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The Climate Change Adaptation Gap: An Actuarial Perspective

Climate Risk Task Force

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This paper was prepared by the Climate Risk Task Force of the International Actuarial Association (IAA).

The IAA is the worldwide association of professional actuarial associations, with several special interest sections and working groups for individual actuaries. The IAA exists to encourage the development of a global profession, acknowledged as technically competent and professionally reliable, which will ensure that the public interest is served.

The role of the Climate Risk Task Force is to deliver on the Statement of Intent for IAA Activities on Climate-Related Risks (SOI) as adopted by Council on 7 May 2020.

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Executive Summary

Adverse outcomes of climate change have already been seen on all continents and in most countries. They are likely to get progressively worse. Even with extensive mitigation actions, these types of changes are highly likely to continue to accelerate. Moreover, the consequences of climate change disproportionately affect low-income countries and poor people in high-income countries. The best defense against future climate-related risks and damages is to transform systems proactively to build resilience. Investment in climate change adaptation now can also reduce the ultimate costs of climate change significantly.

However, progress on climate adaptation has been slow, siloed and incremental, with little evidence of that transformative adaptation that is needed to address significant climate hazards and exposures.[1] There is a substantial gap relative to the level of adaptation likely to be needed given predicted levels of global warming. This is the "adaptation gap" of this paper's title.

Actuaries can contribute to adaptation planning and the assessment of potential adaptation actions, not only in the usual areas of actuarial practice, but through broader application of their experience and skills in risk management, scenario analysis and cost-benefit analysis, along with the application of discounting techniques to assess costs and benefits over the long term.

Decisions affecting climate change adaptation are made under conditions of uncertainty. The uncertainty of future outcomes is at the heart of the climate change discussion. Understanding and communicating these uncertainties is a key role for actuaries. In developing adaptation actions, consideration needs to be given to a range of potential future climate scenarios.

Actuaries can play an important role in inter-disciplinary assessment and discussion of adaptation measures and the role of, and impact on, financial systems. The role of actuaries in relation to insurance, pensions, investments and social security systems will include advising on protection gaps, vulnerabilities, insurability and resilience.

Taking an actuarial approach to climate-related risk management is useful when considering adaptation actions (i.e., identify exposures/vulnerabilities, obtain data/information, assess/model, plan, finance, implement, monitor). Adapting to climate change is a continuous process rather than a one-time event and adaptation risk management has to be addressed on an ongoing basis. Further, adaptive thinking requires both a short- and long-term perspective, applied holistically, to optimize societal outcomes. Actuaries' training in risk assessment and measurement can help fill gaps in knowledge and also quantify, compare and prioritize the uncertainties in alternative future courses of action.

While the role for non-life actuaries in climate change adaptation is evident, all areas of actuarial practice will be affected by climate change adaptation planning. Life, health and pension actuaries will need to consider the potential mortality and morbidity impacts arising from the effectiveness (or otherwise) of adaptation actions. They and investment actuaries will need to consider the maturity of climate change adaptation within investment portfolios. Social security actuaries will need to assess the potential implications for, and potential changes to, social security systems.

To conclude, risk management, cost-benefit and scenario analysis are key requirements for effective adaptation action. Consequently, actuaries have much to offer to enhance adaptation decision-making and address the adaptation gap.

1 Introduction

This paper follows five earlier publications from the IAA Climate Risk Task Force and a joint publication by the IAA and Working Group I of the Intergovernmental Panel on Climate Change (IPCC). It provides an introduction to climate change adaptation and the adaptation gap from an actuarial perspective. It draws, in particular, on the IPCC Working Group II report, Climate Change 2022: Impacts, Adaptation and Vulnerability, published in February 2022.[2]

Readers are advised to refer to earlier IAA publications which provide useful foundations:

- Paper 1: Importance of Climate-Related Risks for Actuaries[3]
- Paper 2: Introduction to Climate-Related Scenarios[4]
- Paper 3: Climate-Related Scenarios Applied to Insurers and Other Financial Institutions[5]
- Paper 4: Application of Climate-Related Risk Scenarios to Asset Portfolios[6]
- Paper 5: Climate-Related Disclosures and Risk Management: Standards and Leading Practices[7]
- Climate Science: A Summary for Actuaries – What the IPCC Climate Change Report 2021 Means for the Actuarial Profession.[8]

Climate change is happening today and will accelerate in the future. Not only is the extent of future climate change uncertain (with potentially greater uncertainty when moving from global to local scales), but it will also cause an escalation in climatic variation. Extreme weather events, such as heatwaves and large storms, are likely to become more frequent or more intense. Potential tipping points such as permafrost melting, sea-ice loss or massive forest dieback are becoming more likely.[9]

1.1 Purpose and Intended Audience

Adaptation, when used in relation to climate, is the process of adjustment to actual or expected climate and its effects. Progress on climate adaptation has been slow, siloed and incremental, with little evidence of the transformative adaptation that is needed to address significant climate hazards and exposures.[10] There is a substantial gap relative to the level of adaptation likely to be needed given predicted levels of global warning. Investment in adaptation now can reduce the ultimate costs of climate change significantly.

Actuaries can contribute to adaptation planning and the assessment of potential adaptation actions, not only in the usual areas of actuarial practice but through broader application of their experience and skills in risk management and cost-benefit and scenario analysis.

This paper aims to provide an overview of the issues involved in adapting to climate change, both in general terms and with a focus on considerations relevant for current areas of actuarial practice. It also aims to identify areas in which actuaries can participate more broadly in adaptation action. Actuarial training in risk assessment and measurement means that actuaries will take account of the uncertainties inherent in designing adaptation solutions and anticipate and quantify the costs and benefits of such solutions over time, having regard to a range of potential climate scenarios.

The intended audience for this paper is two-fold. It is expected that it will be of interest to actuaries who will increasingly need to consider climate-related risks in their current roles. It should also be of interest to a broader set of stakeholders who are involved in adaptation efforts that will benefit from risk management, cost-benefit analysis and scenario testing.

1.2 Outline

Section 2 provides an overview of the topic of adaptation, in the context of a "three lines of defense" model. It discusses limits to adaptive capacity, adaptation planning and a range of potential adaptation actions to address different types of climate-related risk.

Section 3 outlines the potential role for actuaries. It provides an actuarial perspective on the benefits of adaptation and discusses insurance mechanisms to incentivize adaptation action.

Section 4 outlines the application of the risk management techniques typically used by actuaries in the context of climate-related risks.

Section 5 includes case studies from the Caribbean, India and Canada relating to adaptation projects. Although actuaries have had limited involvement to date in climate adaptation work, these case studies illustrate the potential for applying actuarial expertise and techniques in this field.

Section 6 outlines several additional considerations, including the issues relating to vulnerable populations and the need for coordinated approaches.

Finally, our conclusions and the next steps that the IAA Climate Risk Task Force intends to make are set out in sections 7 and 8 respectively.

1.3 Glossary

Readers may wish to consult the Glossary of Defined Terms Used in IAA Climate-Related Risk Publications,[11] in particular for definitions of terms such as "exposure" and "sensitivity", the usage of which is different in a climate change context than the typical usage in actuarial practice.

2 Adaptation, Adaptive Capacity and Adaptation Actions

Adaptation, when used in relation to climate, is the process of adjustment to actual or expected changes to the climate and its effects.

2.1 Adaptation vs Mitigation

The 2015 Paris Agreement aims to limit global warming to well below 2°C, compared to pre-industrial times, and pursue efforts to limit it to 1.5°C. This requires greenhouse gas emissions **mitigation** (subsequently referred to in this paper as mitigation) measures to reduce emissions and the removal of greenhouse gases from the atmosphere. The global temperature has already increased by around 1.2°C since pre-industrial times[12] and the impacts of climate change are already evident; global warming of 1.5°C or 2°C will have a substantial impact on human and natural systems. The adverse impacts of the current level of warming are already being experienced. Hence, **adaptation** action is required on a transformational scale.

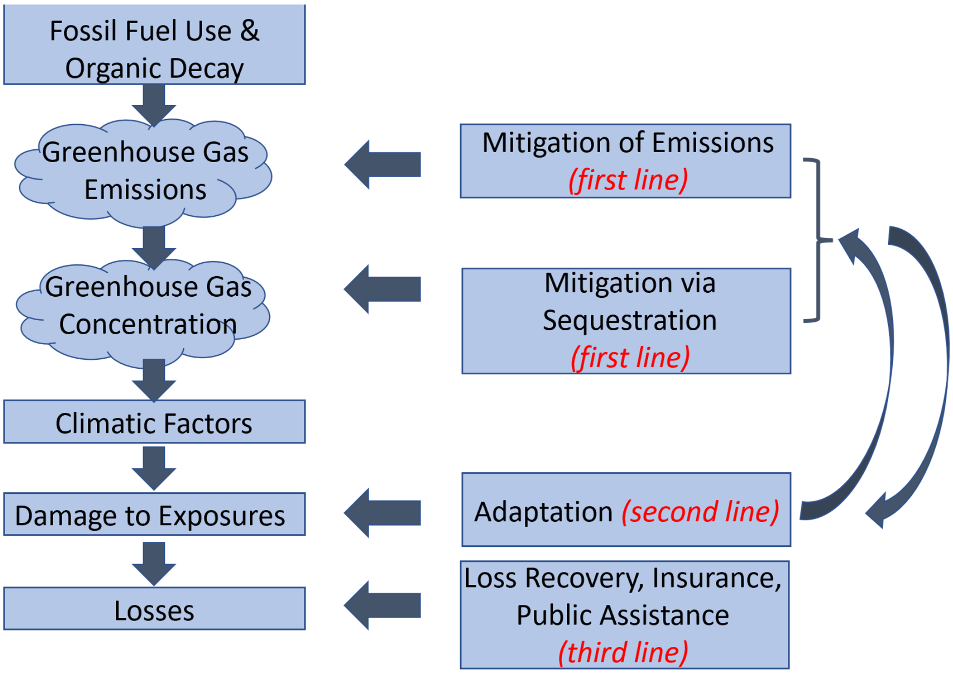
Adaptation can be reactive, occurring in response to climate impacts, or anticipatory, occurring before the impacts of climate change are observed. In most circumstances, anticipatory adaptation will result in lower long-term costs and be more effective than reactive adaptation.

Effective adaptation is not a one-time response to an emergency situation; rather, it consists of proactive measures to deal with collective hazards over time. It involves planning for the possible effects of climate change and taking suitable action to prevent or minimize the damage it may cause. Examples of adaptation actions include adjusting building codes to take account of potential future climate conditions, building and reinforcing flood defenses and prioritizing tree and crop species that are most suited to the changing climate.

2.2 Lines of Defense

Similar to the "three lines of defense" model for risk management, Figure 1 below applies a three-lines-of-defense perspective to climate-related risk, where the three lines comprise mitigation, adaptation and loss recovery.

Figure 1: The Climate Change Loss Process and Lines of Defense



Adaptation represents a line of defense that can eliminate or reduce potential damages and losses that result from climate-related risk. Key elements of the climate change process are shown in the boxes in the left-hand column in Figure 1. A central role is played by the emission of greenhouse gases, most of which are generated as a result of economic activity that increases the concentration of these gases in the atmosphere. Meteorological processes then lead to changes in key climatic factors, including temperature and precipitation, which can damage human health, property and other resources.

