa.europa.eu/content/eiopa-publishes-discussion-paper-methodological-principles-insurance-stress-testing_en.

⁴ EIOPA (4 December 2019). Methodological Principles of Insurance Stress Testing - Comments and Resolutions. Retrieved from <https://www.eiopa.europa.eu/sites/default/files/publications/consultations/stress-test-methodological-principles-comments-andresolutions.pdf>.

The PRA’s supervisory statement of 2019⁵ asks firms to consider quantitative and qualitative metrics in order to monitor their exposure to climate change risks and "to monitor progress against their overall business strategy and risk appetite." The paper emphasises that these metrics should be used by a firm’s board to aid decision making and should be updated regularly. The PRA appreciates that metrics used in this light are something that will "evolve and mature" with experience. Some examples of areas where metrics might be useful are in monitoring climate exposures resulting from changes to investment portfolios and in monitoring the impact of physical risks on outsourcing and supply chains. Physical climate change risks relate to specific weather events (e.g. heatwaves, floods and storms) and longer-term shifts in the climate (e.g. precipitation patterns, sea level rise and rising mean temperatures).

However, the approach by the TCFD in its 2017 report, "Recommendations of the Task Force on Climate-related Financial Disclosures"⁶ is more direct in offering guidance. "Metrics and Targets" are one of four core elements of recommended climate-related financial disclosures set out by the TCFD. Investors and stakeholders, it argues, need to appreciate how a firm measures and monitors both the risks and opportunities presented by climate change. Benefits of the disclosure of this information are that outsiders can:

- More effectively assess a firm’s risk-adjusted returns
- Understand a firm’s exposure to climate issues
- Appreciate a firm’s advances in managing climate issues
- Benchmark firms against one another

The TCFD guidance suggests three recommended disclosures under its "Metrics and Targets" element. First, firms should disclose the metrics used to assess climate risks and opportunities, and they should be aligned with the company strategy and risk management processes. The paper outlines a number of potential risks and opportunities which might need to be covered by these metrics. Risks include changing customer behaviour, exposure to litigation or policy changes, costs of transition to lower emissions technology, reputational issues, increased severity of weather events and rising sea and temperature levels. Examples of opportunities that may need to be covered by metrics include increased efficiency, use of new technology and energy sources, development of climate adaptation and insurance risk solutions and access to new markets and assets. The insurance section of the

"Supplemental Guidance for the Financial Sector"⁷ from the TCFD states that insurance companies should also provide annual aggregated expected losses from weather-related catastrophes for their property business, by geographical area.

Second, disclosure should cover the firms’ greenhouse gas emissions. The purpose of emission metrics is to indicate those firms that have higher emissions and are therefore likely to be more impacted by transition risks.

Finally, firms should describe their climate-related targets used and their performance against such targets. The timeframe for which the target applies should be considered, as should the year from which any progress against the target is measured and the performance indicators that will be used to measure progress.

The TCFD states that it believes that any material information on metrics and targets should be disclosed within annual financial filings. It also says that one of its key areas for further work will be in developing standardised metrics for the financial sector.

In the "TCFD Recommendations Report Annex"⁸ the TCFD suggests specific carbon-related metrics that can be used to assess the carbon exposure of an asset portfolio. The paper offers descriptions, formulae and methodology for each metric suggested. Metrics include a weighted average carbon intensity, carbon footprint, exposure to carbon-related assets and carbon intensity. Appendix 1 of this TCFD report also offers some examples of potential climate impacts by financial category; for example it examines potential climate impacts and metrics in areas such as operational expenditure ("OpEx") and capital expenditure ("CapEx"), tangible and intangible assets and revenue. Example metrics offered by the TCFD are outlined in Figure 1.

FIGURE 1: EXAMPLE METRICS DESCRIBED IN TCFD RECOMMENDATIONS ANNEX, APPENDIX 1

FINANCIAL METRIC	CLIMATE -RELATED IMPACT	EXAMPLE METRIC
Tangible Assets	Change in value of assets based on emissions, energy or water intensity	Value, and percentage by value, of assets located in coastal or flood zones
Assets: CapEx	Increase in CapEx in equipment or technologies to manage transition risk	Percentage of CapEx allocated to low-carbon or renewable assets, deployment of low-carbon technology, efficiency of facilities
Liabilities	Increase in legal liability for climate-related risks	Amount reserved for pending legal actions

⁵ PRA (April 2019). SS3/19: Enhancing Banks’ and Insurers’ Approaches to Managing the Financial Risks From Climate Change. Retrieved from <https://www.bankofengland.co.uk/-/media/boe/files/prudential-regulation/supervisory-statement/2019/ss319>.

⁶ TCFD (June 2017). Final Report: Recommendations of the Task Force on Climate-related Financial Disclosures. Retrieved from <https://www.fsb-tcfid.org/wp-content/uploads/2017/06/FINAL-2017-TCFD-Report-11052018.pdf>.

⁷ TCFD (June 2017). Annex D: Supplemental Guidance for the Financial Sector. Implementing the Recommendations of the Task Force on Climate-related Financial Disclosures. Retrieved from <https://www.tcfidhub.org/Downloads/pdfs/E20%20More%20information%20on%20supplemental%20guidance%20for%20the%20financial%20sector.pdf>.

⁸ TCFD (June 2017). Annex: Implementing the Recommendations of the TCFD. Retrieved from <https://www.fsb-tcfid.org/publications/final-implementing-tcfid-recommendations/>.

