# CLIMATE RISK IN INSURANCE INDUSTRY

by

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## Dedication

I would like to dedicate this work to my Father Late Er. C. Mannappan M.E (Master's in engineering) who always worked and lived to help the underprivileged in the world and to my Mother Mrs. Dharani Mannappan who continues to be a constant source of energy and motivation for our entire family.

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ABSTRACT

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As everyone experience in daily life, Climate change is certainly a reality of the world. It is affecting every species in the world and is also reshaping industries and markets from a business angle. Insurance industry is affected in a unique way as climate risk impacts both sides of balance sheet namely assets and liabilities. Over many years, Insurance industry has developed many models based on past trend data including catastrophe models to handle the risk associated with uncertainties. But this is not enough as the climate risk can be handled only with a sophisticated future looking data analysis and a model needs to be developed for handling the impact of climate risk. By combining the perspectives of catastrophe and climate risk models insurance industry can handle climate risk much better. The sooner businesses and investors understand their climate related financial risks; they will be better placed to handle it and create a market differentiation to grow profitable business.

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# INTRODUCTION – CLIMATE RISK

**Climate change** in the world is now a reality. Every Living (Humans, plants, birds, animals and every other living thing in the earth) and non-living things (infrastructures etc.,) in the world are impacted by climate change either by extreme heat waves or by droughts, wildfires, catastrophic flooding and many more climate change related calamities. While climate change creates adverse consequences for all, its impact can be managed through Climate risk management.

Chapter 1 examines the Climate risk and represents a pressing and intricate difficulty that confronts the present world. As our planet experiences significant environmental alterations, the repercussions for both natural ecosystems and human societies are progressively becoming more apparent. All these threats possess far-reaching implications for global economies, public health, and geopolitical stability. Risk in the climate change setting refers to the likelihood and magnitude of current and projected undesired consequences induced by shifts in temperature, precipitation patterns, and total ecosystem disruption. These dangers are especially severe for vulnerable people, such as those in coastal towns, tiny island nations, and places already dealing with economic inequality. Grasping and tackling climate risk requires a multifaceted approach that combines scientific investigation, policy formulation, and global cooperation. One can strive toward a happier and more resilient society for everybody by recognizing, analyzing, and mitigating these risks.

## 1.1. Background and Context

The risk of changing the climate, or the possible adverse effects of changes in the planet's weather patterns, is a multifaceted and extremely complex issue that has gained a lot of attention recently, mostly because of the widespread environmental damage that

has been directly linked to the global warming phenomenon. It includes a broad spectrum of unfavourable outcomes that might arise from changes in regional and global climate trends. The melting of ice caps & glaciers brought on by rising global temperatures raises sea levels, which endangers coastal ecosystems and livelihoods. Variations in precipitation could cause water shortage, affecting human livelihoods, agriculture, and water resources. Climate change disturbs ecosystems and reduces biodiversity, impacting global food chains and species survival. Climate risk worsens air quality and spreads vector-borne illnesses, affecting public health. It also affects the economy, causing losses in real estate, insurance, agriculture, and tourism. To mitigate these effects and protect vulnerable populations, addressing climate risk is crucial.

As a vital tool for managing risks and financial security, the insurance sector is a mainstay of contemporary economies. It provides a safety net to individuals, organizations, and governments against many unforeseen tragedies, including accidents, natural disasters, illnesses, and life events. In return for premiums, insurance firms provide policies that are used to pay claims in the case of covered occurrences. This is a broad sector that includes reinsurance as well as life, health, property and casualty, and specialty insurance. In addition, insurers are essential to the investing process since they oversee large portfolios that support the stability of the financial markets. To ensure that it continues to be an essential part of both economic and societal resilience, the insurance industry constantly adjusts to shifting risks and regulatory contexts. The insurance industry's continuing endurance and adaptation are demonstrated in (Figure. 1.1) which shows the industry's amazing persistence in the face of changing circumstances.


***Figure 1.1:*** *The resilience of the insurance sector (Vishaka, 2021).*

Climate risk is becoming a more significant and intricate problem for the insurance sector. The industry is experiencing a rise in the frequency and intensity of climate-related disasters including wildfires, hurricanes, and flooding, which calls for a thorough review of danger models, underwriting procedures, and capital sufficiency. Changing regulatory environments about risk assessment and climate disclosure is another challenge for insurers. This risk affects policyholders and their surrounding areas in addition to having financial ramifications. In response, the industry has introduced novel products such as parametric insurance and has prioritized sustainability. In addition to being essential for the financial stability of insurers, comprehending and efficiently controlling climate risk is also necessary to guarantee sufficient protection for people, companies, and communities in a changing environment.

### 1.2. Climate Risk

Climate change has become an indisputable actuality, exerting influence on every aspect of the world, encompassing biological organisms as well as inanimate infrastructure. The repercussions are extensive, materializing as exceptionally high

temperatures, periods of drought, uncontrolled fires, and catastrophic inundations, among other devastating events. The idea of handling climate risks has gained importance as a crucial strategy for mitigating and adjusting to the effects of climate change in response to these enormous difficulties. At its essence, climate risk management entails a systematic examination of the outcomes, probabilities, and reactions to the effects of climate change. Societal constraints play a significant role in shaping adaptation options, as acknowledged by the definition provided by (Adger, 2018) (Baum, 2018). The urgency for implementing such management strategies has seen an exponential increase, because of the ever-expanding perils occasioned by climate change that affect both biotic and abiotic components of Earth's ecosystem. This pivotal institution, through an extensive process of conducting thorough research and comprehensive analysis, has been able to amass a wealth of knowledge that is then disseminated via a series of annual reports. These papers serve as priceless tools, offering vital information about the state of the environment today, its complex ramifications, and a range of viable strategies that may be applied to lessen its negative effects. The IPCC is a global organization that evaluates climate risks and shapes international policies and discourse (CHANGE, 2007). On this project, experts from a variety of fields work together to comprehend the issues brought on by global warming and create workable preventative solutions. Climate risks are multifaceted and affect diverse ecosystems and human systems. A poignant reminder of how vulnerable natural ecosystems and human systems are to the unpredictable and volatile character of climate variations are recent severe weather events, such as extended periods of erratically warm temperatures, extended periods of little or no rainfall, major increases in water levels leading to common flooding, deadly tropical storms with rapidly shifting air masses, and uncontrollably spreading fires through vegetation. In response to this imperative, communities of researchers on a global scale are diligently investigating

and experimenting with a range of diverse approaches to the management of climate-related risks, encompassing innovative technological advancements, comprehensive policy frameworks, and grassroots-driven initiatives rooted within local communities. All these endeavours are aimed at bolstering the capacity of societies to withstand and adapt to the increasingly precarious circumstances resulting from the incessantly shifting climatic conditions.

Climate risk is a major worry for small-scale farmers and pastoralists, particularly in desert areas, because it adds to rural poverty and destroys their long-term livelihood possibility, stifling agricultural investment. The role of production technologies like Utilizing crop germplasm adapted to stress, conservation agriculture, and diverse production systems might help stabilize agricultural output and incomes and lessen the negative effects of climate-related risk. It also emphasizes how crucial institutional interventions are in helping farmers manage risk and safeguard their assets, such as index-based protection and social protection via adaptable safety nets. The success rates of these initiatives in assisting a sizable proportion of extremely poor farmers to overcome poverty are not well supported by the available data (Hansen *et al.,* 2019).

It focuses on climate risk management in agriculture. It discusses the use of seasonal climate forecasts (SCFs) to help in agricultural decision-making. The tercile chances of rainfall categories that are frequently released are difficult to convert into measures that are helpful for decision support, and SCFs are presented in formats that do not help make decisions. To generate relevant data that would aid in making tactical and strategic decisions regarding crop production, the research suggests connecting SCFs with crop models. The software tool developed, Climate-Agriculture-Modeling and Decision Tool (CAMDT), aims to facilitate the translation of probabilistic SCF to crop

responses that can help decision-makers adjust crop and water management practices. CAMDT can be used for exploring different agronomic techniques considering an anticipated seasonal environment, helping to create more intelligent climate adaptation plans. The article highlights that rather than attempting to identify an optimal solution, CAMDT could be used primarily to explore several choices that satisfy stakeholders' interests. A useful tool called CAMDT links seasonal climate data to a crop simulations model, improving risk control in agriculture with practical applications. Tiny-scale Danger is a major issue for farmers and pastoralists, particularly in dryland areas, as it exacerbates rural poverty, eliminates their long-term means of subsistence, and discourages agricultural investment (Han *et al.,* 2017). It talks about how production technologies like conservation agriculture, diverse production systems, and crop germplasm that are adaptable to stress can stabilize agricultural output and incomes and lessen the negative effects of climate-related risk. It also emphasizes how crucial institutional measures are in helping farmers manage risk and safeguard their assets, such as index-based coverage and social protection via adaptable safety nets (Figure 1.2). The successes of these initiatives in assisting a sizable proportion of extremely poor farmers to overcome poverty are not well supported by the available data. To pinpoint and target farming communities and locations where better climate risk control could expedite efforts to lower rural poverty, more research is required.

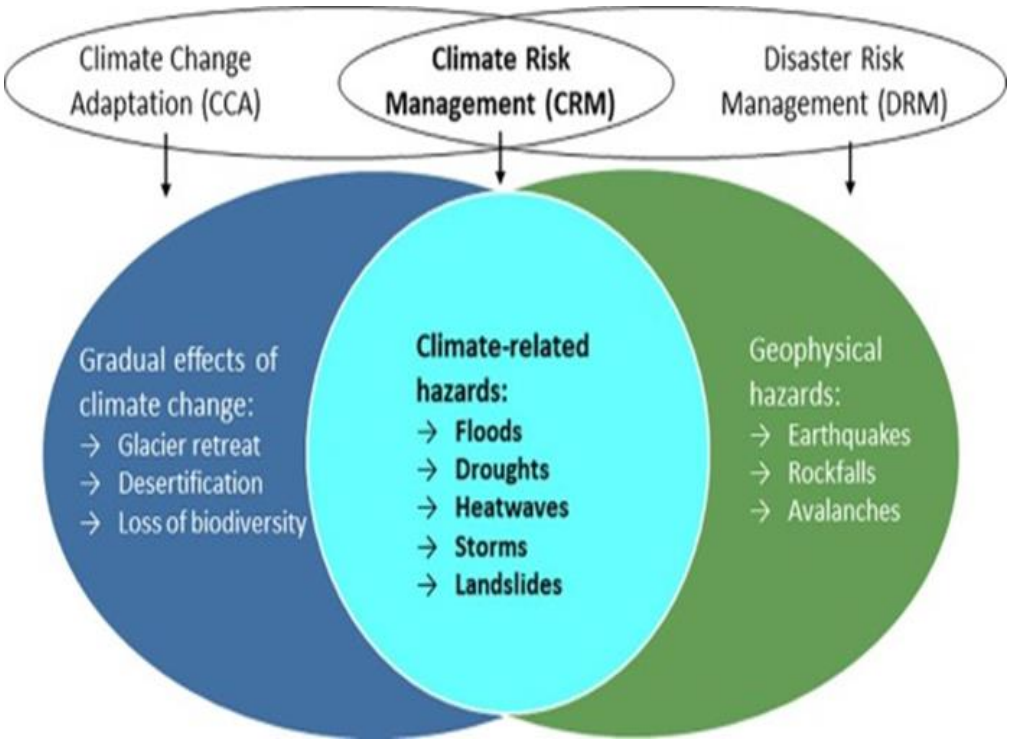


***Figure 1.2:*** *Analysis of Climate Risk Management (*Leitner *et al.,* 2020*).*

It acknowledges the complexity and deep uncertainty in CRM, as climate risks are difficult to quantify across spatial and temporal scales. The paper emphasizes the importance of identifying community members' beliefs and values regarding risk factors and CRM strategies, especially in the face of deep uncertainty, high complexity, and difficult value tradeoffs. It concludes that values should be considered alongside beliefs in understanding and addressing climate risk factors and CRM strategies.

### 1.2.1 Types of Climate Risk

The phrase "climate risk" refers to the unfavorable consequences and challenges brought on by changes in weather patterns and the effects of global warming. These risks can be divided into several groups: Hurricanes, which are floods, fires, flooding, and rising seas are merely a few examples of the extreme weather occurrences that global warming is directly creating. Physical climate risks can lead to damage to infrastructure,

disruption of agriculture, and threats to human lives. Transition hazards are associated with the global shift towards an economy that is low-carbon and sustainable. They include policy changes, technological advancements, and market shifts that can impact businesses and industries heavily reliant on fossil fuels or carbon-intensive practices. Companies may face financial losses due to stranded assets and regulatory changes.

The preferences for climate risk disclosures show how these needs are influenced by weather-specific disclosure costs and benefits. The research also cites the UK obligatory carbon disclosure law, the investor alliance that supports Climate Action 100+, and French Article 173 as instances of climate risk declarations that are looked at (Ilhan *et al.,* 2023). Highlighted are the TCFD guidelines, which center on how measurements and objectives, together with administration, strategy, and risk management, reflect climate threats. Based upon the SEC's interpretative advice, which requires businesses to report substantial risks related to climate change in their 10-Ks, the article discusses the application of text-based metrics of climate risk reporting in the 10-It of US sample corporations.

Future climate risk discusses the distribution of climatic drivers and associated hazards in the present and future climates. It explores the increase in dependence in the upper tail of both drivers in a future climate, which can lead to higher intensity hazards. It mentions that the hypothetical hazards include human heat stress and fire risk. The paper aims to understand the potential risks and impacts of compound events in future climates (Abhayawansa and Adams, 2021).

It assesses the suitability of non-financial reporting systems for reporting on pandemic and climate risk in sectors that were affected by the COVID-19 outbreak and are vulnerable to climate change. It concludes that pandemic and climate change risk reporting is insufficient, emphasizing the short-term hazards of more regulation above

physical threats. In addition to suggesting an entirely novel concept of materiality, the study suggests centering future reporting frameworks around the possibilities and hazards related to sustainable development. To identify the scope and nature of the main hazards to sustainable development and to establish practical mitigation measures, more investigation is required.

It tackles the study topics of whether the non-financial reporting frameworks in place are sufficient and how firms that are vulnerable to risks connected to pandemics and climate change are reporting on these risks (Woetzel *et al*., 2020). It looks at risk declarations from the biggest airlines, cruise lines, and hotel chains regarding pandemics and climate change. The study emphasizes how susceptible these sectors are to virus outbreaks and the effects of climate change, and it calls for significant participants in these sectors to provide more accurate risk reports.