The right-hand column of Figure 1 indicates the key lines of defense against loss due to these factors.

- Mitigation (the first two boxes on the right), the **first line of defense**, is used to reduce the amount of emissions, and capture and store some of the concentration of gases from the atmosphere (the second box on the right), through either natural means such as carbon sinks or technological processes.
- The **second line of defense** is adaptation (the third box on the right), the process of adjustment to actual or expected climate and its effects. For example, the strengthening of building codes to address the increased variability and extremes of rain, wind and heat is an adaptation measure. Other examples are set out in Section 2.8.
- To the extent not eliminated or diminished by adaptation, the **third line of defense**, loss (or disaster) recovery, aims to minimize the ultimate losses that result from the damages induced by climate change. This recovery may come from insurance that can reduce a certain amount of the financial aspects of these damages. Public or charitable assistance

are also major elements that can reduce a portion of the remaining adverse effects of the damages. A key element of the recovery process is learning lessons from damages incurred, especially planning for enhanced future adaptation that can range from improving building structures to moving from high-risk areas.

Significant synergies and trade-offs can exist between adaptation and mitigation (the two arrows to the right in Figure 1). For example, measures to protect ecosystems, such as enhanced cropland management, can both assist adaptation to climate change and enhance carbon storage. However, some adaptation options may have adverse consequences that involve trade-offs with mitigation objectives. For example, although increased use of air conditioning is a primary method used as an adaptive measure to deal with heat stress, it increases energy use and may therefore be an undesirable measure from a climate change mitigation perspective (as well as being unaffordable for many vulnerable populations).

Both adaptation and mitigation actions require investment. In both cases, there is a mismatch in timing between their costs, which are incurred upfront, and their benefits, which accrue over a long period, in the form of either enhanced resilience or less severe losses or damages. This mismatch is a barrier to effective action and needs to be addressed in cost-benefit analyses.

Benefits from climate mitigation are global in nature, whereas adaptation actions and benefits tend to be more on a local or regional level. In practice, the parts of the world that will be most affected by climate change are often those with fewer resources available for both adaptation and mitigation.

To date, the overwhelming majority of globally tracked climate finance has been targeted at mitigation, while only a small proportion has been directed to adaptation.[13] ESG (environmental, social and governance) investment policies have tended to focus on mitigation activities. Progress on climate adaptation has been slow, siloed and incremental, with little evidence of that transformative adaptation that is needed to address significant climate hazards and exposures.[14] However, the urgency of addressing adaptation needs is increasingly being recognized, with a growing focus on integrating climate policies to address both mitigation and adaptation.[15]

Global collaboration and intelligent sharing of resources and data will be fundamentally important to successful adaptation. Policy tools will need adjustment and investment as well.

2.3 Resilience

Resilience, when used in relation to climate, is the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation. Adaptation can strengthen climate resilience. However, resilience also encompasses the management of residual risks which will remain despite efforts to mitigate and adapt to climate change (e.g., due to economic, financial, capacity, social and cultural constraints).

Improving resilience builds on an assessment of current and expected future risk profiles to adequately prepare for tomorrow's context. Given the increase in future risks and the uncertainties involved, improving resilience through developing adaptive capacity is critical to managing these short- and long-term risks.

2.4 Adaptive Capacity

Adaptive capacity is the ability of systems, institutions, humans and other organisms to adjust to potential damage, take advantage of opportunities or respond to consequences.

Under a high-physical-risk scenario, certain adaptation options may no longer be sufficient (i.e., we may reach the limits of adaptive capacity). For example, future temperature or drought conditions in some areas in the world may not allow outside work in the middle of the day, resulting in decreased productivity if loss prevention measures are not taken. Similarly, existing flood defense infrastructure may no longer be sufficient in the face of increasing sea levels, the effects of which may be exacerbated by extreme weather events.

2.5 Maladaptation

"Maladaptation" refers to any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead.

There are consequential risks associated with both failing to adapt and maladaptation. For example, entities that eschew adaptation may face legal and reputational risk. As climate-related disclosures become required, inaction may become evident (for more detail on emerging disclosure requirements, see the above-mentioned Paper 5 of the IAA series on climate-related risk, Climate-Related Disclosures and Risk Management: Standards and Leading Practices). While, in terms of ESG investing, the investor community is currently focused more on mitigation than adaptation measures, over time entities that fail to adapt may be categorized in a manner similar to those that have not done their share in reducing emissions.

Legal or reputational risk may occur when climate change can be observed and stakeholders respond too quickly, planning in ways that lock in development trajectories that give rise to adverse outcomes over a longer term, increasing rather than reducing vulnerability to climate change. Maladaptation may also shift one group's climate problems onto another; for example, a city that lies next to a river could apply an adaptation technique upriver from it that causes a flood or drought in a neighbouring city.

As an example, maladaptation may also result from the use of irrigation, which helps stabilize and increase crop yields and is often a preferred strategy for farmers and policymakers. Irrigation can also be associated with a range of adverse outcomes, including groundwater over-extraction. In addition, large-scale irrigation can also affect local and regional climates, in terms of both temperature and precipitation change.

Insurance can inadvertently foster maladaptation. For example, if farmers are insured without proper incentives (such as reasonable deductions or co-payments) for crop failures, they may fail to modify their planting approach with future climate resilience in mind, with the result that insurance becomes unaffordable or unavailable.

2.6 Cascading and Compounding Risks

The dynamic nature of climate change creates an environment where multiple climate hazards can occur simultaneously and interact with other non-climate-related risks, resulting in compound effects and cascading risks. Cascading risk is when a primary event (trigger), such as heavy rainfall or rapid snowmelt, is followed by a chain of one or more other events, such as consequential flooding or landslides. Compounding risk represents a combination of events that occur at the same time. Both types of risks lead to impacts that are more severe than if they had occurred separately.

An example of compounding risk is the concurrence of heatwaves and severe droughts in Europe in recent years. In the summer of 2022, the combination of evaporation due to a series of heatwaves and the severe lack of rain resulted in water levels falling to extremely low levels in rivers and lakes. In addition to the significant supply chain disruption that ensued, as described in Section 2.8.6, these conditions forced several nuclear power plants to reduce output because river temperatures were too high to cool the plants. The consequences for both supply chains and power generation were exacerbated by Russia's war on Ukraine, the consequences of which were and are severe in themselves.

Cascading risks can be especially dangerous, with broad inter-related and severe consequences that can affect a wide range of businesses and individuals. These may result in significant losses in geographic areas and population segments particularly exposed and vulnerable to them.

Further, climate-related risk drivers may also exacerbate non-climatic risk drivers. As an example, many health-related risks can be exacerbated by climate change, especially affecting those with a higher baseline sensitivity for health degradation, including the elderly and those with chronic conditions. Given demographic trends, this health impact will be further compounded by an increase in those vulnerable populations. Political risks may also be exacerbated by climate-related risks; e.g., strife resulting from scarcity of resources.

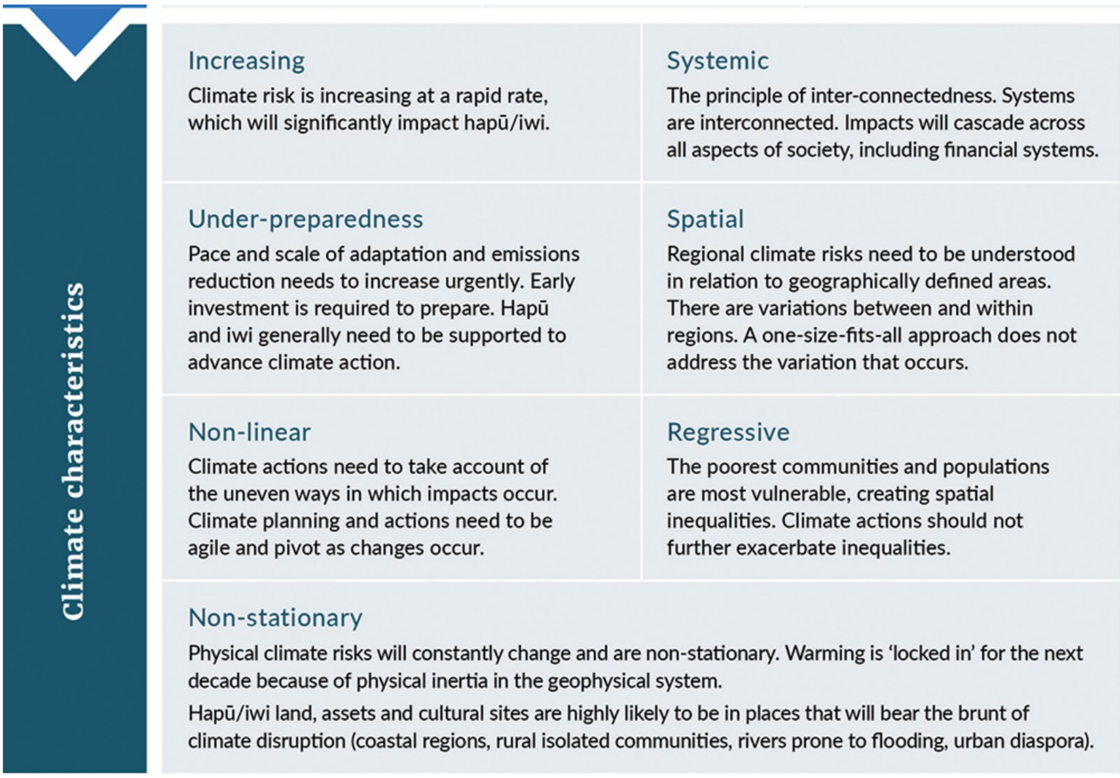
Adaptation plans will need to take potential cascading and compounding risks into consideration. Actuarial scenario modelling techniques may be useful for this purpose.

2.7 Adaptation Plans

Given the level of complexity and uncertainty that permeates climate-related risk assessment, estimating current and future exposures and vulnerabilities to develop adaptation plans can be challenging. However, multiple frameworks for vulnerability-based assessments are being developed. Consistent with current actuarial practice, a commonality among those is a decreasing reliance on broad averages, with a greater focus on a range of possibilities.

Adaptation plans need to recognize and account for the key characteristics of climate-related risk and their unprecedented nature. As an example, Figure 2 provides an extract from New Zealand's most recent national adaptation plan.[16]

Figure 2: New Zealand's National Adaptation Plan – Features of Climate-Related Risks



Note: iwi means tribe while hapū refers to sub-groups within those tribes

2.8 Adaptation Actions

The following sub-sections outline some examples of adaptation actions, with more detailed case studies following in Section 5.

2.8.1 Building Codes

Building codes and land use policies can be adapted to effectively reduce future damages due to climate change and to enhance overall resilience. Such adaptation is all the more important because traditional price signals (such as through property valuations or insurance premiums) may not sufficiently discourage risky development, especially in the context of climate change. Building codes and land use policies are important in the context of storm, flood and wildfire risk, as well as sea level rise. For example, California has mandated special building codes for new homes built in risky fire zones, known as "wildland-urban interface codes".