Whilst the metrics aren't specifically all relevant to insurance firms, they do provide some good examples of how firms can link known financial categories to climate impacts and then to metrics. In some areas, for example changes in intangible assets such as brand value or reputation, the TCFD report does not offer any example metrics. This most likely reflects the lack of measurability in these softer, less tangible, areas.

In summary, although the PRA and EIOPA strongly recommend disclosures from companies regarding the impact of climate change on their business, these guidelines do not always provide specific recommendations as to what metrics companies should monitor or disclose. This report intends to bridge the gap between the regulatory and advisory body requirements and specific metrics that firms could use to monitor the impact of climate change on their business.

CURRENT MARKET PRACTICE

In order to assess where firms are on their journeys in monitoring climate risks and disclosing climate-related risk metrics, we have done a brief survey of publicly available information released by insurance firms with respect to climate change metrics.

We assessed public information for 13 life firms, 10 health firms and 17 property and casualty (P&C) firms, primarily based within the United Kingdom. Information covered included TCFD disclosures, annual reports, Solvency and Financial Condition Reports (SFCRs) and any other climate change-related documents released online. The majority of companies disclosed minimal information on their climate-related risks and opportunities, and generally disclosed no information on climate risk metrics or the types of risk metrics they are monitoring. As one might expect, this indicates that firms are at early maturity in terms of disclosing financial risks of climate change. We would expect to see more disclosure and public reporting in the future in light of the broad regulatory emphasis on disclosure of risks.

Some of the larger companies have TCFD disclosures published on their websites; for example, L&G, Aviva, AXA and AIG have published dedicated TCFD reports. Other firms have published similar types of documents, covering their approaches to sustainability and climate change risks, but these documents don't typically cover specific metrics. Where metrics are disclosed in TCFD reports, they are often limited to those defined by the TCFD, and therefore primarily relate to carbon exposures of either the company or the company's asset portfolio. Publicly disclosed metrics within TCFD reports studied include:

- Carbon emission intensity (tonnes of carbon dioxide per £1 million invested) by asset class
- Company operational carbon emissions

- Investment in low carbon assets, such as low carbon infrastructure or green bonds
- Revenue generated from sustainable solutions
- Fossil fuel reserves
- ClimateWise score⁹
- Climate VaR¹⁰
- Weather-related losses for insurance liabilities
- Target CO₂ reduction required to meet the Paris agreement's 2-degree Celsius pathway¹¹

It should be noted that metrics disclosed by firms won't typically be the same as those that they monitor internally as part of a wider risk framework. In the next section of this report, we look at some metrics that might be relevant to firms.

Climate change metrics

WHERE TO START?

Which risk metrics are appropriate for a firm to monitor? The answer relies upon certain other aspects of a firm's risk management framework being developed in tandem. These supporting components broadly consist of:

1. Being able to articulate where climate change risks touch your business: identifying climate change **risk exposures**. Once understood, metrics assessing the extent of the risk exposure can be monitored.
2. Producing engaging narratives covering routes through which these risks could manifest: identifying plausible climate change **risk scenarios**. Through building an understanding of where risks can arise, it is possible to begin to understand the drivers of risks that cause issues if crystallised. Once understood, metrics for these drivers can be monitored. Additionally, firms can monitor metrics which assess the impact of the risk once crystallised.
3. Defining which outcomes matter to the business: selecting the scenarios that are sufficiently severe to fall outside climate change **risk tolerance**. This helps define which metrics it is most important to monitor, by excluding less material risks.

The following sections identify plausible risk exposures and scenarios which lead to climate change risks causing severe issues for insurance firms. The examples cover climate change risks that firms might typically be exposed to, but are illustrative and intended to be broadly applicable, given that each individual firm will have a unique climate risk profile. The content of this research report is not product-specific and aims to cover life, health and general insurance lines of business.

⁹ The ClimateWise Principles provide a framework for the insurance industry to disclose climate-related risk and opportunities. A ClimateWise score is calculated for participating firms and members are scored on the evidence they provide to demonstrate that they comply with the ClimateWise Principles.

¹⁰ In development by Aviva.

¹¹ United Nations Climate Change. What Is the Paris Agreement? Retrieved from <https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement>.

GENERAL PRINCIPLES

There are a number of general principles worth highlighting when identifying and discussing appropriate climate risk metrics. Given the unique nature of climate risks, these principles are somewhat different from those used for other types of risk metrics.

First, historical data is rarely relevant: metrics must be forward-looking in order to capture the evolving nature of climate risks. As natural catastrophes become increasingly frequent and severe, past data will be insufficient in identifying or assessing future risks. Similarly, transition risks will rapidly evolve as attitudes of policy makers, investors and customers change. This forward-looking requirement will lead to the employment of new and novel techniques and increased use of expert judgement.

Second, time horizons matter. Where possible, metrics should reflect estimation of risks over different time horizons to reflect the long-term nature of climate risks, and how these risks will change over time. For example, metrics and scenarios might want to attempt to assess the risk level within one year, five years, 10 years, and beyond.

Finally, given that climate change is an emerging risk and one where best practice with respect to risk management is developing, many metrics are initially likely to have a “red” status (if using a red/amber/green system to define whether a risk is currently within risk appetite). Firms should then define a set of actions which enable them to transition from the current metric to the point at which the metric status becomes “green.” Additionally, it is important that firms recognise, and ideally disclose, the limitations of their metrics. This will allow firms to appreciate the extent to which decision making should be based upon the metrics, as well as to refine the metrics in the future.