#### *1.2.1.1 Physical Climate Risk*

The negative effects of warming temperatures on infrastructure, the environment, and human health are referred to as physical climate hazards (Nkonya *et al.*, 2015). Climate change causes threats that might have a big influence on numerous sectors (Figure 1.3). Some key physical climate risks include:

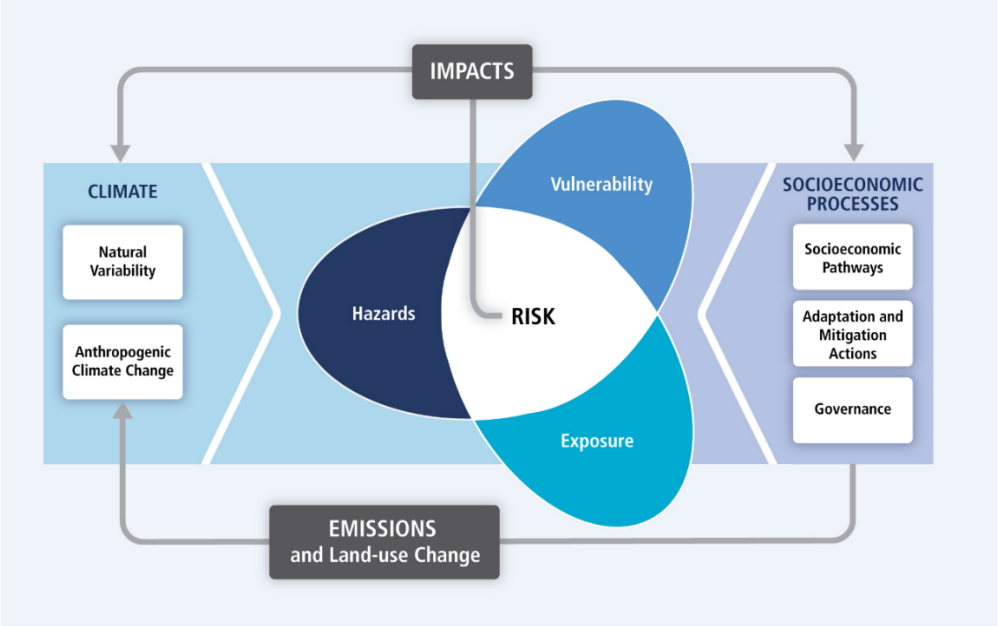


***Figure 1.3:*** *Analysis of Physical Climate Risk (Field et al., 2014).*

Climate change leads to an increase in the frequency and intensity of extreme weather events, such as hurricanes, droughts, floods, and wildfires. High temperatures can damage crops, strain energy systems, and threaten public health, while extreme cold events can disrupt transportation and energy infrastructure. Climate change, including more precipitation and flooding, has the possibility of having a significant impact on agriculture, water resources, food supply, property damage, and infrastructure failure. It also leads to species distribution shifts and biodiversity loss, affecting agriculture, fisheries, and human societies reliant on natural resources (Bonebrake *et al.,* 2017). Physical climate risks can have direct health implications, such as heat-related illnesses during heatwaves or the spread of diseases in altered ecosystems. These health risks are exacerbated by climate-related events like hurricanes and flooding. Socioeconomic variables complicate the problems brought on by changing climate conditions by having a considerable impact on resistance and vulnerability to physical climate threats. Because they have less access to resources and fewer housing alternatives, vulnerable populations

often identified by lower socioeconomic status—face disproportionate effects. Richer people or places may make investments in early warning systems, effective evacuation plans, and robust infrastructure, while poor communities find it difficult to mobilize resources, which exacerbates climate-related calamities. The ability to recover economic sectors is partly determined by the socioeconomic fabric since disruptions caused by climate change can have a domino impact on industry, agriculture, and livelihoods. Communities that rely on climate change-prone businesses like fishing and agriculture are particularly vulnerable. Understanding these socioeconomic nuances and emphasizing customized adaption plans, fair resource allocation, and community empowerment are necessary for effective climate risk management.

Physical climate risk is the potentiality of experiencing detrimental consequences and financial detriments due to calamities precipitated by the alteration of climate patterns. Physical climate hazards encompass unforeseen, severe, and predominantly ephemeral occurrences such as:

**Flooding:**

- Flooding in bodies of water brought on by heavy rains or
- Melting of ice and its related flooding in Oceans or Surface
- Flooding in coastal areas because of strong winds which can create high tides in Oceans.
- Drought
- Wildfires
- Hurricanes, cyclones, and other wind-related extreme climate risks
- Variations in temperature associated with climate threats.

Physical climate risks encompass a range of potential threats, including those that exhibit a gradual progression in their impacts over time. These slow-onset risks possess

the capability to induce sustained alterations in climate patterns, thereby engendering long-lasting consequences for crucial aspects of our societal and economic systems, including the intricate networks of supply chains that facilitate the movement of goods and services. Moreover, the ramifications of such risks extend beyond the mere functional realm, with the potential to significantly influence property value, thus warranting careful consideration and proactive mitigation strategies.

- Changes to local rainfall patterns over time increased or decreased rainfall
- Lack of water
- Sustained shifts in average temperatures and humidity
- Rise in sea level

Climate shocks and climate stressors are distinguished by the Task Force on Climate-related Financial Disclosure (TCFD), which classifies them as acute and chronic hazards, respectively. Because they happen suddenly, acute risks need to be addressed right away, but chronic risks develop gradually and call for preventative and remedial actions to avoid more significant permanent effects. The concept of physical climate risk, as outlined by the Intergovernmental Panel on Climate Change, encompasses the amalgamation of exposure, hazard, and vulnerability. These components frequently coexist, weaving a complicated web of relationships. An additional layer of complexity to the research is the variation in the consequences of physical climate risk across different regions and assets.

Both sudden shocks and slow-onset stressors must be taken into account in a thorough study of physical climate risk, taking into account their unique qualities and interdependencies. The framework of the TCFD emphasizes the need for a comprehensive grasp of the complexity inherent in climate risk assessments and offers companies and communities a useful lens through which to analyse and manage these

risks. Identifying and resolving these problems is essential to constructing climate change resilience.

#### *1.2.1.2 Transition Climate Risk*

The term "transition risk," as used here, refers to the difficult and expensive process of transitioning to a low-carbon economy, which is made necessary by modifications to environmental and or climate legislation, breakthroughs in technology, and changes in public attitudes (Zscheischler *et al.,* 2018). It is important to note that transition risk poses a particularly pressing concern for companies that heavily rely on energy and fossil fuels, as its impact has the potential to exacerbate over time, potentially giving rise to significant fluctuations in asset prices and the emergence of so-called "stranded" assets. As part of this study, two innovative climate risk indicators have been developed through the utilization of text analysis techniques, thereby allowing for the identification and quantification of transition risk within financial markets. In particular, the methodology utilized in this study entails a thorough examination of scientific literature related to global warming, which subsequently facilitates the creation of indicators that accurately distinguish between transition risk and physical danger.

Transitioning towards low-carbon technologies represents a momentous stride in the pursuit of a robust economy and a forthcoming era characterized by diminished greenhouse gas emissions. This changeover from petroleum and coal to sources of clean energy has dangers, including the potential for industry upheaval, restructuring of the economy, and job displacement. It is imperative to address these socioeconomic obstacles to ensure a just transition for impacted communities. Investments in renewable energy sources and infrastructure carry inherent risks, encompassing challenges in finance, technology, and regulations. Supply chain risks are introduced by renewable energy

technologies' reliance on essential minerals. Significant legal and policy frameworks are needed for the transition, and ineffective or inconsistent regulations might affect the transition's efficacy by creating market uncertainty. To manage climate hazards, a comprehensive strategy that includes strong laws, and investments in innovation.

This endeavor brings forth a range of climate-related risks that necessitate careful consideration. The transition from fossil fuel-dependent industries to renewable energy sources could lead to economic disruptions, job losses, and difficulties in certain regions Moreover, supply chain vulnerabilities are a concern due to the reliance of renewable energy technologies on specific minerals and metals. The significance of policy and regulatory risks cannot be overstated, as uncertainties or sudden policy changes can adversely affect investor confidence and impede the growth of renewable energy projects. Similarly, technological and innovation risks loom large, as the transition necessitates continuous innovation, which can lead to project failures or suboptimal performance. Financial risks, social and community challenges, and infrastructure resilience are crucial factors in the transition to low-carbon energy (Figure 1.4). These include long payback periods, revenue uncertainties, and potential policy changes. Addressing these risks is essential for a fair and inclusive transition. Infrastructure resilience is also crucial due to climate change's potential impact on renewable energy installations, especially in extreme weather events.

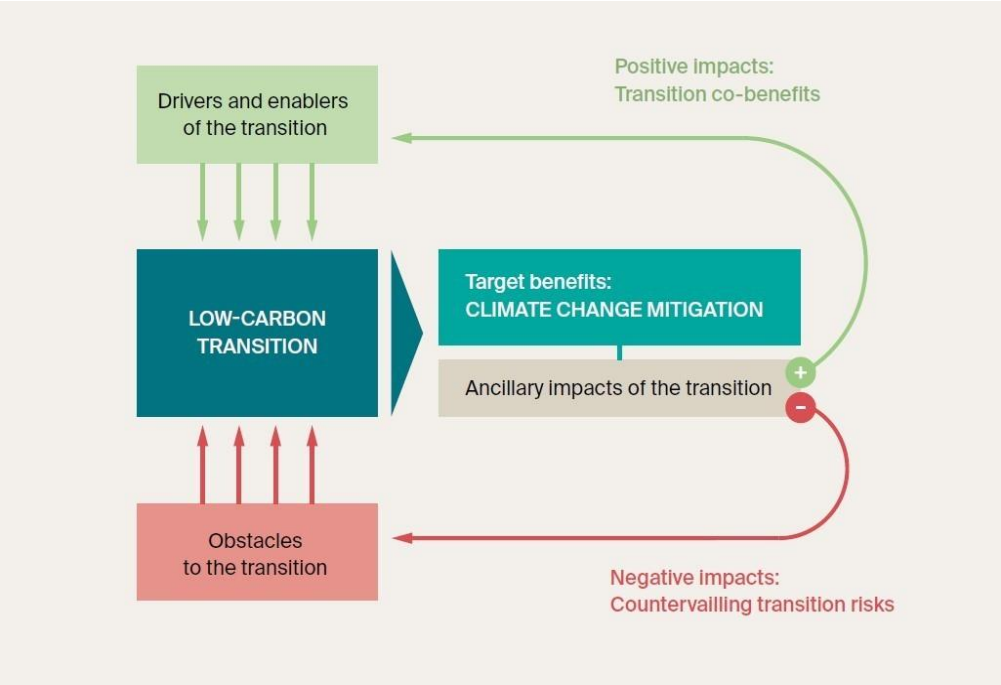


***Figure 1.4:*** *Analysis of Transition Climate Risk (Collins, Florin, Sachs, 2021).*

***Transition climate risks also include:***

- Stranded assets and their depreciation
- Increased capital expenditure for upgrading equipment or insulating buildings.
- Increased costs due to impacts on the supply chain or the costs of raw materials
- Legal liability for failing to comply with regulatory requirements.

In navigating the challenges posed by climate change, organizations must recognize the interconnected nature of physical and transition climate risks. To make informed decisions, businesses should assess both the immediate impacts of physical risks and the longer-term consequences associated with transition risks. A comprehensive

evaluation considering various periods and climate scenarios is crucial. By understanding the combined effects of these risks on their assets, organizations can develop strategies to enhance resilience. This integrated approach is imperative for insulating businesses from the inevitable and evolving threats posed by climate change, fostering sustainability, and ensuring adaptability in the face of a dynamically changing climate landscape.

### 1.2.2 Understanding Climate Change

In the contemporary era, it is imperative to grasp the concept of climate change owing to its vast and notable impacts on both the natural surroundings and human society. Climate change refers to the enduring alterations in precipitation, temperature, and various other atmospheric conditions, and these transformations primarily arise from human activities, encompassing the combustion of non-renewable energy sources, deforestation, and industrial operations. The global rise in temperatures heightened severity and frequency of meteorological phenomena, and alterations in ecological systems all serve as indicators of the repercussions of climate change. The excess release of greenhouse gases into the atmosphere, especially carbon dioxide, is the main cause of climate change. The gradual heating on the Earth brought on by gases that are trapping heat is referred to as "global warming." Studying the science underlying climate change includes examining data analysis, historical climate record evaluation, and climate models. Scientists and researchers are essential in monitoring and forecasting these shifts. Recognizing the socioeconomic effects of warming temperatures, such as community relocation, security of food and water, and financial stability, is also crucial.

A multifaceted strategy is needed to address climate change, including human acts, legislative reforms, international collaboration, and technology innovation. While adaptation techniques concentrate on anticipating and lessening the effects of the changes currently in motion, mitigation measures seek to minimize future warming by reducing

greenhouse gas emissions. Public awareness and education about climate change are vital in motivating collective action and encouraging sustainable practices.

Long-term variations in Earth's weather and temperatures are called "climate change," and human activity such as the combustion of petroleum and coal and deforestation is mostly to blame. The increasing greenhouse effect, which is brought on by growing quantities of greenhouse gases that hold heat in the atmosphere, is the main culprit for this. The effects of this include altered weather patterns, higher seas, and global warming The economy, environment, and public health are only a few of the many negative repercussions of global warming. Extreme weather events are occurring more frequently and with greater severity, endangering coastal towns. An important worry is the rising sea levels caused by ice caps and glaciers melting. Food insecurity results from changes in precipitation patterns that impact agriculture. Loss of biodiversity is increasing as ecosystems become more difficult to adapt.

Mitigating climate change requires global efforts to minimize emissions of greenhouse gases through conservation initiatives, energy from alternative sources, and sustainable behaviours. Uniting nations in the fight against climate change is the aim of international agreements like the Agreement of Paris and adaptation measures. Public consciousness, alterations in policy, and individual initiatives assume pivotal roles in cultivating a sustainable future and diminishing the repercussions of this intricate and pressing global predicament.

### 1.2.3 Impacts on Various Sectors

The evaluation report "Impacts resulting from recent climate-related extremes, including but not limited to heat waves, droughts, floods, cyclones, and wildfires, bring to light noteworthy susceptibility and exposure of certain ecosystems and numerous human systems to the existing climate variability" (Assessing and Managing, 2018).

The phenomenon of climate change has extensive implications in several domains, presenting noteworthy obstacles for economies, society, and ecosystems. Some of the key sectors affected include:

Changes in temperature and precipitation patterns disrupt growing seasons and crop yields (Lesk *et al.,* 2021). Food security problems arise from prolonged droughts, an increase in insects, and severe storms that damage food production. Altered precipitation patterns and melting glaciers impact freshwater availability. Water shortage can result from diminishing water resources, impacting metropolitan areas, industries, and agriculture. As the temperature rises, infections can spread more quickly and be brought on by heat-related ailments. Increased air pollution and allergenic pollen can harm respiratory health. Infrastructure, including buildings, bridges, and roads, is harmed by harsh weather and sea level rise. Changes in temperature and weather patterns affect energy production and distribution. Heatwaves can strain power grids, while hydropower generation may be disrupted due to altered water flows. A species' incapacity to adapt might lead to habitat loss and eventual extinction. Climate risks can impact financial markets and investments. Physical risks, regulatory changes, and market shifts can influence investment decisions and asset valuations. Changing climate conditions impact tourism by altering travel patterns. For instance, warmer winters affect ski resorts, while extreme weather events disrupt travel plans (Cavallaro *et al.,* 2017). Due to increased resource scarcity and dislocation, climate change has the potential to worsen already-existing conflicts. It may also create new security challenges. Extreme weather events and sea-level rise disrupt transportation systems. Damage to roads and airports hinders mobility and supply chains. To lessen the detrimental effects of warming temperatures on these industries, adaptation and mitigation measures are required. These tactics include switching to renewable energy, putting sustainable farming methods into effect,

strengthening the resilience of the infrastructure, and attending to public health issues. Multisectoral cooperation and informed policymaking are essential to confront the challenges presented by climate change effectively.

The insurance sector is essential to the health and survival of many different economic sectors. Its effects are far-reaching, impacting not just individuals but also corporations and the larger financial scene. Businesses might feel safer when they have insurance because it reduces the financial risk of unanticipated occurrences like accidents, natural catastrophes, and legal penalties. Because of this, companies may function with assurance, understanding that they are guarded against any damages. The accessibility of insurance coverage promotes measured risk-taking by investors and business owners, which promotes innovation and economic expansion. Businesses that have insurance as a safety net are more inclined to embark on ambitious undertakings and endeavours. Insurance shields individuals and their loved ones from unanticipated medical bills resulting from mishaps, illness, or property damage.

The insurance business has a big influence on the housing sector since it protects both lenders of mortgages and property owners. This stability contributes to a healthy housing market and facilitates the availability of loans for property purchases. Trade credit insurance supports international commerce by protecting businesses against the risk of non-payment by foreign buyers. This facilitates smoother global trade transactions and promotes economic interconnectedness. The healthcare industry depends on health insurance to make sure people can obtain medical treatment without having to worry about heavy financial obligations. This, in turn, supports the healthcare industry by providing a consistent revenue stream. Providing insurance for major infrastructure projects, such as building and transportation, promotes investment in these fields.

Insuring against potential damages or delays makes these projects more attractive to investors and stakeholders.