Following Hurricane Andrew's devastating toll in 1992, which destroyed and transformed the landscape, new (stricter) building codes were enacted in Florida. Later studies showed that follow-on hurricanes in the same area caused greater structural damage in buildings which had survived Hurricane Andrew and thus were not subject to the newer building codes at the time, relative to buildings rebuilt using stricter standards.[17] This points to adaptive capacity and the use of lessons learned from the past as an incentive to improve resilience. It also suggests that adaptive considerations are needed both at the initial stage of construction design and at the time of renovating.

In planning for a future which is characterized by uncertainty, a shift in mindset is required to reflect the following considerations:

- **Future conditions:** Almost all current building codes take a view of risk based on the present, whereas in designing future building codes, conditions over the expected future lifetime of new buildings need to be considered.
- **Future uncertainty:** Most building codes are based on a static view of risk (from an engineering perspective) and do not consider alternative future states, whereas a stochastic view that considers potential adverse scenarios, based on the probability of various possible hazards, would be more appropriate. This is an area where an actuarial perspective can add significant value.

2.8.2 Heat Health Action Plans

Extreme heat can lead to excess morbidity and mortality. A heat health action plan is an adaptive response to the increasing risk of heat extremes. Such plans can include warning systems and solutions such as climate-friendly urban design and planning and nature-based approaches.

A well-designed plan can link weather forecasts with alert and communication systems and response activities, as well as, and linked to, forward planning measures. These may include public cooling centres, enhanced heat-related disease surveillance, ongoing educational programs, planting trees in urban areas, and encouraging individual actions designed to reduce the health effects of extreme heat events such as seeking shade and altering the pattern of outdoor work.

To support heat-risk-related policy development, the identification and mapping of heat vulnerability "hot spots" within urban areas has been proposed.[18]

2.8.3 Agricultural Practices

The impacts of climate change are becoming increasingly evident for the agricultural sector. Farming activities directly depend on climatic conditions, and farmers are affected by decreasing rainfall, as well as sudden heatwaves, droughts, storms and floods in many regions. Most global climate models project severe and adverse consequences, especially for the world's most food-insecure regions. Without adaptation, Asia and Africa will suffer particularly severe yield declines by 2030 in important food growing areas: for example, wheat in South Asia, rice in Southeast Asia and maize in southern Africa.[19]

Potential adaptation actions include the use of drought-resistant seeds that allow plants to survive during periods of drought; intercropping, where several crops are planted in the same field to help the plants be less susceptible to disease; and precision agriculture, such as the application rate of fertilizers being calibrated to accurately reflect the soil requirements of a particular area.

According to the World Bank, a growing and diverse spectrum of practices have demonstrated that it is possible to simultaneously deliver higher agricultural productivity, greater climate resilience and lower emissions. For example, nitrogen-fixing trees can help improve soil quality and raise farmer incomes in Africa's Sahel, and at the same time also deliver a mitigation co-benefit.[20]

As farming practices evolve to adapt to climate change, the insurance programs that support them also have to adapt. Climate scenarios can be applied to augment historic data for pricing purposes. Incentives could also be provided through premium discounts to reward best practices. However, most crops in poorer countries are currently uninsured.

2.8.4 Responses to Sea Level Rise

Sea level rise poses a distinctive and severe adaptation challenge as it implies dealing with slow-onset changes accompanied by an increased frequency and magnitude of extreme sea level events, including storm surges, which will escalate in the coming decades. A significant increase in sea level is already locked in given the global warming that has already occurred. The ultimate extent of sea level rise, however, is highly dependent on global mitigation efforts and is susceptible to several tipping points, including melting of the Greenland and West Antarctic ice sheets and widespread abrupt permafrost thaw. Responses to ongoing sea level rise and land subsidence in low-lying coastal cities and settlements and small islands include protection, accommodation, advance (i.e., the creation of artificial land above the sea) and planned relocation. These responses are more likely to be more effective if combined and/or sequenced, planned well ahead, aligned with socio-cultural values and development priorities, and underpinned by inclusive community engagement processes.[21]

The case study in Section 5.2 provides an example of a coastal protection initiative in Barbados. This project has been deemed a success, although it is recognized as a short- to medium-term solution, with further adaptation likely to be required in the longer term.

2.8.5 Responses to Other Water-Related Risks and Impacts

For inland flooding, combinations of non-structural measures like early warning systems and structural measures like levees can be implemented. Enhancing natural water retention by means such as restoring wetlands and rivers, land use planning (e.g., no-build zones) or upstream forest management can further reduce flood risk.

Farm management, water storage, soil moisture conservation and irrigation are some of the most common adaptation responses to drought risk. Irrigation needs appropriate management to avoid potential adverse outcomes, however.[22]

The case study in Section 5.3 provides an example of a response to diminishing water supply from the Cauvery river in India, illustrating the potential for nature-based solutions.

2.8.6 Supply Chain Management Strategies

Climate change will have a profound impact on global supply chains.[23]

For example, the droughts in Europe in 2022 exposed the vulnerability of European supply chains reliant on river transport as river levels fall due to drought; e.g., on the Rhine, Danube and tributary rivers. The typical short-term response is partial loading of vessels or running more journeys with smaller ships. However, this exacerbates emissions, especially as low water levels mean more resistance and higher fuel use. Longer-term solutions will be required in order to adapt to the changing climate.[24] These may include changes to ship construction and operation, forecasting systems, logistic chain adjustments and river management measures, such as longitudinal dikes or sediment management.[25]

Two main strategies that can be used to manage supply chain risk and disruption and build resilience are bridging and buffering.[26] Bridging involves the buying organization taking action to help build up the capacity of its suppliers to manage through and recover from disruptions. Buffering involves the buying organization taking action to protect itself from the consequences of supplier failures.

Bridging may include coordination on risk awareness and planning, providing financing or expertise and strengthening the buyer–supplier relationship. However, no matter how resilient a supplier is, supply disruptions may occur due to climate-related risks, so buffering strategies are likely to be required. Buffers to improve a company's supply chain resilience to climate change risks could include holding more inventory or developing excess or back-up capacity that either lowers the impact of a disruption or improves the ability to recover from disruption.

Planning for supply chain resilience will need to take account of not only individual climate risk factors but also the effect of compounding and cascading risks.

2.9 Managed Relocation

Some locations may not be able to adequately manage the losses from persistent severe weather events or temperature extremes. Managed relocation may need to be considered in those situations. Approximately 4.4 million people have been relocated through managed retreat programs over the last 20 years.[27]

A cost-benefit analysis over the long term shows managed relocation can provide better value than other resilience options, and planning frameworks should be advanced for this purpose. However, the affected populations must be sufficiently engaged, and their awareness of risks raised, for relocations to be successful.

2.10 Learning from Experience

The above examples emphasize the importance of developing and maintaining resilience in the climate-related risk adaptation process. More generally, similar areas with prior exposure to climate-related events, while continuing to witness an increase in the frequency, severity and duration of extreme weather in the future, may over time have built better tolerance to the consequences of such events and therefore bounce back more rapidly. Their higher resilience will likely lead to better preparedness for their next similar adverse situation. In contrast, other areas that have not previously been exposed to extensive climate-related risks may lack sufficient knowledge and experience and may not adequately prioritize adaptation action. Their limited experience and adaptive capacity may thus expose them to more severe losses and damages, hence the need for proactivity and innovation.

3 An Actuarial Perspective

3.1 The Role of Actuaries

Collectively, the actuarial profession has a role to play in helping stakeholders better understand the consequences and uncertainties of their decisions on implementing actions or not acting at all on climate adaptation. The actuarial profession can add value to these decisions by leveraging actuarial experience in risk management practices and, in particular, managing uncertainty over long time horizons.

Actuaries have important roles to play in the inter-disciplinary assessment and discussion of adaptation actions and their impact on insurance systems, protection gaps, vulnerabilities, insurability and resilience. Actuaries are also concerned with, for example, the design of insurance products and the sustainability of the companies offering relevant coverage.

More broadly, actuaries are well positioned to assist various stakeholders, including policymakers, with their adaptation-related decisions. Building on data and scientific findings from relevant domain experts, including climate scientists, meteorologists, engineers, etc., actuaries can use their proven skills in assessing risks and opportunities with varying levels of uncertainty to present decision-useful information to boards and relevant stakeholders, including customers, businesses, governments, regulators, rating agencies, etc. Actuaries can help identify and quantify adaptation opportunities, even without extensive historical data, with before-and-after analysis. Actuaries have proven skills in the use of scenario analysis in decision-making.

There are also opportunities for actuaries to partner with other direct and indirect stakeholders. For example, although it is relatively easy to demonstrate the additional cost of climate-resilient building construction, for comparative purposes, the expected cost and impacts of climate change on a less-resilient building code should be rigorously assessed and quantified. This cost-benefit analysis would be expected to use objectively developed alternative scenarios developed by relevant experts.

The remainder of this section provides additional background on how an actuarial perspective on climate risk adaptation is of benefit to relevant stakeholders.

3.2 Cost-Benefit Analysis and Scenario Testing

A recognized actuarial expertise is the ability to conduct decision-useful scenario testing and cost-benefit analysis. This expertise is most useful in addressing climate-related risk generally and adaptation specifically. Naturally, the impacts of climate change need to be considered using scenario projections with and without climate adaptation.

In conducting such testing and analysis, actuaries increasingly work with inter-disciplinary experts to ensure all relevant issues are addressed.

As at the date of this paper, the IAA has produced a number of papers within its series on climate-related risks which address the application of climate-related scenarios, namely the above-mentioned:

- Paper 2 (Introduction to Climate-Related Scenarios)
- Paper 3 (Climate-Related Scenarios Applied to Insurers and Other Financial Institutions)
- Paper 4 (Application of Climate-Related Risk Scenarios to Asset Portfolios).

While these papers do not specifically address the issues related to adaptation, they do illustrate the strength of actuarial expertise in developing climate-related scenarios.

In addition, the limitations of current climate models need to be recognized (e.g., many climate scenarios do not currently account for the costs of population relocation). Users of such models need to consider whether an additional overlay is required to reflect their own assessment of the effects of key elements in the scenarios and models used.

Multiple cost-benefit frameworks for quantifying the financial costs and benefits of adaptation have been developed to demonstrate the financial value linked to services provided by natural infrastructure (such as the restoration of wetlands to control flooding).[28] This focus can be expanded beyond natural infrastructure to cover climate adaptation more broadly. This includes the quantification of losses as a result of adaptation implemented before an event compared with losses after damages are incurred without prior adaptation. Actuaries who are already familiar with before-and-after analysis can contribute their financial evaluations and risk knowledge expertise with scenarios.

Cost-benefit analysis requires credible, useful and timely climate risk-related data, information and analytical tools, and involves the use of models. Actuaries have often developed similar models in other practice areas, the techniques of which can also be applied here. The models can incorporate features of integrated assessment models, although these models are more commonly applied in the study of mitigation. These models incorporate estimates and projections of the components of the drivers-to-loss in the climate change loss process indicated in Figure 1. Key characteristics of this process that need to be captured in the model include the long-term time dimension and uncertainties involved. As noted in Section 6.1, the discount rate used in the model may be lower than a market-based discount rate, to take account of the social value, externalities and uncertainties involved.