RISKS TO ASSETS AND INVESTMENTS

Risk exposures

As discussed above, the first step is to identify the risk exposures posed by climate change. On the asset side, the risks most relevant to insurance firms are:

- The risk of a decline in asset values. As an example, there is the risk of a decline in the value of shares in utility companies or the income yield associated with owning them. This could occur as the economy transitions towards becoming low-carbon and green alternatives become prevalent. Proximate risks are primarily transition-based, although in the longer term physical risks will be applicable to certain types of assets, such as property.

- In the more extreme scenario, assets could become “stranded.” In other words, some assets could become obsolete because they no longer have value or no longer yield income, due to external climate-related factors. Specific future climate-related examples include oil and gas resources held in reserve, which may not be extracted in the future as external pressures or climate consciousness prevent it. Similarly, infrastructure investments could become obsolete if they are usurped by new, green technologies.

Therefore, the first metric worth monitoring is the extent to which assets held within an insurer’s portfolio are at risk of being stranded or at risk of value erosion. An obvious first point of call here would be to assess the carbon intensity of each asset in the portfolio, in order to identify carbon-intensive industries which are most likely to be unviable in the long term, should green alternatives prevail. In order to calculate such a metric, a firm would need to obtain data on the carbon intensity of particular sectors or companies within its bond and equity portfolios, which it can then weight by the proportion of its portfolio invested in each particular sector or company.

External providers of ratings for equities and corporate bonds can be useful in providing data or ratings in this context. Some providers and metrics that insurers are using are outlined in Figure 2. Figure 3 covers AXA as a specific case study.

FIGURE 2: EXAMPLE DATA SOURCES OR PROVIDERS USED TO MEASURE CLIMATE CHANGE EXPOSURE IN ASSET PORTFOLIOS

COMPANY	METRIC	DATA PROVIDER OR PARTNER	DESCRIPTION
AXA ¹²	Carbon intensity	Beyond Ratings	Carbon footprint, expressed in tonnes of equivalent CO2/gross domestic product (“GDP”), for sovereign debt.
Legal & General ¹³	Total Carbon Footprint	Trucost ESG Analysis (S&P Global) and Bloomberg	Carbon footprint of Legal & General’s portfolio, expressed in tonnes of equivalent CO2 per £1 million of revenues.
Aviva ¹⁴	Alignment of investment portfolio to the International Energy Agency’s 2-degree Celsius scenario level	Paris Agreement Capital Transition Assessment (PACTA) model developed by 2Degrees Investing Initiative	Assesses extent to which the utilities sector exposure of Aviva’s corporate credit and equities funds are aligned to the 2-degree Celsius climate warming trajectory target by 2023.

¹² AXA (June 2019). 2019 Climate Report, p. 17. Retrieved from https://www-axa-com.cdn.axa-contento-118412.eu/www-axa-com%2F667045c2-cc3c-4f65-a888-18753c463d9c_axa2019_ra_en_climate_report_2.pdf.

¹³ Legal & General. TCFD Report 2018, p. 29. Retrieved from <https://www.legalandgeneralgroup.com/media/2959/tcf-final-mar2019.pdf>.

¹⁴ Aviva. Climate-Related Financial Disclosure: Aviva’s 2018 Climate-Related Financial Disclosure, p. 12. Retrieved from <https://www.aviva.com/social-purpose/climate-related-financial-disclosure/>.

FIGURE 3: HOW DOES A LEADING INSURER MEASURE CARBON INTENSITY OF ASSETS?

In AXA's 2019 Climate Report,¹⁵ the company reveals that it has collaborated with various data partners to help create a dashboard of climate key performance indicators (KPIs) by asset class. For example, AXA has worked with the Swiss environmental Fintech firm Carbon Delta on climate risk to provide a selection of metrics relating to corporate bonds and equity assets. One particular example is the "Warming Potential" metric, which calculates a "contribution to global warming, expressed in temperature," for a given asset class. Through expressing this metric as a temperature, AXA, with the help of Carbon Delta, is actively trying to increase insight into what a "Paris-aligned" investment portfolio should look like, bearing the 2-degree Celsius limit set out by the agreement in mind.

At a high level, the Warming Potential methodology aims to use top-down data such as the country-level Paris Agreement commitments and bottom-up company-level economic and sector data. The metric combines the following approaches:

- A "sector-specific" approach taking into account the regulatory perspective of a country's economic sectors. For example, carbon-intensive industries such as utilities, which are nonetheless key to the working of an economy, are given a bigger share of the "2-degree Celsius-compliant" carbon budget than other less carbon-intensive sectors.
- A "sector-agnostic" approach, which is based on an absolute emissions intensity view, regardless of the sector or the functioning of an economy. This approach rewards companies performing well, irrespective of the sectors in which they operate.
- Taking into account green patents issued by companies, as an indicator of those firms which are developing the green technologies needed to transition.

As a result, Carbon Delta provides a Warming Potential metric for AXA that takes into account both absolute and sector-relative contributions to climate warming. The key benefit of the approach is that it recognises sector contributions to climate transition, as well as company-specific progress on reducing emissions.

¹⁵ AXA 2019 Climate Report, op cit.

Whilst use of such metrics is a key first step in understanding a current portfolio's exposure, making investment decisions, and monitoring the evolving portfolio going forward, such metrics sometimes do provide a simplistic view of the world. Limitations include the fact that the metrics do not cover monitoring of the drivers of potential decline in asset values (covered in the next section), nor do they convey factors beyond the current carbon intensity of the industry. For example, a company which might appear a poor investment from a carbon perspective could still be a viable long-term investment, if it transitions its business from carbon-intensive products to green and sustainable products. As an example, energy companies that start to transition to producing renewable energy could be viable long-term investments if they transition successfully and at the appropriate time.