An important source of jobs is the insurance sector itself People work for insurance companies in a range of capacities, including revenue, financing, risk evaluation, and claims processing. Overall job stability is influenced by the health of the insurance industry. Insurance rules safeguard policyholders and preserve public confidence in the sector by guaranteeing the financial viability of insurance businesses. Additionally supporting the general stability of the banking sector is this regulatory system. As people become more conscious of the hazards associated with climate change, the insurance sector helps to encourage companies and individuals to embrace sustainable practices. Climate-related insurance products aid in the management and reduction of the effects of environmental problems.

### 1.3. Insurance Industry

The insurance industry might be very beneficial in reducing the threat posed by climate change. In reaction to climate change, the global insurance sector has greatly stepped up its efforts. When it comes to handling disasters, the insurance business naturally has an advantage. The insurance business has backed the creation and advancement of early warning systems for weather-related disasters in susceptible areas (Kong and Sun, 2021). Large insurance companies have formed cooperative associations to advance the insurance industry's response to climate change. The insurance industry can provide corresponding insurance products and risk management techniques to handle the risks brought on by climate change. To reduce both social and economic risks related to climate change, it has improved global collaboration, backed early warning systems, and created insurance and risk management strategies.

Because of the rise in severe events and natural hazard-related damages, climate change presents serious challenges and dangers to the insurance sector. By offering suitable methods for climate change insurance, the insurance sector contributes significantly to both adaptation and mitigation of climate change. Some insurance companies have implemented measures to predict the impact of climate risks, empower their employees, and assess and mitigate greenhouse gases (Hamzeh *et al.,* 2022). However, there are still companies that lack plans for these actions.

Risk-based pricing and annual re-pricing are considered high-priority strategies for insurance companies to address climate change (Daddi *et al.,* 2018). A multitude of economic sectors are impacted by climate change, including the insurance, forestry, agricultural, and tourist businesses. To address the difficulties posed by climate change, the insurance industry works in partnership with authorities, reinsurer associations, business and industrial sectors, civil society groups, and other suppliers of risk administration and insurance services.

The insurance sector is essential to solving the complex problems that climate change presents. Insurance companies are discovering it more and more challenging to pay for the rising expenses of property damage, economic disruptions, and deaths when severe weather events occur more frequently and intensely. The insurance sector faces distinct risks due to climate change, which has caused an important change in the way insurers evaluate and handle these difficulties. A key aspect influencing the insurance sector is the rise in natural disasters such as hurricanes, floods, wildfires, and storms. The increasing number of these occurrences puts pressure on insurers' financial resources, requiring a review of risk assessments and premium structures. It is difficult for insurers to effectively anticipate and manage the corresponding hazards due to the unpredictable nature and seriousness of climate-related occurrences. In addition, the insurance sector is

becoming increasingly concerned about whether areas are insurable. Certain regions may see more extreme weather occurrences because of climate change, making typical insurance coverage impractical or unaffordable. This calls into question the cost and accessibility of insurance for both people and companies operating in high-risk areas.

The significance of proactively participating in climate risk assessments and integrating weather-related data into their processes for making decisions is also being acknowledged by insurers. Insurers may now more fully comprehend the possible effects of global warming on their insurance holdings and modify their policies with the use of sophisticated modelling tools and data analytics. This might entail looking at new financial instruments to reduce risk, reviewing underwriting procedures, and allocating enough reserves for claims due to climate change. Furthermore, resilience and adaptation strategies are greatly aided by the insurance sector. Insurers help people and organizations adopt policies that reduce their exposure to hazards associated with climate change by providing monetary rewards for risk elimination and mitigation (Schäfer *et al.,* 2019). This might involve establishing infrastructure that can survive harsh weather occurrences, improving disaster preparedness, and putting sustainable building techniques into effect.

The collaboration of the insurance industry and the government is imperative in establishing comprehensive frameworks and regulations that adeptly address the inherent risks entailed by climate change Governments may encourage insurers to actively engage in mitigating climate risk by offering regulatory support and incentives, while insurers can offer invaluable insights and data to help climate resilience measures (Figure 1.5). The insurance sector is establishing the benchmark for how to confront the challenges presented by climate change in addition to protecting their financial interests, insurers are helping to create a more resilient and environmentally friendly society in the face of

climate change by reconsidering risk models, advocating resiliency measures, and by actively engaging with climate risk evaluation and management.

***Figure 1.5:*** *Insurance Industry (EHL Insights, 2022).*

### 1.3.1 The Insurance Industry's Role

It undertakes a thorough analysis and examination of the numerous obstacles and difficulties that the insurance industry encounters in its endeavor to enhance the level of customer experience it provides, optimize its business processes, introduce novel and innovative products, and adequately prepare for the intense competition it faces from other sectors and industries Moreover, the current investigation delves into the profound and far-reaching influence and consequences that the introduction and widespread implementation of digitalization have on multiple crucial aspects of the insurance sector (Eling and Lehmann, 2018). These aspects encompass the

inherent imbalance in the availability of information, how risks are consolidated, the severity and frequency of losses, and the interconnectivity of its systems. The ultimate objective of this study is to furnish a comprehensive and meticulous analysis of the intricate and multidimensional repercussions that the process of digitization has exerted on the insurance industry. Additionally, it aspires to ascertain and pinpoint potential avenues for further research from both academic and industry standpoints. Furthermore, this aims to compile an exhaustive database that encompasses all pertinent research endeavors undertaken on this subject matter.

The insurance industry in the country of Ghana delved into an in-depth analysis that specifically examines the various dimensions of trust and their significant influence on customer engagement within the context of life insurance. The paper places a particular emphasis on the crucial role of establishing and nurturing customer trust within the insurance industry to propel and cultivate customer engagement and ultimately foster loyalty among clientele. It explicitly highlights that trust, both in the service provider and in the regulatory body overseeing the industry, serves as a fundamental driver of customer engagement in the insurance sector. The notion is that for insurance companies to effectively cultivate trust among their customers, they must eradicate any factors or practices that breed distrust, such as unwarranted delays in settling claims and the imposition of hidden charges (Agyei *et al.*, 2020). By eliminating these detrimental elements, insurance companies can bolster their trustworthiness, thereby significantly enhancing customer engagement The report also highlights how crucial it is that the regulatory agency, in this case the National Insurance Commission, closely monitors the activities of insurance businesses to ensure that they are compliant with the law. This proactive approach to regulation not only serves to build customer trust but also effectively increases customer engagement. Considering the findings, the paper

prescribes specific strategies that the insurance industry should adopt to foster trust and subsequently encourage customer engagement (Figure 1.6). These tactics include giving competitive and reasonably priced insurance plans, supplying time-saving services, and guaranteeing complete secrecy of client data. By implementing these strategies, the insurance industry can effectively earn the trust of customers and thereby actively encourage and promote customer engagement.


***Figure 1.6:*** *Function of the insurance sector (Knowledge, 2022).*

### 1.3.2 Providing Financial Protection

The primary goal of the insurance sector is to safeguard people financially. This job has greater significance in the larger picture of climate change. Events linked to climate change, such as hurricanes, floods, fires in forests, and unusual weather patterns, put people, companies, and governments at serious financial risk. In situations like this, insurance acts as a vital safety net (Figure 1.7).

***Figure 1.7:*** *Financial Protection (Pilkington, 2023).*

People depend on insurance to shield their houses, possessions, and cars from harm caused by the environment. Insurance plans to aid in the recovery process for homeowners by paying for replacement or repair expenses after a calamity. In a similar vein, covering for losses brought on by severe weather occurrences may be obtained through motor insurance. For businesses, climate risks can result in substantial financial losses. Insurance policies tailored to commercial needs offer protection against property damage, business interruption, and liability claims stemming from climate events (Carrera *et al.,* 2018). These policies assist corporations in effectively addressing the difficulties presented by climate change and sustaining their activities, thereby ultimately making a significant contribution to ensuring economic stability. On a broader scope, governments employ insurance to effectively handle the financial repercussions stemming from climate-related catastrophes. Public entities may obtain coverage to reduce the fiscal burden associated with disaster response and recovery efforts. This allows governments to allocate resources more effectively during emergencies. One innovative approach to financial protection in the face of climate change is parametric insurance. This type of policy automatically disburses funds when predefined climate

triggers, such as wind speed or rainfall levels, are met. It provides rapid access to liquidity, enabling a swift response to disasters.

The insurance industry plays a pivotal role in facilitating financial recovery and resilience. It facilitates efficient management of these difficulties by dispersing the financial weight of climate hazards over a wide range of stakeholders, including individuals, corporations, and governments. The insurance industry's capacity to offer financial security will remain a crucial element of global adaptation and resilience plans as climate change accelerates (Jarzabkowski *et al.,* 2019).

#### *1.3.2.1 Financial Implications for the Insurance Industry*

As a result, insurers are confronted with the daunting task of assessing and pricing climate risks accurately. Climate change's unpredictability and long-term impacts further complicate the industry's financial landscape. Insurers must bolster their financial reserves to cover escalating claims while maintaining their ability to provide coverage for new policyholders. This necessitates a delicate balance to ensure the industry's stability and solvency. Moreover, the insurance sector has a vested interest in fostering resilience and mitigating climate risks, as proactive risk reduction can help contain financial losses. On the investment side, insurance companies manage vast portfolios of assets. These investments are vulnerable to the effects of climate change, especially those associated with petroleum, coal, and high-carbon sectors. As global efforts to combat climate change intensify, stranded assets and the devaluation of carbon-intensive holdings could affect insurers' financial performance. To mitigate risk and adjust to a dynamic economic environment, insurers are progressively integrating climate risk into their investment plans (Munge and Kitiabi, 2017). Modifications to regulations also have a substantial financial effect on the insurance industry. As governments and international bodies

implement climate-related regulations and reporting requirements, insurers must allocate resources to ensure compliance. In this evolving climate, the insurance industry must remain vigilant, adaptive, and innovative to navigate the financial challenges posed by climate change. While the industry is dealing with more risks and complexity, it also can influence good change by encouraging risk mitigation, supporting sustainability, and providing creative ways to deal with the financial effects of climate change (Rahman *et al.,* 2018).

### 1.3.3 Assessing and Managing Risks

The potential hazards and repercussions are significant as the globe faces rising temperatures, intense weather events, altering climate patterns, and rising sea levels. Here are key aspects of assessing and managing climate risks (De Vivo *et al.*, 2021).

***Risk Recognition:*** Understanding hazards is crucial for making decisions in various industries like project management, insurance, and finance. This involves identifying potential hazards, uncertainties, or opportunities that could impact objectives or outcomes. Risk identification encompasses the examination of economic downturns, market fluctuations, and other variables that influence the performance of financial investments. It entails assessing the likelihood and significance of events that could lead to insurance claims. A comprehensive understanding of the operational context and its vulnerabilities is essential for effective risk identification. It enables proactive planning, risk mitigation, and the development of strategies to navigate uncertainty, thereby facilitating more robust and informed decision-making across multiple industries.

***Risk Evaluation:*** Risk evaluation is a crucial aspect of risk management, a methodical examination of hazards to determine their importance and potential consequences. It helps companies and investors determine potential losses in investments or business plans and helps identify obstacles that may hinder project success. The

objective is to furnish decision-makers with invaluable insights concerning the risk landscape, thereby empowering them to engage in judicious resource allocation, execute risk mitigation strategies, and render informed determinations. Extensive risk appraisal can enhance organizational resilience, strategic planning, and uncertainty management, allowing organizations to better understand and manage potential outcomes.

***Risk Reduction:*** A proactive approach to reducing the possibility and effect of any risks or uncertainties is risk minimization. To increase resilience and protect their objectives, organizations in a range of sectors, including management of projects, healthcare, and finance, employ risk reduction techniques. Spreading risk across several assets to lessen the impact of a single failure is a popular risk reduction strategy used in the financial domain: diversification of investment portfolios. By lowering the possibility of unfavourable events, safety procedures, and preventative measures help to lower risk in the healthcare industry. Regular surveillance and the development of alternative strategies are vital aspects of project administration as they facilitate the timely identification and resolution of potential issues. To effectively reduce risk and provide companies the stability and confidence to traverse unpredictable times, a mix of early detection techniques, strategic planning, and preventative actions is needed.

***Adaptation Scheduling:*** In risk management, adaptation scheduling is a proactive and flexible approach meant to deal with the constantly shifting terrain of possible risks and uncertainties. This method entails methodically modifying risk management strategies to consider newly arising issues, developments in technology, and evolving market conditions. Organizations may ensure resilience and adaptation by including elasticity in risk control schedules, which allows them to continually monitor and respond to developing threats. This might involve updating backup plans, reviewing risk mitigation techniques regularly, and incorporating fresh information and insights into the

decision-making process. Organizations may take advantage of opportunities, keep ahead of developing risks, and maintain an efficient and adaptable framework for risk management that fits the changing demands of the company's environment by using adaptation scheduling.

***Instruments of Finance:*** A variety of tradable assets or contracts with a financial value that enables individuals, businesses, and governments to raise cash or manage risk are referred to as instruments of finance. Money market instruments, derivatives, equities, and bonds are examples of common instruments. Stocks give investors a piece of a company's profits and symbolize ownership in the business. Bonds are financial products that simulate a fixed-interest loan made by an investor to a company, typically the government or a business. Options and futures are examples of derivatives that derive their worth from a variety of tradable assets or contracts with a financial value that enable people, companies, and governments to raise cash or manage risk are referred to as instruments of finance. Money market instruments, derivatives, equities, and bonds are examples of common instruments. Stocks give investors a piece of a company's profits and symbolize ownership in the business A fixed-interest investment from a shareholder to an entity, typically a government agency or a corporation, is represented by a bond. Options and futures are examples of derivatives that derive their worth from a fundamental asset and are frequently employed for speculation or risk management. Products from the money market include government securities and other immediate, low-risk financial instruments.

***Observance of Rules:*** Adherence to regulations in risk management is fundamental to efficient risk management strategies in many sectors. Transparency, accountability, and moral behaviour must all be upheld by abiding by established laws, regulations, and internal procedures. To maintain the honesty of what they do and

safeguard the interests of their stakeholders, organizations need to routinely observe and adhere to risk management regulations. This entails doing in-depth risk assessments, understandably communicating risk policies, and putting effective risk mitigation plans into practice. Adherence to regulations not only reduces legal and financial hazards but also cultivates confidence among interested parties. Organizations may secure their long-term sustainability by enhancing resilience, adapting to shifting risk landscapes, and establishing a culture of competent risk management via consistent monitoring and adherence to standards.

***Innovation and Resilience:*** To successfully navigate the complicated and dynamic business world of today, risk management methods must incorporate resilience and creativity. With the use of technology, data analytics, and flexible approaches, innovation enables businesses to anticipate and evaluate new hazards before they become a danger. It entails enhancing agility and responsiveness through ongoing process improvement in risk detection, assessment, and mitigation. The ability to take in and bounce back from setbacks, on the contrary, is resilience. Organizations may reduce potential losses and ensure business continuity by constructing resilient systems that lessen the effect of unanticipated catastrophes. Innovation and resilience work together in risk management to create a proactive and flexible organizational culture that enables companies to flourish in the face of uncertainty and quickly shifting markets.

***Cooperation and Instruction:*** To effectively manage risks, firms must place equal emphasis on collaboration and education. Collaboration across various teams, departments, and stakeholders is necessary to promote a shared awareness of risks and to jointly create mitigation solutions. A thorough risk management framework is enhanced by open lines of communication and a collaborative culture. Furthermore, it is vital to provide unambiguous instructions and direction to guarantee that personnel across all

organizational levels comprehend their respective tasks and obligations concerning risk management. This entails delivering frequent training, sharing pertinent data, and creating procedures for identifying risks and taking appropriate action. Cooperative learning and training work well together to build a risk-aware culture that enables teams to negotiate uncertainty as a group, make wise decisions, and add to the organization's overall success and resilience.

***Planning Scenarios:*** To improve readiness and resilience, risk management planning scenarios entail strategically imagining possible future occurrences. Organizations regularly construct and examine fictitious scenarios that might endanger their business operations. Through the process of creating scenarios, they can recognize weak points, assess possible outcomes, and create methods that effectively mitigate risks. Proactive decision-making and flexible planning are made possible by this forward-looking methodology. A few of the many variables that might be included in scenarios are shifts in the geopolitical landscape, technological breakthroughs, and economic fluctuations. A dynamic and adaptable risk management culture is fostered by the approach, which challenges firms to consider new risks critically. Businesses can keep ahead of changing risks, allocate resources optimally, and create a strong framework for risk management that is in line with their strategic goals by routinely updating and improving these scenarios.