3.3 The Role of Insurance

Insurance has had a long historical enabling role in society through its underwriting and investment activities. It is important, however, to note that considerable weather-related damages and losses are uninsured and left to governments (i.e., taxpayers) and individuals to bear. For example, according to the European Insurance and Occupational Pensions Authority (EIOPA), currently only 23% of the total losses caused by extreme weather and climate-related events across Europe are insured.[29] Insurance coverage is even lower in poorer countries.

One of the main benefits of insurance is to provide a financial safety net following an adverse event, such as a climate-related shock, enabling people, companies and economies to rapidly recover from the shock. Effective adaptation action can enhance resilience by reducing the impact of the shock, at the same time as it can reduce insurance premiums.

The increasing severity of storms (wind, rainfall, floods, etc.) could place a severe strain on insurers, their customers, the vulnerable and governments. Actuaries have an important role in helping these stakeholders get the facts, understand the totality of the issues and recognize how everyone may be affected.

The relationship between risk and capital is well known among actuaries. As hazards become more adverse and volatile and the predictive capability of historical data diminishes, the increasing amount and volatility of climate-related risks can place upward pressure on premiums and downward pressure on insurance margins. As a result, regulators may adjust their capital frameworks.[30] For companies relying on risk-based models or specific parameters based on historical data, increased volatility in actual claims experience or financial results can also lead to higher capital requirements.

Both effective climate adaptation action on the part of its customers and judicious use of reinsurance can improve the overall risk profile of an insurer by reducing potential extreme losses and their volatility (although reinsurance capacity for extreme events is not unlimited). This in turn can reduce capital requirements and insurance protection gaps and increase underwriting capacity. In other words, climate adaptation could offset adverse drivers of insurance premiums, including claim incidence and severity, morbidity and mortality.

This particularly applies to reinsurers who facilitate the smooth operation of, and provide financial backstops to, insurers by bearing greater risks of extensive losses and concentration risks due to extreme events.

Ultimately, climate adaptation can support the long-term availability and affordability of insurance coverage, especially in the context of increasing insurance gaps. This is particularly relevant in developing and emerging countries, where individuals and governments are often under-insured or without insurance.

Climate adaptation may provide the stability required to maintain and expand upon certain existing insurance and reinsurance markets and public–private partnerships. For example, Flood Re, a reinsurance scheme, was set up between the UK government and insurance companies to offer flood cover at affordable rates in high-risk areas until 2040. Efforts to promote property flood resilience as a cost-effective way of limiting flood risk have been undertaken, while a replacement scheme may be developed before the expiry of the current scheme. Moreover, flood performance certificates, like energy performance certificates, could help measure a property's flood risk and specify actions to be taken.

The Institute of Actuaries of Australia has published an extensive report examining home insurance affordability and socio-economic equity in a changing climate.[31] The report overlays both low- and high-emissions scenarios of climate change to project what affordability by household may look like in 2050. Under the climate scenarios considered, the majority of households will see increases in home insurance affordability pressure, but vulnerable households will experience larger increases. The paper shows that the number of Local Government Areas currently facing average premiums of AUD 2,000–3,000 (approx. USD 1,300–2,000) and higher, are concentrated in Northern Queensland, but those areas will spread throughout most of Queensland, and into New South Wales, as well across Northern Australia, under a low-emissions scenario. Under a high-emissions scenario, nearly all of Queensland, Northern Australia and large areas of New South Wales would face significantly higher premiums. The report recommends that investment in resilience measures should be prioritized to address home insurance affordability. It notes that factors such as protective infrastructure, land use planning and building codes, access to goods and services, governance, emergency relief levels, and clean up, recovery and rebuild, all contribute to resilience.

The following are key ways in which insurance can contribute to improving overall adaptation.

3.3.1 Education and Communications

One of the key roles of insurance is to educate and promote risk awareness and action among policyholders. This can be achieved by sharing knowledge concerning climate-related risks and methods of effectively adapting to help reduce or eliminate losses and damages. Effective communication, especially with those who are most vulnerable, can also help to avoid under-insurance, when possible, both before and after adverse events occur. Insurers can also use their relationships with policyholders to offer suggestions for improving resilience.

3.3.2 Premium Pricing and Underwriting

Insurance can support and encourage risk reduction strategies; e.g., by offering lower premiums to reward proactive measures aimed at improving resilience. Insurers can encourage the implementation of measures such as anti-flood doors and windows, better construction materials and early warning systems. These can reduce policyholders' physical risk exposures and insured losses, by means of pricing differentials that reflect the reduction in risk. In February 2023, the EIOPA published a report on the European industry's current underwriting practices regarding climate change adaptation.[32] It sees further room for improvement, especially in terms of standardizing the implementation of climate-related adaptation measures in insurance contracts; e.g., through dedicated risk-based certificates and programs.

The additional cost of insurance can be significant for structures or enterprises where the adaptation measures needed have not been taken, while in extreme cases the risk may become uninsurable. This should provide an incentive to optimize adaptive actions. However, as previously noted, due to the short-term nature of property and casualty insurance policies, the insurance sector is not positioned to offer sufficient incentives for anticipatory adaptation, and complementary public policy responses are therefore likely to be needed.

3.3.3 Develop New Products/Product Features

Insurers could offer new product features to facilitate adaptation. For example, extra payouts could be provided when homes are damaged to pay for risk-reducing features within the rebuild or to rebuild in compliance with stronger building codes (such codes rarely apply to existing construction).

3.3.4 Steer Capital Away from Exposure

Projects that require large amounts of capital are unlikely to attract investment if they cannot obtain insurance to cover exposures that are likely to incur potentially costly damages. As a result, to the extent that insurers provide insurance cover only to projects or companies with sufficient adaptive features, they can contribute to greater protection against climate-related risk. In addition, as important investors of long-term capital, insurers and pension funds can steer their capital to companies and projects that follow sound adaptive practice.

3.3.5 Participate in Broader Adaptation Initiatives

Insurance can be part of a broader societal response to climate change risk. While insurance can help facilitate risk reduction, public policy intervention is likely to be needed to provide effective incentives for adaptation.

Notably, the European Commission is currently funding a EUR 6 million research project[33] with a view to achieving the following outcomes:

- A set of weather and climate risk insurance products to be used or replicated across European Union (EU) regions and communities
- Mechanisms to record, collect and share climate-related risk and losses data
- Guidance on insurance pricing that reflects risk reduction measures
- Trial innovative risk transfer solutions to deal with climate-related risks, including parametric insurance and insurance of nature-based solutions
- Advance public sector modernization when it comes to the demand for insurance solutions for climate adaptation
- Opening up opportunities in the insurance market for cutting-edge risk transfer solutions
- Reinforced policy frameworks to facilitate the allocation of substantial additional national and regional budgets to increase the penetration in the EU of insurance solutions to deal with climate-induced risks.

4 Climate-Related Risk Management

Climate-related risk management refers to the processes used to manage activities and methods employed by individuals, organizations and governments to facilitate their climate-related decision-making. A key element of these processes is the elimination or limitation of damages and losses resulting from climate-related risks through anticipating the risk of harm to resources and assets; i.e., through adaptation. Overall, climate change may be characterized as a risk management problem on global, regional, national and local scales.

Effective climate-related risk management requires applying a holistic view, considering the impacts of all climate-related risks for a country, region, community, business or household. It also needs to be integrated within the broader enterprise risk management framework and should not be managed via a silo approach.

In this section, a general risk management framework is described, the principles of which are applicable to any enterprise. However, the practical application of adaptation to climate-related risks may vary depending on whether the enterprise is a government, community, business or household, as well as by the type of risk addressed.

4.1 Decision-Making Processes

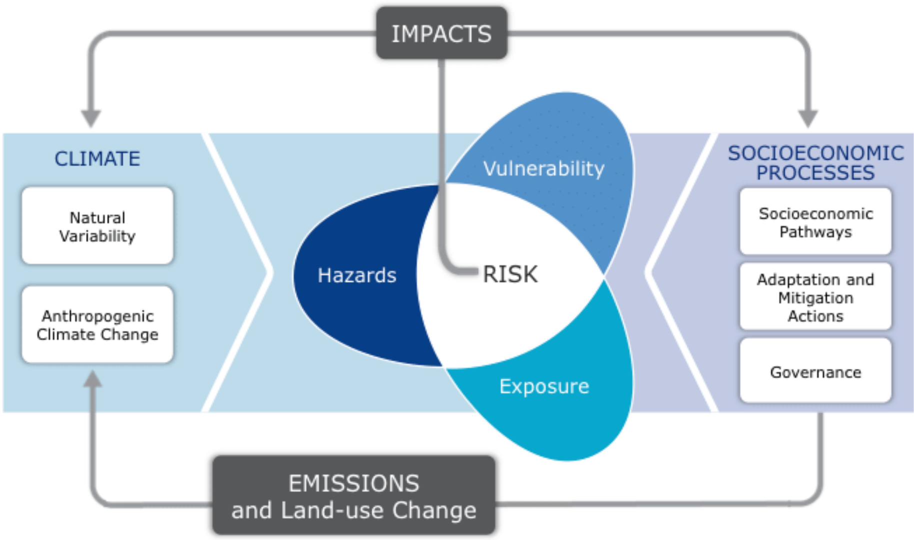
Risk management processes and methods used to facilitate decision-making, from problem recognition to implementation of a solution, have evolved in many contexts, disciplines and applications over the last century. They are central to much of actuarial practice.

Sound and comprehensive decision-making processes are important in the high-level management of climate-related risks. Risk assessments, decision-support tools, early warning systems and contingency planning are assessed by examining the trade-offs involved, all dependent on the local context. Therefore, the primary adaptation action needs to be at that level, involving all relevant stakeholders in the decision-making process. Adaptation-related decisions need to assess potential weather and climate disasters, developing resilience in preparation for future climate change, including potential abrupt change, and extreme events.

These processes require identification of, and agreement regarding, the risks involved, adaptation objectives, alternative options, and the costs and benefits of possible adaptation options, as well as the risk tolerances of the stakeholders. Stakeholder decisions are affected by their adaptive capacity and the types and costs of adaptations needed to address their vulnerability to climate-related hazards. Policies and programs for climate-related property and health outcomes are only beginning to incorporate the challenges and opportunities associated with climate change, although they can be critical for increasing resilience. As a result, the stakeholders may be confronted in the middle of a crisis, rather than in a proactive manner.

Adaptation is needed for areas and populations exposed and vulnerable to climate-related hazards, as shown in Figure 3. The unshaded area, in the intersection of those both exposed and vulnerable to risks, represents those that will likely experience the most significant damages and losses.

Figure 3: Risk as a Function of Hazard, Exposure and Vulnerability



Source: IPCC, 2014 [34]

The allocation of limited resources at global, national, local, business and household levels is difficult. Both synergies and conflicts among multiple objectives will inevitably arise, with stakeholders having in some cases opposing viewpoints and risk/loss preferences. As a result, it is important to define the primary objectives of a potential adaptation action in a comprehensive manner.

An adaptation strategy requires integrated planning, usually based on multiple criteria in which the needs of both human and natural systems are considered. The possibility that adaptation becomes an excuse for not addressing mitigation efforts or that the adaptation strategy becomes a constraint limiting mitigation strategies needs to be guarded against.