There are a number of areas firms can begin to think about that should allow them to progress to more sophisticated types of metrics and monitoring of their asset portfolios. Some ideas and examples are outlined below.

- Assessing the extent to which firms are developing new technologies, products and processes to facilitate transition. Examples could include the number of green patents approved, or the volume of investment in new and green technologies. These types of metrics should help identify those firms within a sector that are making genuine progress towards, and commitment to, transition.
- Looking at sector-specific or country-specific climate-related factors. For example, assessing banks with significant counterparty exposure to industrialised agriculture may yield a clearer understanding of the climate sensitivity of an asset portfolio. Such analysis could also investigate the potential credit risk of sovereign debt for countries that rely heavily on natural resources, including major mining operations.
- Considering interrelationships among sectors. For example, whilst sectors such as utilities, transport and mining are typically carbon-intensive, it is worth appreciating their criticality within society (in the absence of green alternatives) as well as within supply chains for products viewed as "green." Therefore, firms may want to assess the companies within a particular industry that are most robust from a climate risk perspective. This could be achieved through monitoring factors such as those outlined above, or comparing firms to identify factors which make a particular company stand out with respect to managing climate risks.

Risk scenarios

Assessing plausible climate risk scenarios can help provide a context within which to analyse risk exposures, and identify the key drivers of risk worth monitoring.

Looking at the example in which a disorderly transition occurs, its impacts on assets values could be driven by a number of key factors, outlined further below. The Bank of England in its 2021 biennial exploratory scenario (“BES”) report¹⁶ defines such a scenario as a “late policy action scenario, where the global climate goal is met but the transition is delayed and must be more severe to compensate for the late start.” Under such a scenario, action to address climate change is delayed by 10 years, resulting in a greater increase in carbon prices in order to meet climate targets. Behaviour is adjusted in response, but this results in significant impacts on asset prices leading to a macroeconomic shock. Therefore, in such a scenario, physical risks occur quickly and transition risks are severe.

Having identified the extent to which the asset portfolio is exposed to the transition risks of climate change, more sophisticated risk monitoring would then assess the extent to which there are changes in the drivers of asset transition risks, to identify tipping points at which assets might become too risky (i.e., outside of risk tolerance and particularly vulnerable to losses in value). Drivers of asset transition risks may include:

- Regulatory changes. These changes could provide new incentives to buy green alternatives (e.g., subsidies for greener energy sources or travel methods) and therefore divert demand away from current products. Alternatively, regulatory changes could provide a disincentive to use products that are currently carbon-intensive.
- Changes to investor sentiment regarding the future profitability of a company.
- Changes to consumer sentiment toward a company or product.

These types of drivers are particularly hard to condense into single metrics. Moreover, they are particularly prone to changing rapidly, given that changes in perceptions might rapidly alter market participant behaviour. Monitoring of such areas might focus less on particular risk metrics and more on softer qualitative analysis, expert judgement and alternative monitoring techniques. Indeed, the PRA points to use of qualitative tools and metrics as well as quantitative metrics in supervisory statement 3/19.¹⁷

For example, when assessing likely regulatory changes, monitoring may focus on current messaging from governments, political parties and other regulatory bodies. As an example, the EU’s Green Deal¹⁸ gives an indication of the direction European policy makers are heading with respect to climate and environmental policy.

It is then worth examining the extreme opposite scenario, in which there is minimal transition and therefore the resulting physical impacts experienced by the world are high. The BES report defines this type of scenario as a “no additional policy action scenario, where no policy action beyond that which has already been announced is delivered. Therefore, the transition is insufficient for the world to meet its climate goal.” In this scenario the BES paper assumes that companies and consumers do not change their behaviour and so emissions are not reduced. Therefore, chronic changes in weather and more extreme and frequent weather events are experienced. These changes include rising sea levels, flash floods and significant increases in global average temperatures by 2080.

In terms of assets, the main asset class to be affected in this area is property, although other infrastructure assets could also be affected. Such assets are vulnerable to extreme climate impacts; in particular, property valuations are likely to be impacted by increased physical risks such as flooding. Increased flooding risk arises as climate change causes more rainfall within short periods, as well as resulting in rising sea levels. Equities and bonds held by insurers could be indirectly affected if company business locations or assets become affected by these impacts.

To assess the extent of the risk posed by the current asset portfolio, firms should measure their exposure to physical assets affected by physical climate change risks, by calculating the exposure to such assets as a percentage of the total asset portfolio. Further exposure metrics can be developed such as distribution of property portfolio by geographical area, distribution of property by flood risk category or percentage of property in coastal areas. A red/amber/green (RAG) status could be assigned to each geographical area based upon the risk of flooding in each future time period.

The Intergovernmental Panel on Climate Change (IPCC) provides projections of future global rainfall levels, with the UK expecting to experience 10% more¹⁹ average annual rainfall by 2100.²⁰ Such projections can be used to estimate future risk of inland flooding by geographical area and therefore assign a risk rating to property within asset portfolios. Similar risk ratings can be applied using sea level projections to assess risk in coastal areas. Typically, the risk of inland flooding is combined with an assessment of coastal flooding from windstorms to obtain a combined flood risk metric.