***Extended View:*** Looking beyond the apparent issues and considering the entire range of possible effects on a firm is part of an enlarged perspective on risk management. This method acknowledges that hazards are linked together and frequently result from a convoluted network of both internal and external factors. Businesses that embrace an expanded perspective do comprehensive risk analyses that consider political, social, technical, economic, and environmental factors. This more comprehensive viewpoint

makes it possible to detect new dangers early on and get a more sophisticated knowledge of their possible effects. Businesses may create flexible strategies that handle both present and future uncertainties by adopting a comprehensive view. This approach promotes sustainability and resilience in the face of a constantly changing risk landscape. All things considered, a multifaceted strategy integrating scientific data, compliance with laws, financial instruments, and creative solutions is required for the efficient evaluation and control of climate threats. By acknowledging the existence of global warming and proactively addressing its impacts, individuals, organizations, and societies may work toward a future that is more durable and resilient.

### 1.3.4 Challenges Faced by the Insurance Sector

To determine the challenges of strategy implementation by insurance companies in Kenya. The macroeconomic factors considered to affect strategy implementation included strict compliance guidelines, high technology advancement, and high inflation rates (Koech, 2021). Internal factors that affected strategy implementation included a lack of staff involvement, bureaucratic structures, poor communication, and a lack of clear guidelines. Industry-specific challenges included the threat of price wars, stiff competition, rivalry among insurance companies, and strong bargaining power from clients. The study also highlighted the strategy responses adopted by insurance companies, such as linking rewards to strategy implementation and lobbying through industry associations to address regulatory and economic challenges.

Managing change was identified as a crucial step in overcoming challenges in strategy implementation. Employee involvement in both the formulation and implementation stages was recommended to enhance ownership and enthusiasm (Smichowski, 2018). It was also determined that hiring and educating employees with the necessary background and abilities was crucial to the strategy's effective execution.

The ever-changing worldwide financial and environmental context presents several issues for the insurance industry. The growing frequency and intensity of climate-related events and natural disasters is one major problem. The increased frequency of extreme weather events is placing a significant financial strain on insurers as they deal with the rising expenses of claims resulting from hurricanes, wildfires, floods, and other catastrophic occurrences.

Technological disruption is a significant obstacle that the insurance industry must confront. Although technological advancements offer prospects for innovation and enhanced customer experiences, they also introduce novel hazards. The insurance sector faces a substantial challenge in safeguarding sensitive customer data against evolving cyber risks, such as cybersecurity threats. Regulatory complexity persists as a hurdle for the industry. Adhering to and keeping up with constantly evolving regulatory frameworks necessitates significant resources. The complexity is further compounded by the need to comply with diverse and often conflicting regulations across different jurisdictions. Additionally, changing consumer expectations and behaviour presents challenges. Modern consumers desire personalized and seamless experiences, which requires insurance companies to adapt their traditional models to meet evolving demands. For the sector, finding an equilibrium between innovation and upholding the required standards of openness and trust is a constant issue. Finally, the profitability and investment returns of insurers may be impacted by economic risks such as low-interest rate environments and worldwide economic downturns. A mix of technology adaption, planning for strategy, and regulatory compliance is needed to ensure the long-term profitability and resilience of the insurance company in a more complex and interconnected environment.

#### *1.3.4.1 Pricing Uncertainty*

Pricing ambiguity poses a significant hurdle in the domain of climate risk management. This predicament originates from the intricate and ever-evolving nature of climate-related risks, which renders it arduous to determine precise costs and allocate resources efficiently. The assessment of potential damages is further complicated by the unpredictability of climate events, in addition to the inaccuracies inherent in climate models and data. Additionally, the uncertainty surrounding compliance costs is exacerbated by regulatory changes and evolving policies aimed at mitigating climate risks. Furthermore, market volatility in carbon pricing mechanisms and emissions reduction costs introduces an element of unpredictability. Insurers assume a vital role in pricing climate risks, thereby impacting premiums that may fluctuate based on historical climate data and the frequency of climate-related events.

The development and pricing of financial instruments, such as catastrophe bonds and climate risk derivatives, are subject to variation based on market conditions, thereby contributing to the complexity of the situation. To address this challenge effectively, transparent reporting and consistent disclosures are essential, as they enable stakeholders to make informed decisions (Higgins *et al.,* 2020). Employing scenario analysis, which considers multiple climate futures, represents a valuable approach to tackling pricing uncertainty. Innovations in insurance pricing models, including parametric solutions, aim to provide more predictable and transparent structures for managing climate risk. Mitigating pricing uncertainty in climate risk management necessitates collaboration among various stakeholders, data sharing, enhanced risk modeling, and the adoption of long-term perspectives.

### 1.4. Climate Risk Insurance

A sort of insurance called "climate risk insurance" is intended to reduce the financial and other risks related to climate change, particularly those caused by extreme

weather events (Kousky, 2019). Insurance is frequently viewed as a kind of insurance required to increase the impoverished and developing populations' resistance to climate change (Surminski *et al.,* 2016). While simultaneously laying the groundwork for future actions to lessen climate change risk, it supplies post-disaster liquidity for relief and rehabilitation efforts. Insurance is regarded as a crucial adaptation strategy to climate change.

Opponents of the insurance claim that towns with the lowest carbon emissions bear the lion's share of the financial burden associated with it. These insurance programs might be costly for low-income nations because of the high startup costs and infrastructure needs for data collection. It is hypothesized that high prices in high-risk areas with growing climate concerns would deter people from relocating there (Hermann, 2016). Additionally, these programs are frequently late and underfunded, which could be risky for national finances. One significant issue at the micro level is that weather-related disasters typically impact entire villages or regions at the same time, leading to a high volume of claims at the same time. This implies that it must be sold on a massive, diverse basis (Mannappan and Varadarajan, 2022). However, a well-thought-out climate risk insurance can increase resilience while serving as a safety net for nations.

Through the establishment of the Insu Resilience Global Partnership at COP23, the international community made investments to build additional support for this type of insurance. This group backs worldwide organizations like the Munich Climate Insurance Initiative as well as regional initiatives like Climate Risk Adaptation and Insurance in the Caribbean (CRAIC). In 2020, the ACT Alliance released a manual outlining an equitable and climate justice-focused approach for insurance against climate risk.

A financial tool called "climate risk insurance" covers damages from occurrences connected to climate change, therefore reducing the negative impacts of global warming

Climate risk insurance plays a vital role in protecting individuals, enterprises, and societies from the escalating occurrence and intensity of devastating meteorological phenomena such as hurricanes, floods, and droughts. This form of insurance typically encompasses a diverse array of climate-linked perils, encompassing agricultural yield depletion, asset impairment, and commercial interference. It seeks to support resilience and recovery by enabling a prompt and effective reaction to losses brought on by the climate. Solutions for climate risk insurance are actively being developed and promoted by governments, international organizations, and commercial insurers.

Accurately identifying and measuring climate change risks is a significant challenge in implementing climate risk insurance. To maintain the continuous relevance and efficacy of these insurance products, insurers must modify their models and pricing tactics in response to evolving patterns of climate change. A crucial part of more comprehensive plans for mitigating and adapting to climate change is climate risk insurance. It promotes proactive risk management, equitable growth strategies, and the building of a stronger neighbourhood in the face of an ever-changing environment by offering financial protection. The importance of risk management insurance in creating a more sustainable and resilient future is projected to grow as the whole community struggles with the effects of climate change.

### 1.5. Rising Concerns: Climate Change and Insurance

People are becoming more conscious of the effects of climate change. The escalating apprehensions about climate change and its ramifications on the insurance sector are becoming progressively apparent and urgent. The frequency and severity of extreme weather events, such as hurricanes, wildfires, floods, and droughts, have increased due to climate change (Clarke *et al.,* 2022). For insurers, these incidents are a big worry since they cause significant property damage, fatalities, and economic

disruption. Underwriting models and reserve requirements are being strained by the insurers' mounting financial burden from climate-related claims. The issue is made worse by climate change uncertainty, as historical data may no longer be a valid indicator of future risk. Policyholder rates may rise because of insurance firms' difficulty appropriately pricing policies to reflect the changing risks associated with climate change.

Moreover, a major worry is the possibility of not being covered by insurance. Because the likelihood of recurrent climate-related losses is so high, some localities are already losing their insurance coverage. Climate-related disasters can have a greater financial impact on cities, businesses, and individual households, potentially resulting in unstable economies. To tackle these issues, insurers are progressively integrating sustainability aspects and climate risk modeling into their business plans. Additionally, they are trying to motivate policyholders to adopt sustainable behaviors and mitigation strategies. The fact that governments and regulatory organizations are looking into methods to strengthen climate resilience through policy interventions highlights how vital it is to address the relationship between insurance and climate change. Innovation and adaptation within the insurance industry are essential to guarantee its long-term profitability and the protection of policyholders as climate change continues to modify the risk landscape.

### 1.5.1 Increasing Frequency and Severity of Weather Events

Due mostly to weather events becoming more frequent and severe, concerns regarding the changing climate and its significant implications for the insurance sector are developing. It not only causes a spike in claims but also complicates the process of effectively estimating and pricing the changing risk (Figure 1.8). It is common for historical data to lose significance when used to forecast future risk. As a result, deciding

on reasonable premiums and sufficient reserves to cover these rising claims presents a challenge for insurers.


***Figure 1.8:*** *Weather Events (*Meyer *et al.,* 2023*).*

An additional layer of difficulty is the increasing likelihood that certain places will lose their ability to obtain insurance due to repeated losses caused by climate change (Schäfer *et al.,* 2016) (Russel *et al.,* 2018). This exposes businesses and property owners in these locations to the full financial impact of climate-related calamities, which may cause instability in the economy. Insurers must innovate and adapt, as well as take a more thorough approach to modeling climate risk. It emphasizes how crucial it is for policyholders to adopt sustainable behaviors and foster climate resilience. To address these mounting concerns, governments, and regulatory bodies need to underline how urgently they need to address climate change and how it impacts the insurance industry (Surminski *et al.,* 2016).

### 1.5.2 Expanding Environmental Liabilities

A major issue facing the sector is the increased environmental liability considering the growing worries about insurance and climate change. An expanding range of environmental risks is being faced by insurance firms as the effects of climate change become more apparent. These liabilities may result from pollution, destruction of property, or health problems connected to climate-related incidents, among other things (Authority *et al.,* 2015) (Linnerooth-Bayer and Hochrainer-Stigler, 2015).

Events linked to climate change, such as floods and wildfires, can cause environmental harm and subject insurers to claims of contamination and property pollution (Figure 1.9). Furthermore, when policyholders seek reimbursement for medical costs incurred due to extreme weather disasters such as hurricanes or heat waves, liability lawsuits against insurers may result (Menell, 2019).

***Figure 1.9:*** *Environmental Liability (Schieve, 2018).*

The challenge of precisely evaluating and quantifying these environmental liabilities adds to their complexity. Because it affects how insurers evaluate and price risk, this is a significant problem for them. Amidst these concerns, insurance companies are advocating for eco-friendly policies among policyholders to mitigate their

environmental liabilities. Additionally, they are increasingly integrating climate risk assessments into their underwriting and risk management protocols. The insurance sector must adjust to these growing liabilities as climate change continues to develop if it is to remain sustainable over the long run.

### 1.6. Regulatory Framework and Climate Risk

The regulatory framework has a significant influence on how climate hazards are addressed and lessened (D'Orazio and Popoyan, 2019). Governments and regulatory bodies are acting globally to solve the concerns associated with climate change which are becoming more and more important. These regulations cover several facets of risk management related to climate change.

The regulatory framework includes compulsory climate risk disclosure as one of its main elements businesses, especially those in dangerous industries, are facing growing demand from regulatory bodies to disclose details about their risk management and resilience strategies, as well as how susceptible they are to climate change. These kinds of disclosures enable businesses to incorporate risks related to climate change into their business activities and assist stakeholders and investors in making educated decisions.

Regulations also control objectives connected to climate change and carbon reductions. Governments' primary priorities include lowering greenhouse gas emissions and moving toward a low-carbon economy. Businesses are being forced by law to make investments in sustainable and clean operations to abide by rules and maintain their competitiveness in an evolving market (Strine, 2019). Regulators in the financial industry are concentrating more of their supervision and oversight efforts on climate risk. Evaluating financial institutions' approaches to managing and disclosing risks related to climate change in their portfolios is part of this. Additionally, regulators are assessing

how well scenario simulations and stress tests take into consideration climate concerns and their possible effects on financial market stability.

The legislative framework about climate risk is fast changing and is turning into a vital component of the climate risk management process (Davis and Vincent, 2017). Companies and financial institutions must modify their plans and procedures to comply with these changing regulatory requirements as authorities and regulatory bodies insist on tackling climate-related issues. An important advancement in the worldwide endeavor to lessen the effects of climate change is this move toward stricter regulation of climate risk (Attard, 2015).

### 1.6.1 Government Initiatives

Governmental actions are necessary to lower the threats brought on by climate change throughout the world. Governments are acting decisively to address the problems caused by climate change (Pereira, 2017). A typical example of a governmental initiative is the establishment of objectives and strategies for climate action. Numerous nations have made commitments to cut carbon dioxide emissions by predetermined percentages or to reach net-zero emissions by predetermined deadlines These objectives serve as a roadmap for lowering climate-related risks and establishing a low-carbon economy.

Moreover, government programs concentrate on improving climate resilience. This involves making investments in resilient urban design and enhanced flood defenses—infrastructure that can endure catastrophic weather occurrences. Governments may also provide funding for studies and projects about methods of climate adaptation. An additional crucial component of government programs is international collaboration. Countries come together under accords like the one in Paris to fight climate change globally (Kompas *et al.,* 2018). These kinds of cooperative endeavors enable information

exchange, funding, and the use of climate risk mitigation techniques. Governments are proactively mitigating climate hazards and shielding their populations and economies from the effects of a changing climate through rules, objectives, incentives, and international cooperation.

### 1.6.2 Industry Standards and Reporting

The core elements of climate risk administration are company norms and reporting procedures. They provide enterprises with an organized structure for evaluating, disclosing, and controlling their exposure to hazards associated with climate change (Kouloukoui *et al.,* 2019). The evaluation and communication of climate hazards may be made more transparent, consistent, and comparable with the aid of these guidelines. In this field, the Group of Experts on Financial Disclosures Related to Climate Change (TCFD), which has been more well-known recently, is a crucial component. TCFD offers guidelines for businesses to voluntarily disclose financial information on climate change. Organizations are encouraged to share details on their administration, tactics, risk control, and metrics and objectives about opportunities and hazards associated with climate change Participants, shareholders, and others in the community can use these disclosures to assess a company's sustainability and climate change resilience.

In addition, industry-specific rules and standards for reporting have been developed, specifically addressing the distinct risks and obstacles encountered by different industries. As an illustration, the Sustainability Accounting Rules Board (SASB) has created rules tailored to certain industries that assist businesses in disclosing financially significant hazards and possibilities related to climate change in their industry. These guidelines provide businesses and investors with a common vocabulary to talk about climate-related concerns and comprehend their financial ramifications. Mainstreaming climate risk factors into governance and investment choices requires the

creation and acceptance of company norms and reporting systems. They support a more robust and sustainable world economy by making it easier to incorporate climate risk control into regular company operations (Shad *et al.,* 2019).

### 1.7. Evolving Risk Assessment in Climate

The thematic issue and developing science of risk evaluation draw attention to cutting-edge problems in evaluating the hazards associated with climate change within a framework of policy, such as systemic risks, important information gaps, and the complexity of societal solutions. This theme issue's collection of papers looks at several methods for assessing climate risk and emphasizes how these methods may guide strategies and initiatives aimed at reducing and managing hazards. It also discusses the difficulties of integrating the developing field of risk research with adaptation strategies (Adger *et al.,* 2018). To execute prompt solutions, public and commercial entities have formalized risk assessments of the implications of climate change, defining and prioritizing environmental hazards alongside other threats. A risk-based strategy has been promoted by the United Nations Framework Convention on Climate Change, or IPCC, to enhance comprehension of hazards and the function of adaptation. The articles in this theme issue underscore the need for better knowledge, approaches, and the incorporation of risk evaluation into policy-making processes as they address the difficulties and developments in risk evaluation for the climate change adaptation strategy.