Another challenge in the management of climate-related risks is the need to consider risks and opportunities holistically over both short- and long-term horizons. This challenge to effective governance may be due to a potential disconnect between traditional planning horizons and product cycles of one to five years, on the one hand, and, on the other hand, the timescale over which climate-related risks will manifest. Although adverse effects are being felt now, the longer-term effects of climate-related risks may also adversely affect the long-term sustainability of many businesses, including insurers, requiring change to current business models for public interest, regulatory, strategic and competitive reasons.

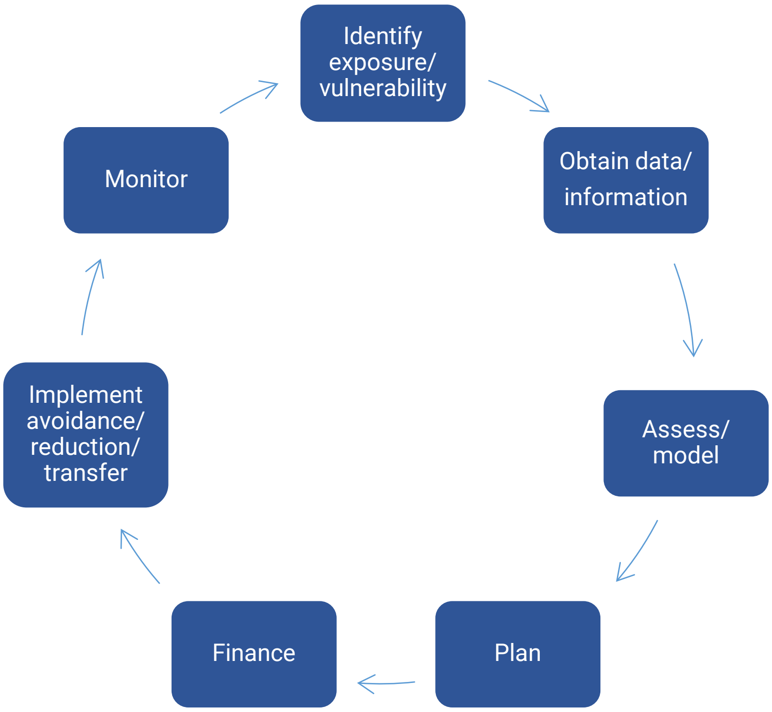
Although the urgent need for adaptation planning and implementation is increasingly evident, competing needs exist, at a global, national, business, household and individual level. There are many types of decisions and forms of analyses and processes that may be drawn on to assess climate-related risks. This is due to the risks differing greatly by type, the extent and nature of exposures and vulnerabilities, and also the range of frequency, severity and timing of risks. Decisions can differ, for example, according to:

- whether they are strategic, tactical or operational;
- whether there are one or many decision-makers and stakeholders;
- which global, national or local considerations are appropriate;
- the level or type of uncertainty present;
- the time available to take the decision; and
- the expected timing of the risk.

4.2 Adaptation Risk Management Process

The adaptation risk management process is shown in Figure 4 with the steps involved described below it.

Figure 4: Adaptation Risk Management Process



The adaptation risk management process aligns with the general risk management cycle that is familiar to actuaries. The following describes the key components of the process as summarized in Figure 4:

- **Identify exposure/vulnerability:** The identification of risks of concern and accompanying objectives and policies for managing those risks will facilitate the development or revision of the models used. Understanding the drivers of and vulnerabilities to various degrees of risk can be useful in implementing each of the subsequent components, as the entire process can be quite complex. Simultaneously, the identification of any co-benefits and opportunities should be undertaken.
- **Obtain data/information:** This addresses the types and risks of climate change, including relevant regulations/laws, vulnerabilities, protection gaps and possible adaptation actions. This can include information gathered by research or from relevant experts or systems, including early warning systems. Obtaining relevant and reliable data on climate-related risks and consequential losses and damages will enhance any cost-benefit analysis. Relevant data and information need to be updated on a regular and as-needed basis, including current (and anticipated) best adaptation practices and effective implementation approaches.
- **Assess/model:** This involves the quantification of the risks and costs with regard to the applicable exposures and vulnerabilities, practical solutions and desired level of resilience. Actuaries can participate in the development of the necessary assumptions involved in assessment and modelling, with values highly dependent on several key factors, including future emissions, current levels of adaptation, interactions among climatic factors, climate sensitivity, insurance protection gaps, adaptive capacity and discount rates. Analysis under alternative scenarios is always appropriate.

  Several tools and models may be used to appraise costs and benefits of available options for ameliorating future risks, as to both implementation and maintenance. Co-benefits and unintentional adverse consequences for various stakeholders that may result from adaptation action should be considered.

- **Plan:** When developing solutions, including relevant stakeholders and experts in the risk management process will ultimately prove valuable. Effective risk reduction requires awareness, the formation of an intent to act, the identification and selection of a plan of action, and the implementation of that plan. A comprehensive and holistic plan is needed, the extent of which may differ by application and the level of planning undertaken. An example of a plan in response to a particular weather hazard is a heat health action plan, described in Section 2.8.2.
- **Finance:** This involves determining the most appropriate, available and affordable method of financing that should be utilized, which can include private or public sector sources, or a public–private partnership. Mandatory or voluntary insurance coverage may be appropriate. A decision is also needed as to whether losses should be financed in whole or part by private sector insurance or public sector programs such as flood insurance in some countries or government loss recovery programs, or self-insured. If financing is expected to be a significant constraint, assessing its implications may be included earlier in this process.
- **Implement avoidance/reduction/transfer:** The implementation stage of the adaptation process may be challenging and expensive. Scaling up adaptation action may be needed to make people and economic and environmental structures more resilient and sustainable. While avoidance or reduction of damages is usually the goal of adaptation, the transfer of the financial costs of hazards is also an approach used to reduce losses. Implementation may take the form of one-time or continuing actions which, together with monitoring hazards and effectiveness, enable ongoing adjustments to meet evolving needs and objectives. It also includes a communication plan to enable and enhance adaptation effectiveness.
- **Monitor:** Regular monitoring and evaluation of the effectiveness of existing adaptation processes against the objectives is warranted. If the current situation proves inadequate to satisfy current and expected future needs, revisions need to be made. However, measuring overall adaptation success (e.g., avoidance of extensive wildfire damages) can be more difficult than measuring the success of mitigation (e.g., the amount of greenhouse gases in the atmosphere). In some cases, it may be possible to estimate what the losses and damages would have been, perhaps on a business-as-usual basis, without the adaptation actions taken. In any case, relevant, reliable and consistent data and observable criteria are necessary inputs to an effective risk management process, either from the local area or areas exposed to similar risks. These can help to determine the desired extent of use and the relative effectiveness of specific adaptive measures.

Although shown in Figure 4 as a unidirectional process, the adaptation risk management process is by necessity one that involves feedback loops (e.g., as a result of new information, new techniques or new financing opportunities). The pathway through this process may not be linear (e.g., depending on when and in what detail the decision-makers may need to understand the applicable climate-related risks and local conditions, and available and affordable options), as both climate-related risks and adaptation processes are dynamic in nature. The development of tools for climate-related risk management, generally using lessons learned from practitioners' experience, may enable some aspects of the decision-making process to be circumvented or at least streamlined.

To date, most climate-related risk adaptation approaches have been developed in and for high- and middle-income countries and typically require significant financial resources for their planning and implementation. Studies are needed to determine whether these options are relevant and useful for less-developed countries to manage and adapt to their climate-related risks. In addition, as in any developing field, innovation is needed to develop more applicable tools and techniques for use in these countries.

An example of an effective risk management process was the adaptation to heatwaves in France. In 2003, 15,000 deaths were attributed to a severe heatwave.[35] A far lower number of deaths (2,000 excess deaths[36]) occurred in record-breaking heatwaves in 2019. This lower number of deaths has been attributed to the enhanced preparedness of the public healthcare infrastructure, the introduction of emergency procedures and the availability of public cooling centres.

4.3 Lack of Data for Adaptation Purposes

Adaptation metrics should address all environment, climate and weather-related risks, as these hazards are inter-related and can exacerbate existing risks. Guidance has been provided in many countries on reporting climate-related losses and damages, although systematic risk assessments are limited.

However, challenges remain in defining and measuring the effectiveness of adaptation at a global scale, across nations or sectors, or for different levels of warming. Many vulnerable countries lack comprehensive data on both economic and non-economic losses and damages, thus hampering effective risk management.

Differing existing standards, sources, data taxonomies or scenarios make sound decision-making more difficult. In particular, it is more difficult to develop and obtain consistent metrics for adaptation activities than for those used for mitigation purposes, as there is a wide range of both hazards and exposed conditions.

Attributing property and health impacts to climate change remains challenging. For example, for health-related risks, impacts can involve mental health and wellbeing, mal- and under-nutrition and food quality, climate-sensitive infectious diseases, etc. Other socio-economic determinants also play an important role in each of these risks, making it difficult to separate the climate-related factors.

Gaps and inconsistencies in available data limit the ability of stakeholders to hold public and private actors accountable and to support needed investments in adaptation.

The Global Resilience Index Initiative (GRII) and the Risk Information Exchange (RiX) under the auspices of the United Nations Office for Disaster Risk (UNDRR) are two initiatives that are contributing to improving climate risk data. Ideally these initiatives can crowd in further collaborations to enhance the open-data environment on climate and disaster risk. They are intended not to compete with private sector model and data providers, but to encourage public–private collaboration.[37]

4.4 Uncertainties

Although there is significant uncertainty regarding climate change, further uncertainty arises as to the effectiveness of adaptation actions under both current and future conditions. The development of climate scenarios should consider a range of potential future climate-related risks and adaptation actions.

Conflicts in values and risk preferences held by different stakeholders mean that some analyses ignore uncertainties relating to expected losses and damages. Actuaries and decision-makers can help structure discussion on the complex issues involved, particularly related to uncertainty. This can be done by building sophisticated models and incorporating alternative possible climate-related risks. These can not only estimate potential consequences but also incorporate alternative options to eliminate, reduce or otherwise manage the risks involved.

Contingency planning will be increasingly important. For example, in the United States, New Mexico's attorney general has launched a readiness task force to prepare for "worst-case scenarios", while Arkansas power officials are establishing emergency conservation measures.[38] These actions have been taken as extreme weather strains power grids and as the United States shuts down fossil fuel plants to help achieve carbon neutrality by 2050. Adaptation of the power system may require contingent alternative power sources. However, these may make power more expensive; i.e., building resilience will likely come at a cost.

4.5 Communication

An important, yet often overlooked, part of the adaptation risk management process is understanding, communicating and convincing others of the need for adaptation, including raising awareness of the risks and cost of not taking adaptive action. Effective communication to policymakers and other stakeholders is therefore essential.

Financial transparency can be provided by public entities and businesses through ESG disclosures. Although the "E" part of this disclosure is sometimes thought of as primarily focusing on mitigation actions, possibly more important to the risks of many entities is the extent and effectiveness of their adaptation to reduce or eliminate potential climate-related losses.