Use of catastrophe models may be helpful in studying scenarios and simulations of extreme rainfall in short time periods.

¹⁶ Bank of England (18 December 2019). The 2021 Biennial Exploratory Scenario on the Financial Risks From Climate Change: A Discussion Paper. Retrieved from <https://www.bankofengland.co.uk/paper/2019/biennial-exploratory-scenario-climate-change-discussion-paper>.

¹⁷ PRA SS3/19, op cit.

¹⁸ European Commission. A European Green Deal. Retrieved from https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.

¹⁹ Compared to 1986 to 2005.

²⁰ IPCC. AR5 Synthesis Report: Climate Change 2014. Retrieved from <https://www.ipcc.ch/report/ar5/syr/>.

Metrics could also cover the extent of diversification among regions of different physical risk within the portfolio, to identify whether risk is being mitigated this way.

Physical impacts and metrics under a minimal transition scenario are explored further within the general insurance liability section later in this paper.

LIABILITY RISKS (LIFE AND HEALTH)

Risk exposures

The main areas in which climate change will impact the liability best estimate calculations of life and health insurers are mortality and morbidity rates. In the medium to longer term, as severe weather events become more frequent and extreme temperatures commonplace, an increase in sickness and storm-related accidents (and therefore death rates), alongside injury and acute health condition rates, can be expected to arise.

Metrics that could be useful in terms of assessing exposure to an increase in mortality and morbidity are those that assess the profile of the current and future book of business. Useful metrics can be based on information which is currently available; some examples are included in Figure 4.

FIGURE 4: EXAMPLE METRICS USED TO MEASURE RISK EXPOSURE IN LIABILITY (LIFE AND HEALTH) PORTFOLIOS

METRIC	DESCRIPTION/COMMENTS
Composition of book by age	Distribution of book in certain age bands will highlight vulnerability of book to increased climate-related mortality and morbidity. Temperature-related mortality risks are typically more pronounced at low and high ages. For long-term business, future composition of book can be constructed by examining age composition of current book at future time points, alongside expected age profile of new business written.
Composition of book by geography	Distribution of book by territory or state in order to indicate the proportion of policyholders based in areas that are at more risk of climate-related extreme weather events. To complement this metric, data is required on relative vulnerability of covered geographies to climate-related risks.
Identifying and monitoring high-risk individuals	Policyholders with health conditions, particularly comorbidities, will be at higher risks from extreme temperature fluctuations.
Composition of book by occupation	Rising heat and irregular weather patterns would affect certain industries more than others, such as agriculture, tourism and sports. Also, transition measures may reduce the need for oil workers, pilots and others. Finally, hazards may increase income replacement claims or lapses due to premiums becoming unaffordable.
Composition of book by product type	Annuities and pure endowment products could experience higher (i.e., more favourable) mortality rates due to climate change.

Risk scenarios

The relevant scenario here is the one in which there is minimal transition and therefore the resulting physical impacts experienced by the world are high. If transition is successful, we would expect the adverse impacts on current mortality and morbidity rates to be closer to minimal.

The metric of interest to firms under this scenario is the increase in mortality or morbidity rates under various temperature projections. This information then allows firms to stress-test their current (or expected future) portfolios to obtain the estimated impact on financial metrics as a result of climate-related changes in mortality and morbidity at various future points.

An outline of how a firm could approach the testing and monitoring of climate-related mortality or morbidity risks is shown in Figure 5.

FIGURE 5: MONITORING OF CLIMATE CHANGE-RELATED MORTALITY AND MORBIDITY RISKS

STEP	APPROACH	MONITORING / METRIC
1	Understand relationship between extreme temperatures and mortality/morbidity rates.	Empirical studies covering changes in mortality rates and/or various morbidity rates at extreme temperatures.
2	Stress and scenario testing of increased mortality/morbidity rates under various temperature projections, and over various timeframes.	- Increase in claims cost under stress - Change in Technical Provisions, Own Funds, and Economic Capital under stress.
3	Monitoring of temperature changes over time.	- Average temperatures, by geography - Extreme temperature incidence - Future temperature projections
4	Testing of approach: would risk metrics monitored have spotted crystallisation of stress scenarios? → Refine and update.	Feedback into steps 1, 2 and 3

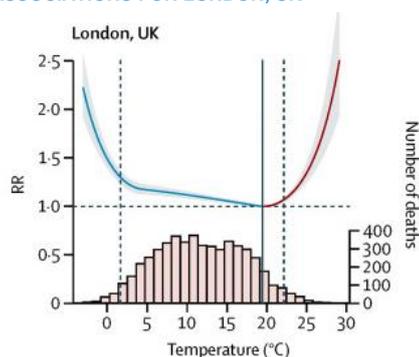
In order to understand the relationship between temperature and health, and monitor the increase in future claim costs as a result of climate change, data is required linking future average temperatures with mortality and morbidity rates.

Mortality

A number of empirical studies have been performed and are available for firms to utilise in order to link extreme temperatures and incidence of increased deaths. For example, a US study by Deschênes and Greenstone²¹ estimates that by the end of the century climate change will lead to increases of 3% in the age-adjusted mortality rate.

A Lancet study, "Mortality risk attributable to high and low ambient temperature: a multicountry observational study,"²² covers temperature-mortality associations across a wide temperature range for a number of countries.²³ The study found that risk increases slowly and linearly for cold temperatures, whereas risk escalated quickly and nonlinearly at high temperatures. As an example, Figure 6²⁴ shows the London exposure-response associations, with related temperature distributions. The distributions of deaths by temperature are shown by the bars (and right-hand side axis) whilst the relative risk (RR) at each temperature is measured by the left-hand side axis. The study showed that temperature is responsible for advancing 8.78% of deaths in the UK.