Since governments, institutions, and organizations have realized the enormous effects of the warming climate on the world, the evaluation of climate risk has undergone considerable changes. An increased sense of pressure to act, a rising amount of scientific knowledge, and the frequency and intensity of climate-related occurrences are driving this transition. In the past, physical threats like extreme weather, temperature rise, and sea level rise were the main emphasis of climate risk assessment. Although they

are still essential parts of risk assessment, their scope has grown to include a wider variety of hazards. Transition risks have gained significance and include those related to the move to low-carbon economies or modifications to government regulation. These risks are important considerations to make when evaluating risk since they affect industries, supply networks, and investments.

Additionally, a deeper understanding of the interconnected nature of climate risks has emerged. Risks once seen as isolated events are now recognized as part of a complex web of interactions. A weather event, for instance, might cause supply chain disruptions, which can result in monetary losses and harm to one's image. This comprehensive view of risk highlights the need for careful risk assessment that considers the long-term implications of rising temperatures as well as their knock-on effects on other businesses and systems. Furthermore, companies are now able to carry out more thorough and proactive risk assessments because of developments in data, simulation, and scenario analysis. They may research various climate scenarios, assess their level of resiliency, and then make educated decisions to lower risks. Risk assessment is anticipated to continue to evolve as climate change takes its course. Incorporating climate risk into standard risk management procedures will become more and more important for businesses looking to grow, adapt, and support a sustainable future. (Figure 1.10) illustrates the evolving risk assessment in climate change, highlighting the changing nature of environmental threats and the need for adaptive strategies.

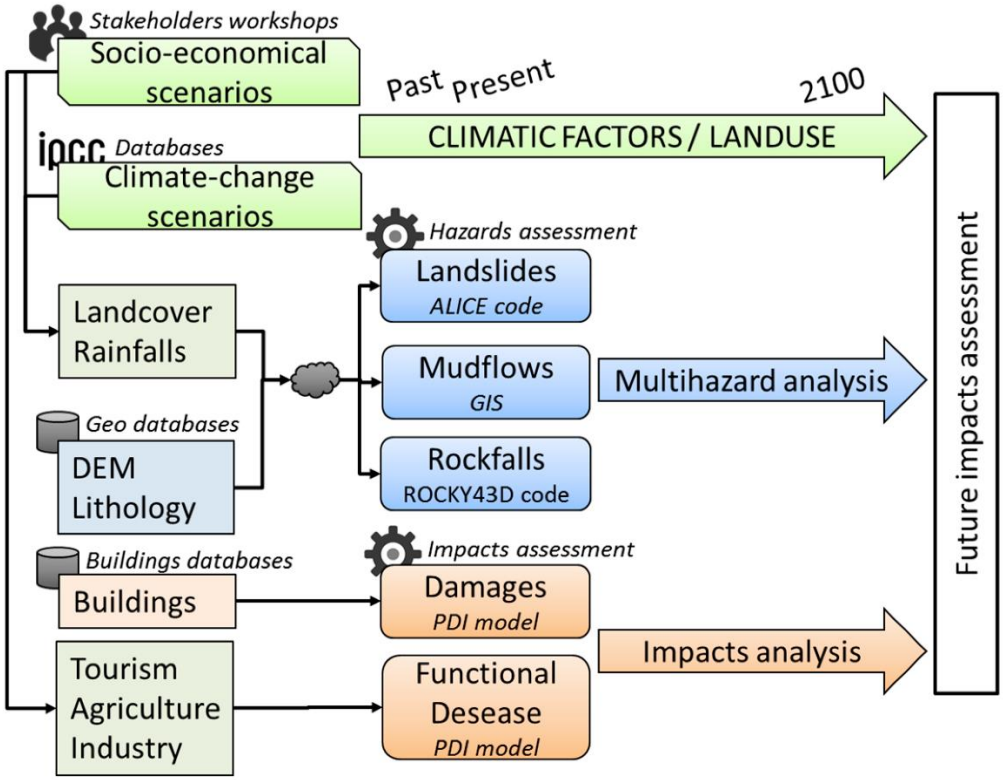


***Figure 1.10:*** *Evolving Risk Assessment in Climate (*Grandjean *et al.,* 2018*).*

### 1.7.1 Integrating Climate Data and Models

It integrates Using machine learning techniques, yields of wheat in Australia may be predicted using satellite and climatic data. outperforms using any one data source or various combinations of sources of data when it comes to wheat yield prediction when climate and satellite data are combined. Important roles are played by climate variables in the model by temperature, water demand, and water supply (Cai *et al.,* 2019). To provide additional and distinct information for yield prediction beyond whatever satellite data can provide, it incorporates climatic data. Climate factors influence yield forecast not only at specific points during the season but also throughout. Owing to the substantial uncertainty in the satellite-based SIF information, the research shows that yield prediction using the enhanced index of vegetation (EVI) as an input

works better than utilizing solar-induced chlorophyll fluorescence (SIF). The paper demonstrates having the capacity to forecast wheat production as much as two months ahead of maturity. The best model, support vector machine (SVM), achieves a yield prediction of 0.73 in predicted R2 in October. Organizations and governments may improve their ability to evaluate risks, adjust to changing circumstances, and make well-informed decisions by utilizing the increasing quantity of climate data and sophisticated modeling approaches.

Climate data provides a foundational understanding of the current climate conditions and historical trends, enabling stakeholders to identify areas of vulnerability. This information includes temperature records, precipitation patterns, sea-level rise projections, and extreme weather events. Moreover, it helps in recognizing how these factors impact various sectors, from agriculture and water resources to infrastructure and health. Sophisticated climate models simulate several climatic scenarios under varying emission routes, providing insight into the future. These models help in projecting long-term climate changes, offering valuable insights into what the world may look like under various climate conditions Moreover, scenario analysis is made possible by climate data and models, allowing stakeholders to investigate the effects of various policy choices, mitigation plans, and adaption methods. Organizations may make well-informed decisions, manage resources efficiently, and increase their resilience to climate hazards by modeling a variety of scenarios.

The integration of climate data and models into decision-making processes extends beyond assessing risks It offers a framework for creating climate-resilient plans, whether they involve sustainable urban development, infrastructure upgrades, or adjustments to agricultural methods. If organizations are to thrive despite the effects of climate change, they must be able to apply this information while making decisions daily.

Decision-makers have access to the knowledge and tools needed to understand, foresee, and resolve climate-related problems when climate simulations and data are included.

### 1.7.2 Identifying Vulnerable Geographies and Assets

Specifically, the difficulties and moral dilemmas associated with working with groups classified as "vulnerable" in human geography research bring to light how power relations and social production contribute to vulnerability (Von Benzon and Van Blerk, 2019). The loss of privacy in research interactions with vulnerable groups which are frequently brought on by institutionalization and the requirement to get access to these populations through gatekeepers is a topic covered in this special edition. The articles cover the intricacies of research partnerships as well as the conflicting obligations and split allegiances that researchers encounter while assisting those who are vulnerable.

The goal of the special edition is to compile accounts of doing geography research with marginalized people or groups, emphasizing the vulnerability that both the subjects and the investigators themselves encounter.

A crucial part of climate risk assessment and adaptation planning is identifying vulnerable geographies and assets. The term "vulnerability to climate change" describes how susceptible a location or asset is to the negative effects of shifting weather patterns This procedure entails determining how sensitive and exposed a location or asset is to risks associated with climate change. Conversely, sensitivity assesses a system's vulnerability to various stresses while accounting for its innate qualities and ability to adjust.

Low-lying coastal locations vulnerable to sea level rise places prone to severe storms, and areas experiencing water shortages because of shifting precipitation patterns are among the geographies that are frequently classified as vulnerable. Critical infrastructure and agricultural zones are among the assets whose resilience and adaptation

to climate changes are evaluated. This identification method relies heavily on advanced visualization, modelling, and data analytics, which help communities, academics, and policymakers identify high-risk locations and put tailored adaption plans in place. In the face of an increasingly unpredictable climate future, stakeholders should prioritize resources, put in place customized resiliency measures, and work toward creating climate-resilient communities by identifying sensitive assets and geographies.

### 1.8. Climate Adaption

Climate adaptation shields people and places from the effects of climate change. Communities might construct seawalls or move structures to higher elevations, for example, to guard against rising sea levels and increasing flooding. Being resilient means that one can endure changes, and adjusting to climate change can help us do so. To thrive and live, one must both limit the amount of warming by cutting greenhouse gas emissions and adjust as the climate changes. To better understand the implications of climate change to which one must adapt, one may prepare to make communities less sensitive to it by using climate models, which provide scenarios of future climate change. To adapt to climate change, people might use local, national, international, and individual options. Government policy changes are the driving force behind some adjustments. The advancement of technology has led to further adaptations. Planning and engineering can help areas adjust to changing environmental conditions. People are being forced to migrate due to climate change, thus coordinated global adaptation measures that guarantee as many places as possible are habitable can be helpful.

Neighbourhoods, ecological systems, and people must proactively adapt and take the necessary actions to minimize the negative consequences of warming temperatures and seize new opportunities. This is known as climate adaptation. Effective adaptation becomes critical as global temperatures increase and weather patterns grow more erratic.

Developing robust infrastructure, putting into practice sustainable farming methods, improving the handling of water resources, and enacting laws that support community resilience are important aspects of climate adaptation. It also entails integrating climate concerns into conservation initiatives, urban planning, and disaster readiness.

Education and community engagement are crucial for effective climate change adaptation because they help individuals identify and reduce local hazards. This might involve creating early warning systems, encouraging eco-friendly behaviour, and putting in place flexible governance frameworks. Unity needs are required. To exchange information, combine resources, and promote group answers to the problems presented by climate change, collaborative efforts at the local, national, and international levels are necessary. Ultimately, resilient communities and sustainable development are the goals of effective climate adaptation, which also attempts to protect ecosystems and humans from the consequences of changing climatic circumstances. The intricacies of a shifting environment must be handled with a proactive, comprehensive strategy to build a more resilient and environmentally friendly future.

### 1.8.1 Adapting to the Changing Climate

Adapting to the changing climate is an urgent and multifaceted challenge that humanity faces in the 21st century. As the Earth's climate continues to evolve due to the impacts of greenhouse gas emissions, one must take proactive measures to mitigate the consequences and ensure the resilience of our communities and ecosystems. One key aspect of adaptation involves building climate-resilient infrastructure. This includes constructing flood defenses, designing buildings to withstand extreme weather events, and improving water management systems to address changing precipitation patterns (Burke and Emerick, 2016). Additionally, transitioning to renewable energy sources and

adopting energy-efficient technologies is vital in reducing greenhouse gas emissions, which contribute to climate change.

Agriculture must also adapt to shifting weather patterns and increased instances of extreme weather events. Implementing sustainable farming practices, diversifying crops, and improving water efficiency are essential for food security. Furthermore, protecting and restoring natural ecosystems, such as wetlands and forests, can help absorb carbon dioxide and buffer against the impacts of climate change. Adaptation efforts should be complemented by robust disaster preparedness and early warning systems to protect human lives and livelihoods. Additionally, public awareness and education campaigns can help foster a culture of sustainability and encourage individuals and communities to take action.

#### 1.8.1.1 Benefits of adapting to climate change

- Climate adaptation measures help communities become more robust to the effects of climate change. This includes better defense against severe weather conditions including storms, droughts, and floods.
- By minimizing damage to infrastructure and interruptions in the supply of food and water, climate resilience can help protect economic stability. Jobs in fields like disaster preparedness, sustainable agriculture, and renewable energy are also produced by it.
- Crop diversification and water-efficient farming are two examples of agricultural adaptation strategies that improve food security by strengthening and sustaining farming practices in the face of shifting weather patterns.

- By reducing the prevalence of climate-related diseases including vector-borne infections and bolstering healthcare services during extreme events, climate adaptation can improve public health outcomes.
- Adapting to climate change can help safeguard ecosystems and species that are vulnerable to its shifting conditions. There are long-term ecological and financial advantages to protecting natural areas and increasing biodiversity.
- Water management solutions that adapt to climate change guarantee a steady and sustainable supply of water, which benefits both rural and urban areas and supports aquatic ecosystems.
- Transitioning to renewable energy sources as part of climate adaptation initiatives reduces reliance on fossil fuels, improving energy security and lowering greenhouse gas emissions.
- Climate-resilient infrastructure, such as sea walls, flood barriers, and stormwater management systems, ensures the long-term functionality of essential facilities and services.
- By addressing the unique vulnerabilities of marginalized populations and guaranteeing that they have equal access to resources and protection, climate adaptation strategies can be created to advance social equality.
- As nations cooperate to exchange resources, expertise, and technologies, adapting to climate change opens new avenues for international cooperation and diplomatic ties.

#### 1.8.1.2 Impacts of adapting to climate change

The impact of climate change adaptation is felt in many different ways by the environment, the economy, and society. Reducing the negative consequences of global warming and preserving a sustainable future need adaptation to climate change.

- Increased readiness and robust infrastructure lessen the financial toll that extreme weather occurrences take.
- Food production is protected by adaptation strategies including water management systems and drought-resistant crops.
- By tackling heat-related illnesses, vector-borne diseases, and air quality, climate adaptation can enhance public health.
- Investments in climate-resilient infrastructure protect against sea-level rise, flooding, and extreme weather events.
- By safeguarding vulnerable species and ecosystems, adaptation helps maintain biodiversity.
- A steady water supply is ensured via better water management, which lowers the likelihood of droughts and water scarcity.
- Transitioning to renewable energy sources lowers greenhouse gas emissions and energy-related climate consequences.
- Climate adaptation can reduce the need for mass migrations caused by environmental stressors.
- More resilience to the effects of climate change benefits local communities and promotes sustainable development.
- Market stability and a reduction in the financial strain on insurance companies are two benefits of climate adaptation strategies.
- Developing strategies to adapt to climate change promotes global collaboration and knowledge exchange.

### 1.8.2 Promoting Climate-Resilient Practices

Rising sea levels, loss of ice caps and icebergs, rising global temperatures, and changed water composition are some effects of climate change. To stop climate change and lessen its consequences, one must adopt sustainable practices like afforestation, increase the use of energy that comes from renewable sources, reduce greenhouse gas emissions, and follow the 3Rs. Many coastal towns are modernizing their natural facilities which include their coastlines, mangrove forests, reefs of coral, and salt marshes, to become more robust to climate change. Dams, levees, embankments, flood diversion systems, and flood plain zonation and management are examples of flood prevention measures that preserve natural resources. Reusing floodwater to address water constraints could be part of an integrated approach to floodwater management (Singh *et al.,* 2021).

Encouraging habits that are climate resilient is one of the most crucial ways to address the growing issues brought on by climate change. These practices cover a broad range of tactics and actions that support the sustainability of ecosystems and communities while simultaneously lowering sensitivity to threats associated with climate change. Sustainable farming is one of the main strategies to enhance climate resilience. The resilience of our food systems can be strengthened and their ability to endure catastrophic weather events and altered weather patterns associated with climate change can be increased by promoting agricultural practices including crop diversity, no-till farming, and water-efficient irrigation. Natural ecosystem restoration and conservation are equally important. In addition to providing habitat for biodiversity, woods, and coastal habitats also sequester carbon and regulate flooding. By preserving these habitats, one lessens the effects of climate change and establishes natural barriers against calamities linked to climate change.