The effects of climate-related risks can appear remote, particularly because they may emerge or manifest in full form past a business or household's normal planning time horizon. Recognizing current or recent climate change-related disasters can provide more immediate encouragement to take adaptive action.

Throughout the risk management process, sound governance practices and appropriate communication with stakeholders are necessary. If beneficial, governance and financial systems may need to be redesigned to work across silos and with appropriate stakeholders involved.

Another important consideration immediately prior to or during an extreme weather event is the rapidity of communication. Effective and timely early warning communications can reduce or even avoid damages from risks including flood, storms, wildfires, heatwaves and drought.[39]

A communication plan needs to be sensitive to the audience. Practical advice, rather than nebulous warnings, is needed, especially for those who are most vulnerable.

4.6 Systems Thinking

The complexity and uncertainty of climate-related risk means that adaptation strategies need to be developed using a systems thinking approach (for more on this, see the above-mentioned Paper 3 in the IAA climate-related risk series, Climate-Related Scenarios Applied to Insurers and Other Financial Institutions, which includes a chapter on systems thinking). This will help provide the tools to address the many interdependencies and potential consequences of alternative pathways over the short, medium and longer term.

5 Case Studies

5.1 Introduction

The following case studies provide examples of climate adaptation projects being conducted across the globe. They are intended to illustrate local adaptation-related initiatives to address climate-related risk. Each case study is intended to illustrate different aspects of adaptation.

The Barbados case study illustrates some of the issues related to rising sea levels and coastal erosion. Of course, sea level rise is affecting jurisdictions around the globe and affecting their decisions to relocate (e.g., Jakarta), enhance their coastal defences (e.g., the Netherlands), etc.

The Cauvery case study illustrates the complex issues involved with river systems which are relied upon for fresh water, irrigation, fishing, hydro-electricity, transportation, etc. Weather volatility can play havoc with the conflicting demands of the users of the river, and systems thinking is required in building solutions across multiple stakeholders. Many river systems around the globe are facing similar issues, the Colorado and Rhine rivers being two of them.

The Canadian case study illustrates the challenges in estimating the costs and benefits of adaptation for a jurisdiction. This case study focuses on Canadian infrastructure and costs of upgrading different structures to meet current and expected weather conditions. The study also identifies the significant cost savings resulting from early action. Jurisdictions around the globe will similarly need to consider their own adaptation plans and expected costs.

While currently there is limited actuarial involvement in climate adaptation work, actuarial skills and techniques can support inter-disciplinary efforts and systems thinking in this space. Taken in combination with traditional actuarial expertise in areas such as scenario testing and cost-benefit analysis, actuaries have much to offer to enhance adaptation decision-making.

5.2 Case Study #1: Barbados – Southwest Coast Boardwalk

5.2.1 Background

The coastal zone of Barbados is the country's main economic asset. It consists of sandy beaches, fringing reefs and other coastal ecosystems distributed along 97 km of shoreline. It supports a tourism industry that, in 2008, accounted directly and indirectly for 39% of gross domestic product (GDP).[40] Due to its location, Barbados is moderately exposed to hurricanes and tropical storms. The country is also highly susceptible to (1) coastal beach erosion along the west and south coasts and (2) cliff instability along the east coast (Scotland District), either from storm events or from ongoing processes such as shoreline sediment transport and soil and rock slippage. Also, as more than 50% of Barbados' population of 276,000, and 95% of the tourism-related physical plant and other critical infrastructure, are concentrated in or near the coastal zone, coastal risk is high.

A study conducted by the Inter-American Development Bank (IADB), Indicators of Disaster Risk and Risk Management, determined that for the year 2008, the probable maximum losses that Barbados could suffer as a result of a catastrophic (hurricane or earthquake) event with a return period of 100 years (10% probability of occurrence in 10 years) amounted to USD 423 million, or 11% of GDP.[41]

Climate change is affecting and has the potential to severely modify the above climate-related risk profile of Barbados by altering the frequency and severity of existing coastal hazards, as well as generating new hazards such as sea level rise. In addition, deteriorating water quality associated with effluent discharges in near-shore waters has resulted in significant mortality rates of coral reefs, which provide a natural barrier against wave erosion and produce sand that nourishes beaches. In 2008, estimates indicated that over 80% of Barbados' fringing reefs had deteriorated.[42] Since shoreline restoration through natural sand production is a slow and costly process, the solution to shoreline instability in the short to medium term is the construction of shoreline stabilization structures that are sustainable and hazard-resilient.

5.2.2 The Rockley to Coconut Court Component of the Barbados Coastal Infrastructure Project

In 2008, the Barbados government directed each ministry to assess its risks and vulnerabilities from a changing climate. The Coastal Zone Management Unit (CZMU) identified a number of critical projects for adaptation to climate change, and the South Coast Boardwalk project of 2008 was the first large-scale project to be implemented.

The following corresponds to the adaptation risk management process shown in Figure 4:

I. Obtain data/information

At the start of the project, much of the project area was characterized by run-down and semi-derelict properties. The structures on the seafront frequently consisted of vertical walls, including property and low boundary walls that were historically constructed in the active beach zone, too close to the shoreline.

CZMU had already been monitoring the stretch of beach and noticed the loss of beachfront in certain areas, resulting in people walking on the road and the closure of businesses.

It undertook many studies to understand the shoreline, and used the following decision criteria for positioning possible beaches and headlands:

- Technical feasibility
- Acceptability with respect to environmental impacts
- Legal viability with respect to land ownership
- Cost viability
- Construction access
- Public access proximity (parking, washrooms, vendors)
- Compatibility with adjacent land use.

II. Assess/model

The proposed layout of the works for the Rockley to Drill Hall frontage had been developed based on a study of oceanographic conditions and an assessment of their impact on the sediment transport dynamics and beach stability along the southwest coast. The scheme was designed to be coordinated with the existing coastal structures, thereby minimizing both environmental impacts and capital costs.

The deep water and near-shore wave climates were defined through the application of numerical models of waves generated throughout the North Atlantic, hurricane wave and surge modelling, and wave transformation modelling.

Numerical simulations were completed to determine the erosion potential of sand beaches based on two key factors: wave height (and water level) and beach width (wider beaches lose sand faster).

A range of different solutions was tested, and it was determined that a headland-beach concept (where a number of concrete headlands would be constructed, and sand placed between them) would relatively effectively retain the beaches with a 30% loss projected over a 20-year period after construction.

Figure 5: Example of Headlands

Photo courtesy of Antonio Rowe, Deputy Director of CZMU

III. Plan

The final plan consisted of five headlands, projection into the sea of 20 to 25 m, a land base for amenities of 250 to 500 sq m and a perimeter design similar to a structural promenade. The headlands were built with granite revetments and were designed to withstand a 1-in-50-year event. It was considered too costly to design for a 1-in-100-year event.

IV. Finance

The contract cost for the original scope of works was USD 9.2 million. Additional works were implemented at a cost of an extra USD 2.5 million. The project was largely funded by the IADB.

V. Implement avoidance/reduction/transfer

The project commenced in July 2007 and was completed in December 2008. The original estimated timeframe was six months; however, unfavourable sea conditions, stakeholder interventions and an increase in the scope of the work extended the project by 12 months.

VI. Monitor

A clause in the project loan agreement required annual maintenance inspections. Although this clause expired in 2015, maintenance inspections continue to be undertaken annually and repairs undertaken as necessary. No beach nourishment has been required since the completion of the project.

Environmental concerns raised during implementation and monitoring discussions were:

- Adverse impacts on the marine environment from construction
- Adverse impacts on coral reef and seagrass habitat from construction
- Local erosional effects of coastal infrastructure
- Cumulative effects of sand trapping by groynes on erosion of the downstream turtle nesting and recreational beach.

Despite these concerns, the project has been considered a success. It has become the model for other successful coastal reconstruction on other parts of the island and around the world. While this coastal reconstruction is a short- to medium-term solution, it does not solve the underlying issues of deteriorating near-shore water quality and the mortality of coral reefs. Possible long-term adaptation strategies would include investments in solutions such as island-wide sanitation and drainage improvements and perhaps the relocation of homes and businesses to a safe distance away from the coast.

Figure 6: Before and After Photos

Looking north

Looking south

Photos courtesy of Antonio Rowe, Deputy Director of CZMU

5.2.3 Actuarial Implications

This case study illustrates the importance of properly considering the effects of climate change and possible adaptation measures for Barbados and its land, beaches, people, structures and economy. Addressing these issues requires their inclusion in risk management and scenario analysis in both the public and private sector. It also requires cooperation and partnership among all stakeholders to minimize protection gaps. Actuaries have strong roles in providing advice on these matters to governments.

While no actuaries were involved in the implementation of this project, it is possible to see how actuaries could assist with risk management and with assessing the range of potential solutions. Actuaries could extend the risk management analysis for this project to other competing adaptation projects so that short- and long-term solutions can be compared effectively, and could assist coastal property insurers in estimating the benefit of these types of adaptation projects to the insured.

5.3 Case Study #2: India – Cauvery River

5.3.1 Background

The Kaveri or Cauvery (Anglicized version) is a major Indian river flowing through the states of Karnataka and Tamil Nadu. The Cauvery rises in the Western Ghats at an elevation of 1,341 m above mean sea level and flows for about 800 km before its outfall into the Bay of Bengal.[43] The Cauvery is rain-fed and heavily dependent on both the southwest and northeast monsoons.

Figure 7: Path of River Cauvery through the States of Karnataka and Tamil Nadu

Source: NaanCoder – Own work, CC BY-SA 3.0,
https://commons.wikimedia.org/w/index.php?curid=30636315

The Cauvery provides water for irrigation, household consumption and the generation of electricity. The river has supported irrigated agriculture for centuries and served as the lifeblood of the ancient kingdoms and modern cities of southern India. Access to the river's waters has pitted Indian states against each other for decades. The Cauvery's delta is thickly populated and frequently affected by tropical cyclones formed in the Bay of Bengal.

The river basin covers 81,155 sq km and is reported to have an average discharge rate of 677 m^3 per second. Approximately 540 million litres of water per day is diverted from the Cauvery to provide drinking water to Bangalore some 100 km away.

The health of the Cauvery and its interdependent natural and human systems are facing severe challenges, due to both human actions and climate change. This case study illustrates the complexity of the issues faced by this river system and a promising project focused on adaptation.

5.3.2 Water Sharing

For many decades the states through which the Cauvery flows have battled over the sharing of the river. Finally, in 2018, the Supreme Court made a determination as to how the water would be shared, and established the Cauvery Water Management Authority (CWMA) to address the ongoing dispute between the states. A subsidiary Cauvery Water Regulation Committee (CWRC) was also formed to monitor water management on a day-to-day basis, including the water level and inflow and outflow of reservoirs in all the basin states.

5.3.3 Rainfall

Since the Cauvery is rain-fed, changes in rainfall have a significant effect on the flow or discharge rate of the river. In turn, reservoir levels, water for crops and human consumption, and possibly hydro-electricity are all impacted. For example, in August 2003, inflow into reservoirs in Karnataka was at a 29-year low, with a 58% shortfall.[44] Similarly, after the weak 2016 monsoons, the reservoir levels were again at record lows.