FIGURE 6: OVERALL CUMULATIVE EXPOSURE-RESPONSE ASSOCIATIONS FOR LONDON, UK



Source: Mortality risk attributable to high and low ambient temperature: A multicountry observational study.

The limitation of these types of studies is often that they tend to use and analyse historical data. However, to the extent that the historical data is available linking death rates at extreme temperatures, this data can be extrapolated to link projected increases in temperature to future potential changes in mortality rates. However, the temperature-mortality relationship is not necessarily linear, whilst impacts are likely to vary by geography and between populations because of adaptation and acclimatisation effects.

²¹ Deschênes, O. & Greenstone, M. (1 October 2011). Climate Change, Mortality, and Adaptation: Evidence from Annual Fluctuations in Weather in the US. Brookings. Retrieved from <https://www.brookings.edu/articles/climate-change-mortality-and-adaptation-evidence-from-annual-fluctuations-in-weather-in-the-u-s/>.

²² Gasparrini et al. (20 May 2015). Mortality risk attributable to high and low ambient temperature: A multicountry observational study. Lancet; Vol 386. Retrieved from [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(14\)62114-0/fulltext](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(14)62114-0/fulltext).

²³ Australia, Brazil, Canada, China, Italy, Japan, South Korea, Spain, Sweden, Thailand, UK and US.

²⁴ Solid grey lines are minimum mortality temperatures and dashed grey lines are the 2.5th and 97.5th percentiles. "RR" is relative risk.

²⁵ The IPCC has identified potential future temperature paths. See <https://www.ipcc.ch/report/ar5/syr/>.

²⁶ British Heart Foundation. Practical Support. Retrieved from <https://www.bhf.org.uk/informationsupport/support/practical-support>.

Firms may want to ensure that they continue to review the results of such studies over time, as more analysis in this area becomes available.

Once links have been made between temperature changes and mortality rates, and stress tests performed at various temperature projections,²⁵ then metrics can be used as indicators of the emergence and progression of the risk. This could involve monitoring metrics which record the progression of temperature over time, and the expected projection of temperatures in the future.

Morbidity

Morbidity risks will vary by health condition. A key focus in morbidity metrics will be to develop an understanding of the relationships between climate-driven events, such as extreme temperatures, air pollution levels, and weather events, and various health conditions.

Insurers should identify and monitor health conditions that would contribute significantly to overall claims experience. Insurers face the risk that the impacts of climate change may result in claims occurring earlier, and potentially with more severe conditions, than if there were no extreme climate scenario. Such trends would lead to increases in claim frequency as well as increases in the severity of health conditions, leading to higher claim costs.

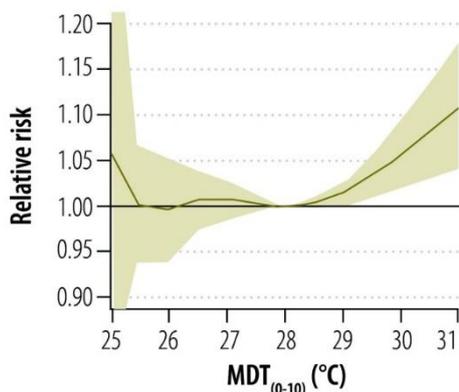
Illustrative examples in Figure 7 consider health conditions which may flare in extreme weather.

FIGURE 7: MONITORING OF CLIMATE-RELATED MORBIDITY RISKS

HEALTH CONDITION	RISK DRIVER
Heart disease	Heart disease is exacerbated in significantly warmer and colder weather. Research indicates dramatic changes in temperature may also increase heart attack rates. ²⁶
Respiratory conditions	High temperatures can raise the levels of ozone and other pollutants.
Cancer conditions	Exposure to increased heat from hotter weather, or reduced air quality, may increase the rate of some cancers within a population.
Infectious diseases	Higher levels of waterborne disease spread through flood risk, malaria zones spreading to places which have become hotter.
Diagnostic services	Frequency of chronic conditions increase, e.g., asthma due to air quality, increasing diagnostic services use even if treatment of condition is not covered.
Mental health	Impact of natural disasters on a policyholder's environment may cause additional stress, e.g., having to move due to flood risk.

The study "Hospital admissions as a function of temperature, other weather phenomena and pollution levels in an urban setting in China,"²⁷ which looks at the region of Hong Kong, has used 10 years of data to look at patterns in temperature-related hospital admission rates for respiratory and infectious diseases as well as cardiovascular disease. The study found that, during a hot season, hospital admissions increased by 4.5% for every 1°C increase above 29°C, and during a cold season, hospital admissions increased by 1.4% for every decrease of 1°C within the range of 8.2 to 26.9°C.

FIGURE 8: RELATIVE RISK OF HOSPITALISATION AS A FUNCTION OF MEAN DAILY TEMPERATURE LAGGED BY 0 TO 10 DAYS ($MDT_{(0-10)}$) WITHIN HONG KONG



Source: Hospital admissions as a function of temperature, other weather phenomena and pollution levels in an urban setting in China.

This study illustrates impacts that may translate to meaningful measures for private medical insurance (PMI) insurers. Similar metrics for an insurer's relevant region can provide a starting point for measuring the impact of climate change for health insurers, with consideration to limitations mentioned on such studies earlier.