Another crucial component of climate-resilient activities is water efficiency. Encouraging responsible water management promotes the sustainable use of this limited resource, especially in areas with unpredictable precipitation or water scarcity. This includes cutting back on domestic water use and optimizing industrial processes and agricultural irrigation. Furthermore, protecting our cities and infrastructure investments from climate risks requires us to push for climate-resilient infrastructure, such as structures made to resist extreme weather events and resilient transportation networks. One can lessen greenhouse gas emissions and improve energy security by switching from the usage of energy from fossil fuels and the problems they bring to energy from alternative sources including solar and wind power. If one encourages practices that are robust to climate change and work together to mitigate its effects, climate change might be an element of prosperity for people, communities, and civilizations. This multidimensional strategy not only improves resilience but also sustainability, resulting in a more secure and equitable future for all.

### 1.8.3 Innovations in Risk Transfer

As the hazards connected with climate change increase, innovations in risk transfer mechanisms are becoming more and more crucial to managing and adapting to the phenomenon. These technologies will allow governments, communities, and vulnerable individuals to transfer the financial burden of climate-related repercussions to the larger insurance and financial sectors. The development of parametric policies represents a significant advancement in insurance. Instead of requiring laborious and time-consuming claims exams, these insurance policies rely their payouts on predetermined weather- or climate-related triggers. This tactic helps victims of climatic disasters quickly receive financial support, which speeds up their rehabilitation and reduces the administrative burden on insurance companies.

Furthermore, as a financial mechanism for risk transfer, climate risk bonds have become more popular. Governments and private companies alike are issuing these bonds, which are connected to climate-related incidents. Bondholders receive payment in the case that the prearranged climatic event materializes, transferring the issuer's financial burden to the bond investors. Programs for microinsurance and risk pooling are two more creative ways to manage climate risk. Through the pooling of resources from multiple individuals or small-scale farms, these strategies distribute the risk more widely, resulting in cheaper insurance costs and greater accessibility for those who live in high-risk locations.

### 1.9. The Imperative of Climate Risk Mitigation

Mitigating climate risk is an urgent and compelling global priority. It originates from the crucial need to limit and mitigate the negative effects of climate change, which has become one of our generation's defining problems. The deliberate endeavor to reduce greenhouse gas emissions to limit the magnitude of global warming and its domino effects is known as climate risk mitigation. Many important reasons emphasize this imperative. Mitigating climate risk is mostly about averting disastrous effects. It is essential to cut emissions to prevent the worst effects of these occurrences. Furthermore, safeguarding vulnerable communities is the foundation of the mitigation imperative. As low-income and marginalized groups frequently experience the worst effects of climate change, environmental justice and social equality become critical issues (Hansen *et al.,* 2019).

Preserving biodiversity also requires mitigation. The wide variety of species that inhabit the globe are seriously threatened by ecosystem disruptions and habitat loss resulting from climate change. These habitats and the animals that live there can be preserved if one can restrict the increase in global temperature. Additionally, by lowering

the high expenditures connected with property damage, agricultural losses, and higher healthcare costs brought on by climate change, reduction of the risk also promotes economic stability. Moreover, mitigation has numerous health advantages. By lowering the prevalence of respiratory disorders and heat-related illnesses, reducing emissions can both improve air quality and public health. This helps to reduce the geopolitical tensions that frequently result from resource constraints in addition to promoting energy security. Climate risk mitigation demands international cooperation. Countries around the world must work together to set and meet carbon reduction targets, share sustainable technologies, and assist developing countries in their climate efforts. It is critical for human civilization's long-term viability, striving to ensure a habitable world for present and future generations. By stimulating innovation in clean energy, transportation, and agriculture, mitigation fosters the creation of sustainable solutions that will be essential in combating climate change. It is an ambitious but essential objective to achieve net-zero carbon emissions when emissions are balanced by removals using techniques like carbon capture and storage and afforestation. All things considered, the urgency of reducing climate risk is an environmental, moral, economic, and social need that needs immediate and continual action at the local, national, and international levels to halt global warming and rescue the ecosystem.

### 1.10. The Need for Collaboration and Industry Resilience

To prepare for disruptions, supply chains need collaboration since it fosters partner synergies, real-time information exchange, and risk minimization. Supply chain collaboration involves mutual benefit, information exchange, and cooperative planning, all of which are critical elements of resilience. Since most supply chain interruptions happen at the first-tier supplier, communication between buyers and suppliers is especially crucial when examining supply chain resilience. By improving visibility,

velocity, and flexibility, information-sharing, cooperative communication, and joint relationship-building are essential collaborative activities that boost supply chain resilience. By enhancing visibility and averting poor decisions during risk events, collaborative activities like information sharing, goal congruence, decision synchronization, and cooperative knowledge production support supply chain resilience (Scholten and Schilder, 2015).

Our connected and fast-changing world has made the need for industrial resilience and cooperation more and more clear. Amidst worldwide predicaments like climate change, pandemics, and economic volatility, cooperation between diverse stakeholders and the development of industry resilience has become crucial for the sustenance and progress of societies and economies. On many levels, cooperation is crucial. Primarily, it is essential for handling intricate worldwide matters. For example, to limit its impacts and adapt to the changes currently occurring, climate change requires cooperation across nations, industries, and research institutes. Similar collaboration is required between governments, pharmaceutical corporations, and healthcare groups to efficiently produce and disseminate vaccinations and treatments in the event of a worldwide pandemic. In technology and innovation, teamwork is also essential to success. Collaborations between businesses and academic institutions promote progress in the technology industry, resulting in innovations across a range of domains, including renewable energy and artificial intelligence.

Furthermore, the ability of industry to withstand unanticipated difficulties is essential. Regardless matter the source of the disruption natural disasters, economic downturns, or geopolitical unrest, businesses and industries must be resilient and flexible. Diversifying supply chains, implementing flexible and sustainable company processes, and making investments in technology and staff development that can survive shocks in

the future are all part of resilience. The requirement for industry resilience and collaboration is especially critical in the context of environmental sustainability. To shift to more sustainable practices and lessen their environmental impact, industries must work together globally. This entails adopting green technologies, putting the circular economy into practice, and following environmental laws. These cooperative initiatives can reduce environmental harm while also opening up new markets and opportunities for sustainable goods and services.

### 1.11. Impact of Climate Risk Insurance

To investigate the impact of climate change risks on funding decisions made by publicly traded companies worldwide. According to the study, insurance can lessen the negative impact that climate risk has on business performance and unpredictability in profitability (Huang *et al.,* 2018). The findings of the regression demonstrate that climate risk significantly affects performance volatility, and for expositional purposes, the coefficients that depend on climate risk have been multiplied by 100. Nevertheless, none of the sources cited specifically address the effects of climate risk insurance.

One of the most important tools for tackling the mounting problems caused by climate change is climate risk insurance the globe experiences more frequent and severe weather-related disasters, including hurricanes, droughts, floods, and wildfires, and resilience, and financial stability are vital. An essential function of climate-related insurance is to facilitate individuals' recuperation, companies, and communities from the catastrophic effects of such occurrences. This insurance offers policyholders a safety net that can provide financial support in the aftermath of climate-related disasters. It provides coverage for a broad variety of losses, including fatalities, business disruptions, and property damage. By providing this financial security, climate risk insurance reduces the economic burden on individuals and governments, allowing for faster recovery and

reconstruction efforts. Moreover, climate risk insurance serves as an incentive for proactive risk management and mitigation strategies. Because these actions can lower their premiums and possible losses, individuals and groups with insurance are more inclined to make investments in climate-resilient policies and infrastructure. Furthermore, the safety of vulnerable people who are disproportionately impacted by climate change depends on the availability of climate risk insurance. Climate risk insurance is essential for reducing the negative effects of climate change because it fills the financial hole that frequently prevents communities from rebuilding and moving on after a disaster. Offering financial protection, encouraging risk reduction techniques, and fostering resilience, ultimately helps to create a society that is more ecologically conscious and climate resilient.

### 1.12. Problem Statement

The insurance sector is essential to controlling the financial effects of climate change. A growing number of severe storms and their intensity, changing climatic trends, and rising global temperatures are all contributing to the insurance sector's growing worry over climate risk. This issue statement aims to address the different challenges that the insurance sector has in accurately assessing, valuing, and managing risks related to climate change. A primary issue is the difficulty in accurately estimating and forecasting these risks, which can result in policyholders having insufficient coverage or being underinsured. Adapting their investment portfolio and underwriting methods to a rapidly changing environment scenario is another difficulty faced by insurers. In addition, insurers face a great deal of obstacles from the possibility of changes in regulations and market dynamics, as well as from the requirement for increased openness and disclosure. Achieving a delicate balance between the need to maintain profitability and the obligation to offer sufficient protection against climate risk requires creative thinking and strong risk

management procedures The insurance industry is obliged to directly address the matter of climate change to safeguard not solely its fiscal soundness, but also the durability of the economy and the individuals it caters to.

### 1.13. Motivation

The important relationship that exists among social well-being, monetary security, and environmental sustainability serves as the study's driving force. An existential danger from climate change is the increased frequency and intensity of severe storms like wildfires, hurricanes, and floods. Consequently, the insurance industry is under tremendous strain, as it is a vital tool for risk transmission and management The insurance industry is crucial to the world economy, and consumers and financial institutions worldwide will be greatly impacted by how successfully it handles claims and losses related to climate change. The increasing discrepancy between the real expenses incurred by the environment's impacts and the rates received by insurance companies may have systemic ramifications. The ramifications for society are enormous since, in the aftermath of climate-related disasters, underinsured or insured communities may suffer catastrophic financial losses due to inadequate coverage, which will impede recovery and increase dependency on public expenditures. To properly ensure the adaptability and long-term viability of this crucial industry, policymakers, legislators, and other stakeholders must possess a thorough understanding of the climate risk associated with the insurance business. To stay in business and safeguard the interests of their customers, other businesses, and society at large, insurance firms need to control climate risk.

### 1.14. Objectives

- The study's goals are broad and include addressing important issues as well as enhancing the insurance industry's sustainability and climate change resistance. These goals consist of:

- To evaluate the risks that the insurance business faces from climate change, both now and in the future, including extreme weather, rising sea levels, and changes in climatic patterns.
- To create sophisticated risk models and techniques that reliably measure and forecast climate-related hazards, allowing insurers to decide on underwriting and pricing with more knowledge.
- To assess insurers' capital sufficiency, reinsurance plans, and investment portfolios in light of climate risk to assess their financial viability.
- To look at how the regulatory environment is changing about risk from climate change and evaluate how ready the sector is to comply with these regulations.
- To evaluate methods for offering diversification and identify prospective market prospects for underwriters in climate-resilient goods, such as generic insurance.
- To assess how policyholders are affected by climate risk and suggest ways to guarantee sufficient coverage and just compensation in the case of weather-related calamities.
- To investigate how insurers may support internal and external climate mitigation and adaptation strategies to support environmental sustainability.
- To interact with legislators, regulators, and business stakeholders to promote cooperation and information exchange to successfully manage climate risk.

- To promote ethical communication to investors, clients, and the public by encouraging openness in the reporting of environmental risk exposures and strategies.
- To provide best practices and suggestions to help the insurance sector become more resilient over the long run to climate change so that it can continue to meet society's demands for risk management.

### 1.15. Significance of the study

The substantial effects of climate change are driving huge reforms in the insurance sector. The assets and liabilities of insurance companies are severely jeopardized by their susceptibility to climate-related calamities. To comply with changing regulatory requirements, insurers must develop complete Net Zero plans and sustainability policies. This underscores the industry's increasing dedication to tackling climate-related issues.

In the past, insurance companies' main business activities did not adequately incorporate the monetary and monetary consequences of climate change. However, with the identification of the effects of climate change falling within the categories of physical, liability, and transitional risks, there has recently been a paradigm shift. Organizations may monitor and quantify risks thanks to this integration, demonstrating a proactive approach to reducing possible impacts.

Different strategies are used to address social, environmental, governance, and cultural (ESG-C) aspects in the two main sub-domains of the insurance industry: casualty and property insurance and life insurance. The adoption of ESG-C criteria by life insurers in their financial decision-making processes has been more rapid. But as business pressure to incorporate ESG-C considerations into their operations grows, property and casualty insurers with their reduced investment risk are catching up. The emphasis is now

on going forward and producing money rather than being defensive (Climate Change, 2022). P&C insurers are starting to realize the income potential that ESG-C factors provide, especially those in the corporate-specialized P&C insurance market. As the economy shifts to a low-carbon one, green buildings, and renewable energy initiatives are presenting both new threats and excellent possibilities. This change in outlook calls for modifying business models to include information on transition risks, strategically allocating resources, and experience, and leveraging the possible advantages of an economy with low carbon footprints.

Globally uniform ESG reporting requirements are becoming more and more in demand; according to the EY Global Institutional Investor Survey, 89% of investors support obligatory reporting. This illustrates how openness and accountability are becoming more and more important when evaluating insurers' ESG performance (Building Climate Pathway, 2022). The increased frequency of catastrophic weather occurrences is posing a challenge for insurers in terms of financial losses. Although industry guidance has been provided by disaster risk models historically, these models are inadequate in addressing the dynamic dangers posed by climate change. The advent of climate risk models, which employ projection-based simulations derived from greenhouse gas emissions, offers insurers a chance to modify their business strategies. Successfully navigating the terrain of climate hazards might help one seize business opportunities and lessen monetary losses brought on by lack of preparation (Climate Change, 2022). A comprehensive strategy to risk management as well as company adaptation is required due to the significant impact of warming temperatures on the insurance sector. For insurers to effectively handle the problems presented by climate change, take advantage of income possibilities, and guarantee long-term sustainability, it is imperative that they integrate ESG-C variables, implement standardized reporting

standards, and employ climate risk models. This information emphasizes how crucial it is for the insurance sector to handle climate threats.

### 1.16. Organization of the Study

An organized method is necessary for the structuring of a complete research to explore the various facets of a crucial subject. In this case, the thesis methodically presents the findings of research focused on certain goals. The thesis is divided into five sections, each of which emphasizes the significance, objectives, and relevance of the study, particularly about the domains where the insurance sector and climate change intersect. In the second chapter, a comprehensive review of the literature is presented, critically analysing earlier studies, theories, and noteworthy discoveries on climate risk in the insurance industry. Setting the foundation for comprehension of the background and knowledge gaps is this examination of the literature.

The third chapter describes in detail the Research Methods that were used, together with the data sources and mathematical tools that were used in the investigation. The fourth chapter subsequently furnishes an all-encompassing examination and synopsis of the study's discoveries. This critical examination advances knowledge of the difficulties the insurance sector faces considering climate change.

The fifth chapter emphasizes the research's contributions to the insurance industry and society at large. The main findings from the study are emphasized, along with their wider ramifications. This last chapter clarifies how the research might influence procedures in the insurance sector and emphasizes the study's importance in the academic community. These chapters' well-organized structure guarantees a cogent and thorough examination of the interactions between the insurance industry and climate change, offering insightful information for both scholarly discussion and real-world applications.

## 1.17. Summary

The study focused on Risk related to climate change in the realm of insurance which is a growing and complex challenge. Climate risk refers to the likelihood and magnitude of undesired consequences induced by shifts in temperature, precipitation patterns, and ecosystem disruption It has significant effects on public health, geopolitical stability, and the international economy. The management and mitigation of climate risk are significantly aided by the insurance sector. It provided financial protection against various unforeseen events, including those related to climate change. Insurance companies need to review their risk models, underwriting procedures, and capital sufficiency to adjust to evolving hazards and regulatory frameworks. They also offer innovative products like parametric insurance and focus on sustainability. The study's goals were to examine how digitization has influenced the insurance industry and to suggest relevant future research topics. The idea of transitional risk, which relates to the shift to a low-carbon economy, was also covered. For businesses that depend significantly on electricity and fossil fuels, transition risk was a critical issue since it might cause large swings in asset values. To develop strategies that are climate resilient, the study emphasized how crucial it is to include environmental modelling and data in decision-making processes. It underlined how important precise risk reporting is, especially for industries that are susceptible to pandemics and climate change. The research demanded more precise risk disclosures from major players in these industries, including hotel chains, airlines, and cruise lines. The study is divided into five chapters that discuss the study's importance, aims, and relevance, a review of current scholarship on risks associated with climate change in the insurance sector, research methodology, information sources, and analytical techniques employed.