Variations in rainfall (e.g., varying strength of the southwest and northeast monsoons) have had a significant effect on reservoir levels from year to year. Further, it is reported that there is a trend towards fewer rain days but heavier downpours leading to greater instances of flooding, landslides and soil erosion. The longer time between rains is making it more difficult for farmers to raise their crops. In recent years, poor rainfall has meant that the Cauvery may run dry before reaching the sea.

Figure 8: Dry Venar River, a Tributary of Cauvery in Thiruchirapalli District

Former Public Works and Irrigation employee A. Deivasihamani showing the dry Venar river, a tributary of the Cauvery in Thiruchirapalli district

The variable nature of monsoons makes India one of the regions most vulnerable to water-related disasters associated with climate change and extreme weather events.

5.3.4 Pollution

The Cauvery has been affected by increasing levels of agricultural run-off as well as untreated waste that empties directly into the river.

5.3.5 Soil Erosion and a Promising Adaptive Measure

Over a 30-year period, there has been a 28% reduction in forest cover along the banks of the river due to the intensification of farming, as well as urbanization along the river.[45] In turn this has resulted in reduced levels of water retention by soil near the river, flooding and soil erosion.

The preservation and rebuilding of forests in the Cauvery watershed can be an effective adaptation measure by reducing the effect of floods and droughts, while recharging groundwater.

In response to the need to revitalize the Cauvery river, in 2019 the Isha Foundation launched a movement, "Cauvery Calling",[46] based on the "tree-based agriculture" model. The plan is to plant 2.42 billion saplings in the Cauvery river basin over a period of 12 years with a view to helping 5.2 million farmers to bring 1.61 million hectares under green cover.

The tree saplings are crowdfunded: anyone can sponsor a tree sapling by donating INR 42 (USD 0.50). These saplings are planted on the land of participating farmers. This removes the constraint of scaling up green cover due to limited forest lands.

The other advantage of adapting using a tree-based agriculture model is that, compared to cash crops like paddy and sugarcane, trees are more resilient to the extreme climates of excess rainfall and drought. Trees also help in improving soil quality, replenishing groundwater by making the soil permeable and revitalizing the Cauvery.

5.3.6 Actuarial Implications

This case study tells the story of a river system that millions of people depend on for drinking water, hydro-electric power, irrigation for farming, etc. It appears that the river can no longer deliver 100% of the needs of all who wish to or must use its waters. All must share in the necessary decisions and compromises in order to avoid unnecessary adverse shortfalls to one group of water users over another. This case study strikes a note of optimism that adaptation measures can make a difference and, if acted on at a sufficient scale (and in combination with other relevant adaptation activities), they can improve the situation for all who use the river.

Actuaries can be of assistance in advising riverine stakeholders such as governments on the collective issues being faced, the impact of further climate change, the favourable effect of adaptation and the risks of inaction. Applying actuarial skills in risk management, health care, mortality, losses, damages, economics, scenario analysis, insurance products, etc., actuaries can advise key stakeholders on the various risks and opportunities involved so that vulnerable populations are protected, and the costs of climate change are shared among a variety of public–private partnerships.

5.4 Case Study #3: Canada – The Cost of Climate Adaptation (IBC/FCM Report)

5.4.1 Background

This case study presents a 2020 Canadian report[47] which highlighted the costs of climate change, adaptation measures and the economic imperative to take advantage of the benefits of adaptation. The Insurance Bureau of Canada (IBC) and Federation of Canadian Municipalities (FCM) commissioned Green Analytics to establish a credible estimate of the investment in municipal infrastructure and local adaptation measures needed to reduce the impacts of climate change in Canada.

5.4.2 Summary of IBC/FCM Report

According to the IBC/FCM report, in the past decade climate adaptation in Canada has progressed from research to public engagement, to actions to reduce the impacts of climate change. All levels of government have developed climate change adaptation strategies and are investing in specific adaptation measures. The IBC/FCM report established the first credible estimate of the investment in municipal infrastructure and local adaptation and disaster mitigation measures needed to reduce the impacts of climate change in Canada.

The report identifies that municipalities, as the owners and operators of 60% of the public infrastructure in Canada, are on the front lines of both the impacts of climate change and the solutions to protect Canadians. However, municipalities cannot shoulder the cost of adapting to climate change alone. The report notes that climate change adaptation is a shared responsibility among all levels of government and will require a long-term commitment to action.

According to the report's findings, "avoiding the worst impacts of climate change at the municipal level will cost an estimated CAD5.3 billion per year, or equivalent to 0.26% of Canada's GDP. Studies have shown that investments in resilient infrastructure have a return on investment of $6 in future averted losses for every $1 spent proactively."

5.4.3 Preparation of Estimates

Adaptation cost estimates were collected for a variety of communities across Canada. As detailed in the IBC/FCM summary document,[48]

> the estimates were based on vulnerability and risk assessments done at the local level, usually by a municipality. The adaptation cost estimates were adjusted to allow them to be compared between communities and added up at the national level. For each location, the estimates in the database included location, such as province or territory; infrastructure type, such as buildings, green infrastructure, roads and water treatment; and climate-related risks, such as drought, erosion, flood, heatwaves and wildfires.

The final database contained 414 adaptation cost estimates for 34 communities across the country. For each community, GDP values were added to the database. The cost of adapting to climate change was then determined relative to the size of the local economy, expressed as a percentage of local GDP.

This analysis determined that an average annual investment in municipal infrastructure and local adaptation measures of CAD 5.3 billion (see Table 1 below) would be needed to adapt to climate change.

Table 1: Estimate of the Annual National Level of Investment in Adaptation at the Local Level

REGION	% NATIONAL GDP	REGIONAL GDP ($ BILLIONS)	AVG REGIONAL COST OF ADAPTATION : GDP (%)	AVG REGIONAL COST OF ADAPTATION : GDP ($ BILLION)
East	5.55	$111.6	3.2	$3.6
North	0.50	$10.1	0.37	$0.04
ON/QC	58.15	$1,168.82	0.12	$1.4
Prairie	22.57	$453.7	0.06	$0.3
West	13.20	$265.3	0.015	$0.04
TOTAL				**$5.3**

Source: IBC and FCM, February 2020, http://assets.ibc.ca/Documents/Disaster/The-Cost-of-Climate-Adaptation-Report-EN.pdf

Given the scale of the long-term cost of adapting to climate change, the report finds that public funding may need to be leveraged by new forms of private capital.

The report's summary document[49] identified that:

- Flood, erosion and permafrost melt are associated with the highest adaptation cost-to-GDP ratios of 1.25%, 0.12% and 0.37% respectively.
- From an infrastructure perspective, buildings, dikes and roads require the greatest investment in adaptation with cost-to-GDP ratios of 2.01%, 1.18% and 0.47% respectively.

- From a regional perspective, Canada's East at 3.20% and North at 0.37% have higher ratios. The four highest costs as a percentage of GDP in the database are coastal communities in Eastern Canada.

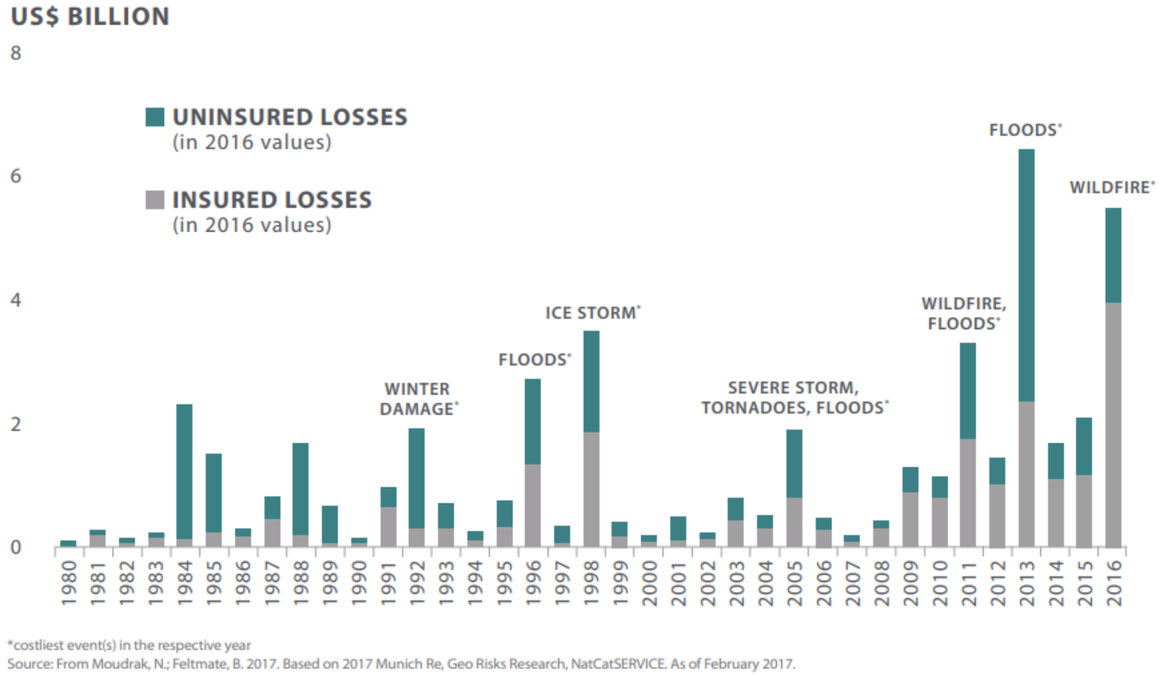
5.4.4 Sharing the Costs of Climate Change

The report notes that insured losses only account for a portion of the full costs attributed to catastrophic weather-related events. Further, the report states:

- that an accepted standard for capital losses is for every dollar of losses borne by insurers in Canada, $3–$4 are borne by governments, households and businesses;
- this sharing of costs varies depending on the type of catastrophic event – for example, insurance policies are less likely to cover flood protection compared with fire protection; and
- the spread of losses borne by governments, households and businesses would be even greater if indirect costs were included.

Figure 9, extracted from the report, provides an example of the additional costs associated with uninsured losses from catastrophic events, illustrating the insurance protection gap by type of damage.

Figure 9: Catastrophic Losses from Natural Disasters, 1980–2016 (Values in USD 2016)



Source: IBC and FCM, February 2020, http://assets.ibc.ca/Documents/Disaster/The-Cost-of-Climate-Adaptation-Report-EN.pdf

Also from the report, Table 2 shows the cumulative natural disaster-related losses split into those covered by federal Disaster Financial Assistance Arrangements (DFAAs), insured losses and those outstanding (i.e., not covered). Importantly, 37% of losses are not covered by insurance, resulting in a potential burden on the various levels of government and taxpayers generally.

Table 2: Cumulative Losses, DFAA and Insurance Payments (2005–2014) ($millions)

	FLOODS		CONVECTION STORMS		HURRICANES		WINTER STORMS		TOTAL	
	LOSSES	% OF TOTAL	LOSSES	% OF TOTAL	LOSSES	% OF TOTAL	LOSSES	% OF TOTAL	LOSSES	% OF TOTAL
Total loss	$12,505	100%	$7,314	100%	$718	100%	$10,452	100%	$30,989	100%
DFAA	$3,465	28%	$20	0%	$138	19%	$1,267	12%	$4,890	16%
Insurance	$4,982	40%	$5,726	78%	$436	61%	$3,552	34%	$14,696	47%
Outstanding	$4,058	32%	$1,568	21%	$144	20%	$5,633	54%	$11,403	37%

Source: Parliamentary Budget Officer of Canada 2016

5.4.5 Benefits of Climate Adaptation

The report cites various studies, in Canada and abroad, of the benefits of adaptation actions to reduce the future costs of climate change.