Metrics to measure the impact of climate change scenarios, such as extreme weather and rising global temperatures, will need to be specific to each health condition or service type, and look at the likely changes in the persistency rate for each health condition, linking them to claim frequency, claim severity or both.

Data on individuals' chronic conditions would be important to help determine the risk to an insurer due to changes in a particular risk driver. For example, insurers will need to know how many asthmatics are in their portfolios to be able to estimate the impact of increased pollution from high temperatures. Given the level of data insurers hold, it is unlikely this level of information is available for the purposes of climate change modelling, and assumptions based on a general population may need to be made.

Whilst PMI products are typically short-term policies, to effectively incorporate climate change modelling into business strategy, projecting over a longer term will be important.

Monitoring both mortality and morbidity conditions should entail reviewing past projections and analysing any changes to key assumptions and metrics. These may indicate a changing pattern and potentially a need to update metrics used in Step 1 of Figure 7 above.

Insurers should consider checking for the emergence of new scientific research which could form the basis of further metrics, and can be incorporated into step 2 of Figure 5. As climate change modelling grows, there are likely to be increasingly sophisticated sources of information that will be valuable for these purposes.

INSURANCE RISKS (GENERAL INSURANCE)

Risk exposures

Climate change will mainly impact the liability best estimate calculations of general insurers through higher claim costs. General insurers who write property insurance are exposed to the risk that the frequency or severity of extreme weather events increases as global temperatures continue to rise, resulting in a greater amount of physical damage to properties from floods and storms. Similarly, insurers that write crop insurance are exposed to the risk that severe weather events, such as floods or droughts, will result in greater physical damage to crops and hence reduced revenue for the producer.

Additionally, general insurers may provide environmental liability coverage for companies that are at risk of causing environmental damage. These policies typically cover the cost of repairing damage to the environment. As climate change effects become more severe, companies that are thought to be compounding this, such as oil companies, are more likely to have a greater number of claims made against them, and for larger amounts, resulting in higher claim costs for those insurers covering them.

Similarly to life and health risk, metrics which could be useful in terms of assessing exposure to an increase in claim costs are those that assess the profile of the current and future book of business, so that insurers can monitor the exposure to any potential large losses or accumulation of risks. Some examples are included in Figure 9.

²⁷ Chan, E.Y., Goggins, W.B., Yue, J.S., & Lee, P. (1 August 2013). Hospital admissions as a function of temperature, other weather phenomena and pollution levels in an urban setting in China. Bull World Health Organ. Retrieved from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3738307/>.

FIGURE 9: EXAMPLE METRICS USED TO MEASURE RISK EXPOSURE IN GENERAL INSURANCE (GENERAL) PORTFOLIOS

Composition of book by geography	Distribution of book by territory or state in order to indicate the proportion of properties based in areas which are at more risk of climate-related extreme weather events. To complement this, data is required on the size of recent losses due to severe weather events in each of the territories or states where business is written. Information is also required on the effects of any mitigation in place (e.g., flood defences).
Composition of book by company type	Distribution of book by company type in order to indicate the proportion of companies that may be exposed to higher risks of causing environmental damage, which leads to further climate change. To complement this, information is required on how these firms are mitigating their potential risks.
Composition of book by product type	Distribution of book by product type, as some products sold by general insurance companies are more exposed to the effects of climate change (e.g., property insurance).

Risk scenarios

The relevant scenarios here are where there is minimal transition and therefore the resulting physical impacts experienced by the world are high.

The metric of interest to firms under this scenario is the increase in claim costs under various weather-related projections.

Firms could use commercially available or bespoke catastrophe models, which simulate thousands of years of plausible potential events applied against a portfolio of properties, to assess the effect that climate change has on their portfolios. With more data emerging on the effects of climate change, firms could use modified models to consider future trends and allow for different scenarios in their catastrophe modelling. Various scenarios firms could consider include:

- An increase in the global average temperature.
- An increase in the global average rainfall.
- An increase in the peak wind speed of storms.
- An increase in the intensity of hurricanes.

Both the leading commercial catastrophe modellers and specialist climate science firms are making progress on adapting simulations that reflect alternative climate assumptions to underpin their frequency and severity distributions at highly local levels.

A key issue for firms, when assessing the different scenarios noted above, is to try to identify how much more frequent the most severe events could become. For example, as a result of the impact of climate change, does a 1-in-200-year event (i.e., an event with a 0.5% probability of occurring each simulated year) now become a 1-in-20-year event (i.e., an event with a 5% chance of annual occurrence)? Measured against a particular

portfolio, we can also consider the increase in the probability of losses. Does a 1-in-200-year loss (a loss amount expected to be exceeded with a 0.5% probability each simulated year) become a 1-in-20-year loss (a loss amount expected to be exceeded in 5% of years)? This will have an impact on the capital requirements for the general insurer, so it is an important factor to consider.