# CHAPTER II:
# REVIEW OF LITERATURE

## 2.1. Introductions to Climate Risks for Corporations

Chapter 2 examines the complex terrain of climate risk, illuminating its diverse character and far-reaching ramifications. As the global environment experiences extraordinary changes, identifying and managing related risks becomes critical. This navigates the complexity of climate risk, studying its numerous kinds, consequences on various industries, and emerging risk assessment and administration solutions. By giving a thorough overview, this seeks to provide readers with the information needed to appreciate the complexities of climate risk, creating the groundwork for educated decision-making and resilient approaches in the face of an unpredictable climatic future. Climate risk is a multifaceted issue that affects natural systems, social frameworks and economic landscapes. It includes both physical and socioeconomic effects, demonstrating weaknesses across industries. The research investigates alternative risk assessment approaches to provide a complete knowledge of climate risk and create the framework for successful risk reduction and adaptation measures. This investigation assists readers in making educated judgments and responding to the uncertainties provided by climate change, supporting a proactive reaction to the uncertainties.

Climate change is exerting a notable influence on corporations, whether it be directly or indirectly, using asset destruction and supply chain disruption, among various other contributing factors. Consequently, there has been an increasing focus on the management of climate change, signifying its growing pertinence in contemporary

discourse. Predominantly, the literature available on climate change and climate risk emphasizes the role of the public sector in addressing this multifaceted issue. By contrast, the private sector, particularly corporations, adopts a secondary role, assuming responsibility for the provision of financial support for research endeavours concerning climate change and its associated risks It becomes apparent that there are two essential, urgent steps that organizations need to implement to successfully manage and reduce the risks related to climate change.

## 2.2. Review of Literature

### 2.2.1. Corporate Actions in Response to Climate Risks

Corporations are increasingly pushed to take proactive actions in response to mounting climate dangers. Climate-related incidents are becoming more frequent and severe, prompting a paradigm change in corporate tactics. Companies are implementing comprehensive risk management systems that include climate-related risks, indicating a greater understanding of the possible consequences on operations, supply networks, and overall company resilience (Tenggren *et al.,*2020). Climate risk factors must be integrated into tactical choices, and supply chain management, including long-term planning. Furthermore, companies are studying environmentally friendly methods and innovations as part of their reaction to climate concerns, integrating their company models with the demand for responsibility for the environment and resilience amid climate change.

Corporations find themselves obligated to redirect their financial investments towards the procurement of products that are supportive of the climate and low-carbon economy, to mitigate the adverse effects of carbon emissions on the environment. Businesses should devote a large amount of their funding to green project implementation and the promotion of sustainable and environmentally friendly practices.

All countries require corporations to provide a comprehensive explanation of their climate risk exposure in their financial statements This imperative directive ensures that corporations are accountable for their vulnerability to climate-related hazards, thereby upholding transparency and fostering informed decision-making. The disclosure of their financial and assets exposure to climate risk is pivotal in assessing and determining their strategic approach to capital management. By doing this, corporations can evaluate the financial effects of climate change, create asset protection plans, and allocate resources as efficiently as possible.

The TCFD Guidance provides comprehensive guidelines and recommendations about the coverage of climate risk exposure at the financial system level. This covers a broad spectrum of variables and aspects that must be considered into account when evaluating and controlling climate risks in the financial sector. However, it is important to note that the company-level requirements for conducting a sound climate risk assessment present an advantageous opportunity for further enhancement and improvement. To effectively traverse the difficulties and seize the possibilities posed by climate change, companies may improve their comprehension and oversight of climate risks with the help of these needs (Sanderson, 2019) (Mannappan and Varadarajan, 2023). Organizations may enhance their sustainability and adaptability amid an increasingly unpredictable and changing environment by following these company-level guidelines, which will help them establish better and more effective plans for tackling climate risk. Moreover, putting good climate risk assessment procedures in place at the corporate level can help achieve the overarching objective of creating a financial system that is more robust and sustainable overall (Figure 2.1). It is feasible to collect and assess this data at the system level, enabling a more precise and complete evaluation of climate-related financial risks, by guaranteeing that individual enterprises have a clear and

thorough awareness of their exposures to climate risk. Consequently, this facilitates the development of legislation and regulations that are appropriate for mitigating these risks and augmenting the stability and resilience of the economy. So, company-level requirements for sound climate risk evaluation should not be seen as just another regulatory burden, but rather as an excellent chance for organizations to enhance their risk management capabilities, support the long-term sustainability and viability of the economy overall, and eventually encourage constructive change in reactions to climate change.

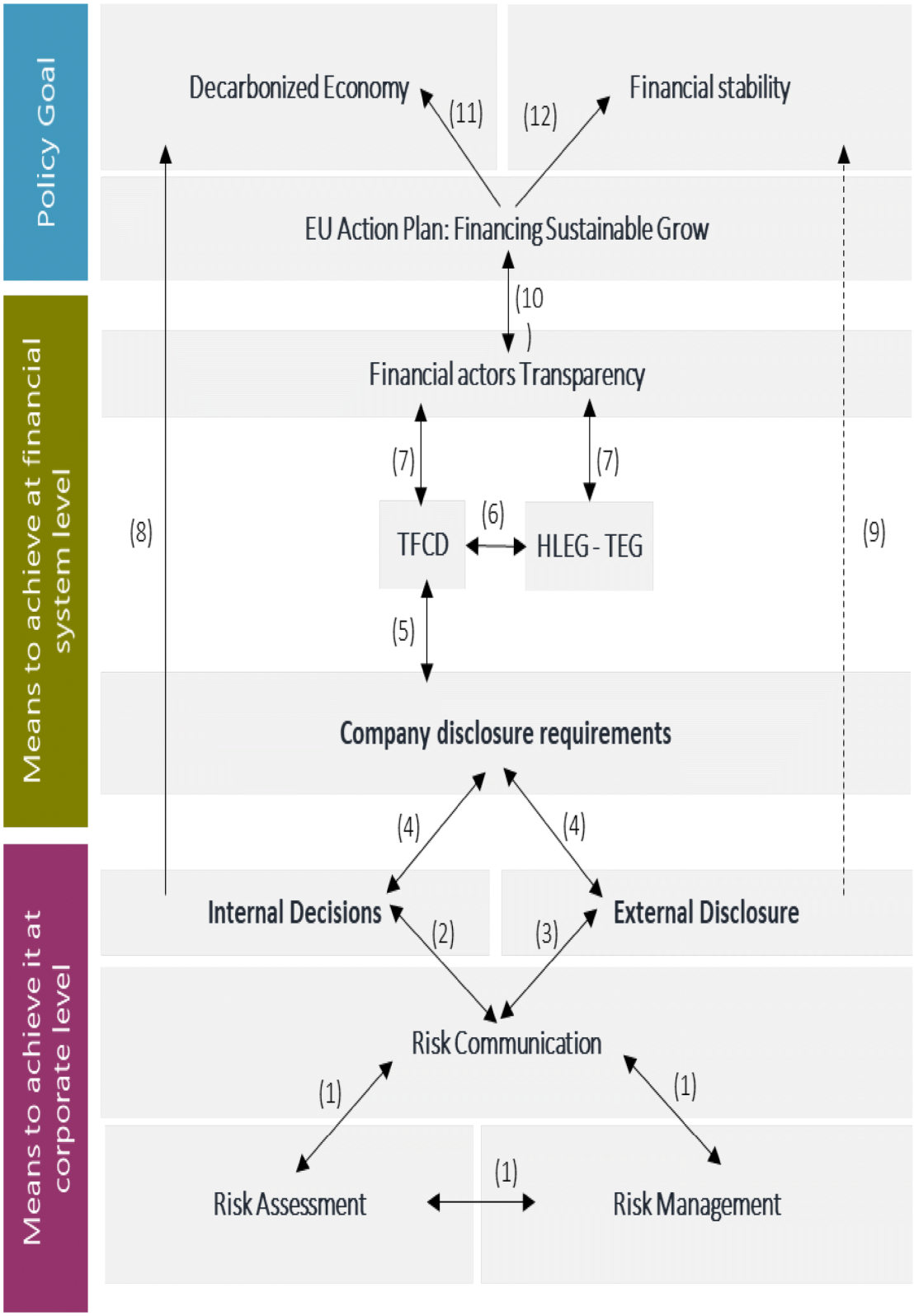


***Figure 2.1:*** *How do climate risks affect corporations (*Sanderson *et al.,* 2019*)*

The link between the environment, capitalism, and companies demonstrates how the idea of global warming as a concern may be used to justify specific corporate policies and operations (Carney, 2015). Risk is viewed as an act of politics since it affects whether acts are judged acceptable. Their study also emphasizes the possibility of financial rewards from carbon risk arbitrage. Furthermore, it investigates the relationship between crisis management and ecology, highlighting the importance of a global view and strategic solutions to crises in economic operations.

There are three stages in the business reaction to the effects of climate change: framing, localization, and normalization (Wright and Nyberg, 2017). This paper contends that criticism drives the procedure of turning the problem of global warming into regular company concerns. Their essay shows the limitations of depending on corporate and market answers for dealing with the climate catastrophe.

Physical changes induced by climate change can cause issues for businesses (Gasbarro and Pinkse, 2016), as well as the need to develop an adaptation strategy. Their study addresses the oil and gas business and finds four forms of adaption behaviour: pre-emptive adaptation, reactive adaptation, continuous adaptation, and postponed adaptation. Their paper finishes with recommendations for managers and policymakers. Unfortunately, the article's full text is now unavailable.

Climatic risks exacerbated by emissions of greenhouse gases pose to mankind (Mora *et al., 2018)*. They discovered evidence of 467 pathways in which environmental risks such as becoming warmer, heat waves, rainfall, flooding, drought, fires, hurricanes, rising sea levels, and shifts in the landscape and ocean chemistry have impacted the health of people, water, food, the economy, infrastructure, and security. According to their report, if emissions of greenhouse gases are not rapidly decreased, the world's population will face numerous climatic risks by 2100, with certain coastal areas

suffering up to six hazards at the same time. Their findings emphasize the need to address greenhouse gas emissions, which exacerbate a variety of dangers that endanger human life.

#### *2.2.1.1 Diverting Financial Investments to Climate-Friendly Products*

There is a perceptible trend in monetary investments toward environment-friendly products in response to the mounting urgency of climate change. Shareholders are growing increasingly mindful of environmentally responsible companies' long-term profitability and sustainability. Shareholders are growing increasingly mindful of environmentally responsible companies' long-term profitability and sustainability. The growing significance of green bonds, environmentally friendly investment funds, and ecologically focused financial products reflects this reallocation of financial resources. Companies that show a commitment to minimizing climate risks and supporting sustainability earn a larger proportion of financial investments. This shift reflects a greater recognition within the financial industry of the need to align investments with environmentally responsible practices, supporting the global effort to combat climate change.

Climate change receives increasing attention due to environmental damage caused by global warming (Naeem *et al., 2023)*. The GCC countries, known for their oil and gas production, are focusing more on renewable energy and sustainability. Their study used a cross-quantilogram approach to examine the high interdependence between these assets. Their study discovers favorable correlations between clean energy equities and GCC stock performance, implying possible diversification advantages. Their findings add to the body of knowledge on environmentally friendly finance and give useful insights for investment managers as well as investors within the GCC markets.

#### *2.2.1.2 Mandatory Climate Risk Disclosure in Financial Statements*

Governments and financial regulatory entities are progressively acknowledging the importance of climate change as a financial hazard and are instituting measures to ensure transparency. This disclosure typically encompasses details on how climate-related factors, such as severe weather occurrences or regulatory alterations connected to environmental policies, might impact the operations, assets, and liabilities of the organization. These disclosures can encompass various facets, comprising greenhouse gas emissions, resource consumption, and strategies for resilience. By integrating the disclosure of climate risk into financial reporting, enterprises are prompted to proactively assess and manage these hazards, contributing to a more knowledgeable and sustainable investment environment (Linnenluecke *et al.,* 2015). Ultimately, mandatory climate risk disclosure aligns financial reporting with the broader objective of addressing climate change and fosters responsible corporate conduct in the face of evolving environmental predicaments.

Institutional investors value and request climate risk disclosures (Ilhan *et al., 2023)*. Their research shows a high demand for these disclosures, with investors actively encouraging companies to improve them. Analysis of ownership data indicates a positive link between institutional ownership focused on climate issues and better climate risk disclosure by firms. Their study highlights the impact of institutional investors on corporate transparency and sustainability practices. Table 2.1 illustrates the advantages and research gaps of Corporate Actions in Response to Climate Risks.

***Table 2.1:*** *Comparability of Corporate Actions in Response to Climate Risks (Source : Mannappan and Varadarajan 2023)*

| Author | Year | Aim | Advantages | Research Problem |
|---|---|---|---|---|
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|---|---|---|---|---|
| Carney | 2015 | Examine the relationship between corporations, capitalism, and the environment and make the case that the risk of global warming and the arbitrage of carbon dioxide justify economic activities. | Investigate the relationship between corporations, capitalism, and the environment | Looks at how business strategies are justified by the theory of global warming, with a particular emphasis on carbon risk arbitrage. |
| Wright and Nyberg | 2017 | It looks into how businesses adjust to climate change and breaks down their responses into three phases based on how their operations evolve. | This research looks into the methods companies are using to lessen the consequences of climate change. | Highlights the dependence on corporate actions and points out three phases in the business response to climate change. |
| Gasbarro and Pinkse | 2016 | The need for adaptation and how climate change can impact companies through physical changes, highlighting four types of behaviour that can be adapted. | Discusses adaption techniques used in the petroleum and gas sector and offers suggestions to managers and decision-makers. | Companies may be affected by the physical changes brought forth by climate change and offer solutions. |

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|---|---|---|---|---|
| Mora *et al.,* | 2018 | Determine the ways that environmental concerns affect food, water, health, financial markets, infrastructure, and security. | Emphasizes the urgency of reducing greenhouse gas emissions and provides evidence of various manifestations of climate dangers. | To decrease the release of greenhouse gases by 2100 to lessen the danger that comes with climate concerns. |
| Ilhan *et al.,* | 2023 | Demonstrates how institutional investors evaluate and ask for disclosures on climate risk. | It shows a strong need for environmental danger disclosures and actively promotes their improvement. | Institutional investors affect business sustainability and transparency policies. |
| Naeem *et al.,* | 2023 | Gain knowledge about the growing focus on the threat posed by climate change, particularly in the GCC nations as they transition to renewable energy sources. | Finds positive connections between GCC stocks and renewable energy stocks. | Provides information for investors and investment managers by examining the strong correlation between the performance of GCC stocks and renewable energy stocks. |

### 2.2.2. TCFD Guidance and Opportunities for Improvement

Organizations can utilize the framework developed by Task Force on Climate-related Financial Disclosure (TCFD) to assist them in disclosing in their financial reporting the opportunities and risks associated with climate change. TCFD promotes the alignment of companies' disclosures with recommendations about governance, strategy, risk management, and metrics and targets. By offering a consistent and comprehensive approach, TCFD empowers investors, stakeholders, and the market to evaluate and compare companies' exposure to climate risks as well as their strategies for addressing them.

Opportunities for enhancement within the TCFD framework are found in the improvement of the consistency and comparability of climate-related disclosures. This entails refining methodologies for the measurement and reporting of climate-related metrics, ensuring clarity in the definition of key terms and scenarios, and fostering broader adoption of the TCFD framework across various industries. Furthermore, businesses may explore innovative approaches to incorporate climate-related matters into their general accounting records to demonstrate their commitment to sustainable and ethical business operations.

A methodological framework that consists of seven easy stages has been proposed to help efficiently conduct climate risk assessment This proposed framework aims to give a comprehensive picture of the process of assessing climate risk, accounting for both external and internal aspects, including disclosure and decision-making and management procedures. Organizations may ensure a comprehensive and methodical strategy for climate risk assessment by adhering to this framework, which will allow them to evaluate and manage the possible risks presented by warming temperatures in an integrated way (Sanderson, 2019). The framework offers an ordered and methodical methodology that

leads firms through the several phases of assessing climate risk, from gathering and analyzing data to creating risk-reduction plans. It highlights how crucial it is to take into account both internal and external elements that affect climate risk, realizing that a thorough grasp of the larger environment in which an organization functions is necessary for an effective risk assessment. Organizations looking to include climate risk evaluation in their operations and choice-making procedures will find this suggested methodological framework to be a useful tool as it offers them a well-defined and organized road map for managing the risks related to climate change.