It includes the following observations:

> The 2016 [Canadian] Office of the Auditor General's report on federal government support for mitigating the effects of severe weather … [cites] Public Safety Canada's estimate that every dollar invested in disaster mitigation in Canada saves $3 to $5 in recovery costs … [50]
>
> In 2017/2018, the US National Institute of Buildings Sciences looked at the results of 23 years of federally funded mitigation grants provided by the Federal Emergency Management Agency (FEMA), U.S. Economic Development Administration (EDA) and U.S. Department of Housing and Urban Development (HUD) and found disaster mitigation funding can save the nation $6 in future disaster costs, for every $1 spent on hazard mitigation. [51]
>
> The NRTEE[52] (2011) found that adaptation strategies are [cost-effective] ways to reduce the economic impacts of climate change ranging in a benefit-to-cost ratio of 38:1 under a high climate change, high growth scenario, to 9:1 under a low climate change, slow growth scenario. In coastal areas, for example, prohibiting new construction in areas at risk of flooding as well as undertaking strategic retreat … reduces the costs of climate change to only 3–4% of what the costs would have been without adaptation. The NRTEE also found that the cost to build a new house, bridge or transmission line that is adapted to climate change for its lifecycle only adds 0–5% to the construction costs. This is significantly cheaper than restoring or rebuilding infrastructure post-damage.

5.4.6 Actuarial Implications

Based on this case study, actuaries can contribute to the greater recognition and use of adaptation measures through, for example:

- fostering greater use of public/private partnerships to reduce protection gaps, make effective use of insurance mechanisms and reduce the fiscalization of climate costs;
- gathering data and research on the costs and benefits of various adaptation measures;
- ensuring that their clients' risk management incorporates climate-related risk expertise, including with respect to the benefits of adaptation measures;
- assisting stakeholders in understanding the uncertainties involved in modelling climate-related risks, including adaptation responses; and

- advising governments on the benefits of adaptation for public infrastructure.

6 Further Considerations

6.1 Time Horizons

Adaptation action can require large upfront investments of human, financial and technological resources, while benefits may only become visible in the next decade or beyond. Accelerated commitment and follow-through are promoted, for example, by rising public awareness, building better business cases for adaptation, accountability and transparency mechanisms.[53] The risk management of climate-related risks and climate change, including adaptation, requires consideration of both short- and long-term perspectives.

Cost-benefit analysis allowing for the expected time horizon of both costs and benefits requires the selection of an appropriate discount rate. This may be lower than a market-based discount rate, to take account of the social value, externalities and uncertainties involved. This is referred to as a social discounting process. This important concept, developed in the first instance by Nobel Prize winner Joseph Stiglitz, is the subject of a paper entitled Social Discounting: Application to the Risk Management of Climate Change.[54]

6.2 Vulnerable Populations

Appropriate consideration of population composition and distribution is critical in understanding the vulnerability of different groups of people.[55] The environmental and health consequences of climate change disproportionately affect low-income countries and poor people in high-income countries, while profoundly affecting human rights and social justice.[56] Climate change is already a driver of migration patterns, and this will increase in future.

Significant questions of social justice may arise in conjunction with adaptation solutions, noting that socially marginalized groups often experience disproportionate exposure to risk and affordability problems. Some approaches can be designed to benefit those who are vulnerable, such as well-placed (relative to those without air conditioning) public cooling centres in areas subject to extreme heat conditions.

For example, a recent UK assessment of future flood risk found that those living in deprived areas, as measured by income distribution, will suffer disproportionately as flood risk worsens. Another study showed how in Phoenix (America's hottest large city), neighbourhoods in the lowest 10% of income distribution are on average 2.5°F hotter than those in the top 10%.

At COP27, developed nations reached an historic agreement to establish a "loss and damage" fund for the benefit of vulnerable nations to help them address the consequences of climate change.[57]

6.3 Coordinated Action

Multiple stakeholders are inevitably involved in adaptation efforts, including governments, regulators, communities, businesses and households, at global, national, state/provincial and local levels. Actions pursued by certain stakeholders may have unintended consequences for others. The pathways for adapting, for example, residential insurance products offered in a particular jurisdiction may be affected by actions taken by national and local governments. These have many interdependencies that need to be recognized in relation to such adaptation tools as building codes, flood and fire defenses, and disaster management.

Greater coordination and engagement across levels of government, business and community serves the move from planning to action and from reactive to proactive adaptation. [58]

Insurance companies can potentially partner with governments at national, regional and municipal levels to establish appropriate regulatory frameworks to promote, for instance, land use planning, building codes and early warning and emergency response systems.

As of 2022, according to a World Health Organization report, half of the countries globally are not yet protected by multi-hazard early warning systems. [59]

The investor community can leverage climate-related disclosures to apply pressure on corporations to pursue adaptation, as well as to reduce emissions. These disclosures should be prepared in a consistent manner with the help of regulators and their advisors. Overcoming data and information issues, as described earlier, needs to be given high priority to make these disclosures meaningful and useful.

The use of detailed risk analyses developed in conjunction with insurance and risk transfer approaches can both raise awareness and provide valuable information to channel risk reduction efforts. By providing a price for these risks, insurance can promote incentives for investing in adaptation and encouraging behaviour that reduces exposure and vulnerability. This can be enhanced by applying underwriting restrictions or premium discounts.

The costs and benefits of adaptation may fall to different stakeholders and over different time horizons. Governments, business, asset owners, service providers and users need to consider both the costs and benefits of adaptation, weighted in a broader context of space and time. Actuaries can support policy development by helping to develop frameworks to quantify and assess direct and indirect costs and benefits, identifying those that are indirect and the uncertainties involved.

The World Bank Group's Action Plan on Climate Change Adaptation and Resilience points to estimates of additional needs for adaptation that range from USD 30 billion to USD 100 billion a year by 2030. It points to public–private partnerships as a key approach to finance adaptation. [60] The private sector can potentially contribute new systems and technologies for adaptation as well as financing, the public sector can provide the required institutional frameworks, and risk can be shared between the public and private parties.

As discussed earlier, uncertainty is central to the interdependent risks involved in adapting to climate change. Its impact for any particular adaptation decision depends on factors such as the time horizon and reversibility of the decision, the relative importance and severity of climate factors for the decision and the costs of buffering the decision against uncertain developments. [61] As described in Section 4, actuarial risk management techniques can help support decision-making under conditions of uncertainty.

6.4 Role for Governments and Supervisors

Effective incentives are required in order to drive the actions required to reduce and manage climate-related risks. Incentives for effective implementation of adaptation action can be provided (1) by governmental rules and regulations, including taxation, or (2) through insurance pricing and product design. However, non-life insurance policies usually only cover one year (other than in rare cases; e.g., Japanese fire insurance or French construction insurance), while climate change impacts are likely to emerge over decades. This mismatch means insurance price increases may not provide sufficient incentive for adaptation action. Hence, public policy responses are required to drive effective adaptation.

6.5 The Role of Disclosure

Ensuring that adequate attention is devoted to adaptation action without detracting from the urgent emphasis that is, of course, required on mitigation efforts is a balancing act. From a governmental perspective, while most countries have published national adaptation plans, political discourse nevertheless gravitates towards mitigation issues. Current corporate climate-related disclosures are almost exclusively focused on mitigation action, with little reference to adaptation. This is an issue that requires the attention of both standard-setters and investors.

Note that the need for climate-related disclosures is receiving attention from standard-setters such as the International Sustainability Standards Board (ISSB) as it plans to finalize two relevant standards (i.e., S1 – General Sustainability-Related Disclosures and S2 – Climate-Related Exposures) in 2023. For more detail on emerging disclosure requirements, see Paper 5 of the above-mentioned IAA series on climate-related risk: Climate-Related Disclosures and Risk Management: Standards and Leading Practices.

7 Conclusion

Adverse outcomes of climate change have already been seen on all continents and in most countries. They are likely to get progressively worse, even with extensive mitigation actions.

The best defense against future climate-related risks and damages is to transform systems proactively to build resilience and to reduce the exposure, vulnerability and inequality that drive disasters and their damages. More extensive risk data and information, enlightened policies and products will help to support actions taken to reduce losses and damages. While there is growing evidence of the benefits of early warning systems, existing early warning systems remain insufficient[62] and more extensive efforts are needed.

As outlined in the AR6 WGII report, "At current rates of adaptation planning and implementation the adaptation gap will continue to grow … As adaptation options often have long implementation times, long-term planning and accelerated implementation, particularly in the next decade, is important to close adaptation gaps."[63] A report by the Canadian Climate Institute has demonstrated that if adaptation is invested in now, many of the ultimate costs of climate change can be halved.[64]

An effective comprehensive risk management process will help to reduce losses and damages. More effective adaptation-related data and information will enable better risk management planning on behalf of both the public and private sectors, on both national/community and personal levels. Without such data and information, managing climate risk-related uncertainty will be difficult.

Developing and enhancing loss models and scenarios and communicating key assumptions and uncertainties can help stakeholders better understand the implications for their organizations, society and individuals. These are core actuarial skills. Actuaries are also experienced in collaborating with other professionals to manage risks and are well placed to contribute to the adaptation risk management process.

Actuaries can contribute to the design of solutions that will help reduce climate-related losses and damages. For example, future building codes will need to reflect potential future climate scenarios, which actuaries can support using stochastic risk assessment tools.

Actuaries can also help design incentives for the private sector to implement solutions through such mechanisms as insurance pricing and product design. They also have a role in the preparation of financial disclosure of risk management actions taken by entities towards the identification, quantification and implementation of adaptation actions.

While the role for non-life actuaries is evident, climate change adaptation will need to be considered across all areas of actuarial practice. Life, health and pension actuaries will need to consider the potential mortality and morbidity impacts arising from the effectiveness (or otherwise) of adaptation actions. They and investment actuaries will need to consider the maturity of climate change adaptation within investment portfolios. Social security actuaries will need to assess the need for changes to social security systems.

To conclude, risk management, cost-benefit and scenario analysis are key requirements for effective adaptation action. The actuarial profession has extensive skills and experience that are directly useful in inter-disciplinary decision-making relevant to climate adaptation. Given the scale of the risks and opportunities posed by climate change and adaptation, actuaries have an important role to play.

8 Next Steps

This paper is the sixth in a series of papers that the IAA Climate Risk Task Force has committed to develop. The first five papers in the series are available on the IAA website.[65] The last paper of seven planned in this series will address the link between climate-related risk scenarios and social security.

The IAA plans to refresh the papers in this series periodically, given the rapid pace of change in the climate-related risk space.

The IAA Climate Risk Task Force welcomes and encourages input and involvement in these activities; please send comments through the IAA Secretariat (secretariat@actuaries.org).

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