It is important for firms to attempt to understand the link between rising global temperatures and the effect that this increase could potentially have on the amount of damage caused to the environment. The Environmental Defense Fund (EDF) has highlighted this direct link for rainfall,²⁸ in addition to the damage caused by storms and hurricanes.²⁹ In particular, it notes that:

- Higher temperatures increase the amount of evaporation. This leads to more moisture in the atmosphere, which results in a higher intensity of rainfall. The EDF estimates that intensity of the rainfall from Hurricane Harvey in 2017 was 15% higher as a result of human-induced climate change.
- Higher intensities of rainfall will lead to increased floods, whilst in the winter it will result in more severe snowstorms.
- Higher global temperatures will also impact the frequency of Category 4 and 5 storms. Warmer oceans fuel storms with water vapour and heat, causing them to intensify quickly. This means storms may bring increased wind speeds and rainfall when they make landfall.
- Higher storm surges are also more likely due to rising sea levels and the high winds during hurricanes which push these waters inland.
- A major factor affecting the destructive power of hurricanes is the amount of time they spend on or near land. Recent hurricanes, such as the Category 5 storm Hurricane Dorian in 2019, are moving much more slowly than before. Traditionally, hurricanes travel at around 10 to 35 miles per hour (generally more slowly in latitudes farther south). Dorian crawled at 1.2 miles per hour for an extended period, causing more than USD 3.4 billion in damages over two days in the Bahamas. Had it done the same near, say, Miami (a relative stone's throw away), the property damage would have been many times worse.

Insurers with exposure to areas often affected by floods, hurricanes and other weather storms should consider monitoring metrics such as projected temperatures in those geographies and projected intensity of rainfall. They should also examine their books of business to measure the percentage exposure to sustained temperature increases.

Firms could also use the scenarios that have been set out in the IPCC's fourth assessment report³⁰ as a basis for any analysis. The report covers a range of scenarios incorporating temperature and sea level rises.

²⁸ EDF. Extreme weather gets a boost from climate change. Retrieved 15 May 2020 from <https://www.edf.org/climate/climate-change-and-extreme-weather>.

²⁹ EDF. How climate change makes hurricanes more destructive. Retrieved 15 May 2020 from <https://www.edf.org/climate/how-climate-change-makes-hurricanes-more-destructive>.

³⁰ IPCC (2007) Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

Under each of the scenarios above, firms could assess the effect that different stresses have on their claim costs and hence their Technical Provisions, Own Funds and Economic Capital.

Firms could also consider standard metrics related to catastrophe modelling, such as the occurrence exceedance probability (OEP) and the aggregate exceedance probability (AEP). They enable firms to assess the probability of a level of loss occurring from a single large event, and the probability that the aggregate loss in a given time period exceeds a certain amount, respectively.

Firms can monitor these metrics over time to assess how their risks have developed. Temperature increases assumed in their scenarios can also be monitored against actual temperature increases over time, so that firms can recalibrate any assumptions that they are using for their modelling.

It is more important though for firms to assess these metrics on a forward-looking basis, to ensure that they manage their risks when underwriting new business and they are not overly exposed to the effects of climate change. This will assist insurers in managing their current exposure and preferred target levels of total exposure.

OPERATIONAL RISKS

Risk exposures

A final place in which risks could arise is the area of operational risk. Key impacts from the physical risks of climate change include issues such as disruption to supply chains or service providers and more frequent business interruption. The latter could arise due to aforementioned issues with suppliers and counterparties, or if more frequent and severe weather events make certain business locations inaccessible in the short or long term.

Metrics to monitor in this area are therefore those which:

- Identify the company exposure to business locations that are particularly vulnerable to business interruption or displacement from climate issues.
- Identify the exposure to suppliers and providers that are geographically based in areas which are at particularly high risk.
- Identify the extent of diversification in the above two areas.

Such metrics would help the firm identify its exposure to future climate-related business interruption, which will then indicate the extent to which mitigation actions such as improving operational resilience, or diversification of suppliers and business locations, are required. To support the development of such metrics, climate data on the relative risk of flooding, storms and warming by geography is key. For general insurers, metrics already monitored with respect to the insurance portfolio could be useful in this context.

On the transition risk side, key risks might include:

- Risk of legal challenges in response to climate-related failures by companies. Such failures might include failure to mitigate climate risks, to adapt to climate change or to disclose material financial risks from climate change.
- Risk of reputational or brand damage if products, actions and external disclosures do not keep pace with regulator, government, consumer and investor expectations.
- Increased expense outgo associated with complying with new regulation and investing in new technology.
- Introduction of new risks through the use of new technology.

These types of risks are slightly more complex to monitor, in that it is unlikely that an insurer will be able to condense them down to single numerical indicators of risk emergence or risk exposure. Instead, risk monitoring is likely to be qualitative and based on expert judgement. For example, in the area of reputational management, firms might carry out surveys to ascertain the extent to which opinion of their brands or certain actions are favourably viewed. Indeed, the disclosure of positive and successful action by a firm with respect to climate change is a key way in which reputational risks arising from climate change can be managed and mitigated.

Conclusions

In summary, there are a number of key areas in which firms can monitor appropriate metrics to assess the extent of their exposure to climate risks, as well as the emergence of these climate risks. When developing physical risk metrics, the use of climate data and science is key, as is the ability to link this data to the relevant insurance risks. Where data is not always available, expert judgement overlay is required, both from insurance risk expert and climate expert perspectives. With respect to the latter, external sources of data and judgement may be required.

When thinking about the softer, less tangible drivers of transition risks, qualitative data and monitoring may be more appropriate than numerical metrics.

Firms should ensure that they focus on reviewing and refining metrics, given that this is a rapidly developing area of risk management, and that best practices will emerge over time. This is particularly key given the “new” and evolving nature of this risk, and the fact that transition risks can emerge rapidly. Firms can utilise the metrics they develop to specify appropriate actions to remediate any current discrepancies with risk appetite.

Surrounding all of this work is the need for firms to also focus on disclosure of metrics to encourage market understanding of risks and avoid a disorderly transition, in line with regulatory expectations.



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