Identifying, assessing, and managing possible risks related to climate change requires a methodical and thorough approach, which is what is involved when carrying out a specific company climate risk assessment. Usually, the procedure consists of many crucial phases.

First and foremost, businesses must evaluate how vulnerable they are to physical climate hazards, taking into account elements like setting, exposure to extreme weather, and asset sensitivity. This entails carrying out an exhaustive examination of supply chains, operations, and infrastructure.

Second, businesses have to examine the regulatory environment, comprehending how present and upcoming climate-related laws may affect their operations. Evaluating the possibility of carbon pricing, emissions controls, and other pertinent measures is part of this. In the third stage, the business's transition risks are assessed, taking into account potential effects on its business activities and financial performance from changes in investor mood, technical improvements, and market preferences. Businesses are required to engage in communication with various parties of interest, such as investors, customers, and employees, to comprehend their anticipated outcomes and apprehensions about climate change-associated matters (Figure 2.2). This action promotes openness and

assists in bringing the company's climate plan into compliance with stakeholder expectations.

Finally, a comprehensive plan to address climate risk should be developed, incorporating adaptation and mitigation techniques, to increase resilience and seize new opportunities. For a climate risk management approach to continue to be effective, periodic evaluation, reporting, and re-evaluation is essential. All things considered, developing a specific company weather risk evaluation is a continuous procedure that has to be continually enhanced as the environment changes.

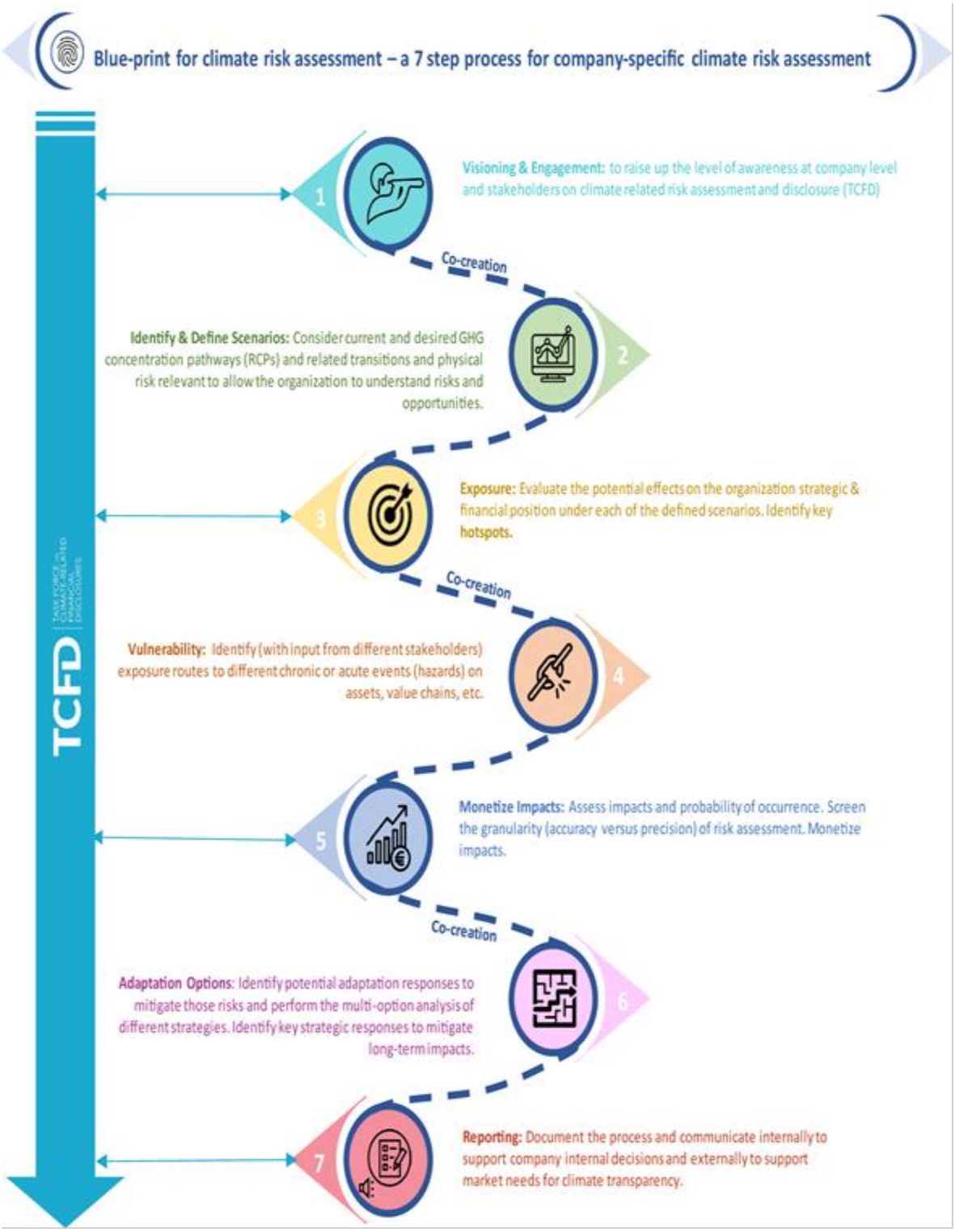


***Figure 2.2:*** *Company-specific climate risk assessment (*Sanderson *et al.,* 2019*).*

The revolutionary potential for TCFD reporting in the field of sustainable accounting (O'Dwyer and Unerman, 2020) propose numerous research objectives to address the issues that reporting firms and investors encounter when implementing TCFD-style sustainability risk, opportunity, and dependency reporting. Their study underlines the need for new climate-related scenario evaluation and dissemination techniques, as well as the possibility for academic research to offer strong evidence to improve the practical effect of TCFD reporting. Their essay is the first to emphasize the need for academic study in this field and its potential to alter corporate sustainability accounting and reporting.

Corporate climate change disclosure and its effect on financial stability are emphasized (Amar *et al., 2022)*. It draws attention to the part played by financial regulators and central banks in mitigating climate-related risks. The Working Group on Financial Disclosures Related to Climate Change and the Network of Organizations for the Greening of the Financial System's publications are cited in the text. Additionally, it talks about "green swan" events—extreme climate-related occurrences that have the potential to put the financial system at risk. The link between environmental disclosure, corporate value, and disclosure levels is also examined in the book, as is the contribution of sustainability reporting to increased accountability and transparency.

Climate-related Financial Disclosure recommendations put into practice, highlighting the necessity of measuring and disclosing climate-related risks and opportunities is realized and a task force is formed for it (Kyriakopoulou *et al., 2022)*. It makes recommendations for strengthening central banks' disclosures on climate change and its effects on the larger financial system. Their study promotes a framework that is adaptable to evolving definitions, facts, and techniques. The suggestions are meant to encourage more practical use of TCFD guidelines, and they may be applied to different

central bank portfolios. Table 2.2 illustrates the advantages and research gaps of TCFD Guidance and Opportunities for Improvement.

***Table 2.2:*** *TCFD Guidance and Opportunities for Improvement (Source : Mannappan and Varadarajan 2023)*

| **Author** | **Year** | **Aim** | **Advantages** | **Research Problem** |
|---|---|---|---|---|
| O'Dwyer and Unerman | 2020 | The TCFD reporting's potential in sustainable accounting is examined in the book. | The research aims to address the challenges faced by investors and reporting companies in implementing TCFD-style sustainability reporting. | The potential of academic research to impact business sustainability accounting and reporting, as well as the necessity of creative methods for evaluating and disseminating climate-related scenarios. |
| Amar *et al.,* | 2022 | Stress the significance of business global warming disclosure and how it affects the stability of the | The relationship between environmental disclosure, company value, and | Investigates how greater accountability and openness are aided by |

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| | | financial system. | transparency, and the critical role that central banks and financial regulators have in reducing climate-related risks. | sustainability reporting. |
| Kyriakopoulou *et al.,* | 2022 | Implementing the TCFD recommendations emphasizes the importance of measuring and disclosing climate-related risks and opportunities. | The report suggests that central banks should improve their climate change disclosures by creating a flexible framework that can adapt to evolving definitions, facts, and techniques. | To promote the practical application of TCFD guidelines across various central bank portfolios. |

### 2.2.3. Methodological Framework for Climate Risk Assessment

Extensive research and evaluation of potential dangers that may arise as a result of climate change are part of the rigorous and methodical technique used to perform a climate risk assessment. This methodological framework is utilized for this purpose. To evaluate and ascertain the probability and chance of occurring of extreme weather events, this meticulous process usually entails the integration and combination of a wide range of

information and data sources, which includes but is not restricted to satellite data as well as location-based information. The main goal of this structure is to create a strong and trustworthy probabilistic framework that can be efficiently applied for the forecasting and anticipating of hazards associated with climate change by accounting for local as well as global elements. Thus, the application of this technique substantially aids and encourages decision-makers in the formulation and development of suitable and successful strategies targeted at the mitigation and reduction of the unfavorable effects and outcomes linked with climate-related risks. The ultimate objective of these endeavors is to augment and strengthen the degree of readiness and adaptability that is exhibited as well as shown in the face of the constantly shifting and developing climate conditions, consequently offering and supplying useful and perceptive data, expertise, and direction that can be utilized and applied.

Hazard-aware business procedure management (R-BPM) merges risk management with business process management to enhance organizational structure and efficiency (Lamine *et al., 2020)*. To assist the use of R-BPM, the authors suggest the Business Process-Risk Integration Method and a related tool named adoBPRIM. The BPRIM framework is made up of three major components: a single meta-model for risk and company procedures, and a language for modeling for defining dangerous scenarios. Their essay also contains an instance analysis in the healthcare industry to highlight the BPRIM framework's use.

A methodological framework for assessing the likelihood of extreme weather occurrences using satellite and location-based data (Jha *et al., 2022) is presented*. It makes use of studies on the risks associated with heavy rainfall in India and incorporates both local and global aspects into a probabilistic model. In numerous districts throughout Indian states, there is a significant probability of heavy rainfall, according to the report.

Their framework's goal is to assist decision-makers in developing strategies to lower the likelihood of catastrophes brought on by heavy rains.

The possibility of durum wheat farming with no-till soil management being effective (Gristina *et al., 2018) was proposed*. The influence of crop residue management, cropping systems, aridity index, and soil management on yield was examined by the researcher using data gathered from extended field experiments. They discovered that crop management had an impact on the effectiveness of no-till and that it fared better in regions that had lower aridity index values. Depending on the dryness index, their study suggests a methodology for estimating the likelihood that various soil management strategies will be adopted When choosing which management strategies are best for cultivating durum wheat, farmers and policymakers may use the information as an instrument for decision-making.

***Holistic Approach to External and Internal Climate Risk Assessment***

The shortcomings of probabilistic techniques for conveying unpredictability in environmental research and the notion of "storylines" as a replacement (Shepherd *et al., 2018) is key*. Without assigning probabilities, storylines are defined as physically self-consistent tales of past or likely future events. Storylines are considered a tool to increase risk awareness, boost decision-making, divide ambiguity, and explore the limits of plausibility. Their text also includes an example of a plot involving a rain-on-snow incident in the Swiss Alps and the activities conducted in response.

The necessity of risk evaluations and decision-making tools for managing climate change-related challenges in cities—particularly flooding and extreme precipitation events is important (Gandini *et al., 2021).* Their essay suggests a comprehensive, multi-

stakeholder approach to evaluate hazards and vulnerabilities in the city's building stock to facilitate adaptation measures and advance sustainable development. Their paper also presents a categorization approach for examining the building stock and the application of the CityGML multiscale data structure for urban modeling. The relevance of efficient instruments for risk evaluation for urban planners is emphasized in their article's conclusion, which also appreciates the money and assistance received for the research. Table 2.3 illustrates the advantages and research gaps of the Methodological Framework for Climate Risk Assessment.

***Table 2.3:*** *Comparability of Methodological Framework for Climate Risk Assessment (Source : Mannappan and Varadarajan 2023)*

| **Author** | **Year** | **Aim** | **Advantages** | **Research Problem** |
|---|---|---|---|---|
| Lamine *et al.,* | 2020 | The concept of integrating risk management and business process management to guarantee hazard-aware business process management. | The Business Process-Risk Integration Method (BPRIM) and adoBPRIM tool for implementing R-BPM, analysing an instance in the healthcare industry using the BPRIM | The goal is to improve organizational structure and efficiency through the implementation of R-BPM. |

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| | | | framework. | |
| Jha *et al.,* | 2022 | The paper presents a methodological framework for evaluating the probability of extreme weather events utilizing satellite and location-based data. | The probabilistic model incorporates local and global factors to aid decision-makers in developing strategies to reduce the likelihood of heavy rain-related catastrophes. | To evaluate the probability of extreme weather events, focusing on the risks linked to heavy rainfall in India. |
| Gristina *et al.* | 2018 | The potential of durum wheat farming with no-till soil management and investigates the impact of crop residue management, cropping systems, aridity index, and soil management on yield. | Utilizes field experiments to evaluate the efficacy of no-till farming methods and proposes a methodology for estimating the likelihood of implementing | The impact of numerous parameters on the success of zero-till cultivation in durum wheat production. |

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| | | | different soil management strategies. | |
| Shepherd *et al.,* | 2018 | Analyse the drawbacks of using probabilistic methods to represent uncertainty during environmental research and propose the idea of "storylines" as a substitute. | Introduce the use of narratives as a tool to split ambiguity, improve decision-making, raise risk awareness, and investigate the boundaries of plausibility. | Drawbacks of probabilistic methods and suggest narratives as a substitute for them to portray uncertainty in environmental research. |
| Gandini *et al.* | 2021 | Consider if risk assessments and decision-making instruments are essential for handling climate change-related issues in urban areas, including floods and excessive precipitation incidents. | The risks and weaknesses in the city's building stock to expedite adaptation strategies and promote sustainable development. | Examine the necessity for effective risk assessment tools in urban planning, particularly for handling issues connected to climate change |

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| | | | | in metropolitan areas. |

### 2.2.4. Models for Measuring Climate Risk

To evaluate the possible effects of warming temperatures on different sectors, models for quantifying climate risk are essential. These models integrate scientific, economic, and environmental data to quantify risks associated with changing climate patterns. By employing advanced analytics and scenario simulations, these models help businesses, governments, and organizations understand the potential vulnerabilities they face. They provide valuable insights for strategic planning, risk mitigation, and policy development Furthermore, these models support sustainable behaviors, increase readiness and resilience, and assist decision-makers in tackling the complex issues brought on by climate change.

Natural disasters are growing more common primarily as a consequence of climate change, causing massive economic damages (Kling *et al., 2021)*. Developing countries are more exposed to these consequences. Their study looks at how climate vulnerability affects capital costs and credit availability in the private sector. They discover that climate vulnerability raises enterprises' loan costs but not their equity costs. They also discover that enterprises in climate-vulnerable regions have limited access to capital. These findings emphasize the detrimental impact of warming temperatures on the economy and the need for climate resilience investment.

#### 2.2.4.1 *Importance of Climate Scenario Models*

The difficulties in analyzing and comprehending droughts in the region known as the Mediterranean, particularly in the setting of changing climate scenarios is a concern (Tremblay *et al., 2020)*. It goes over the many sorts of droughts and the climatic scenarios that go with them. Their essay also underlines the need to include atmospheric evaporation in dryness indicators and investigates vegetation's sensitivity and resilience to drought. Drought monitoring and forecasting rely heavily on remote sensing and modeling. Droughts have been increasing in the Mediterranean region and are anticipated to continue, according to scientists. Their essay continues by emphasizing the importance of more research to remove ambiguities and improve our comprehension of drought in this region.

The coldest month's lowest temperature, yearly precipitation, annual average temperature, and hottest quarter's mean temperature were the most relevant parameters influencing habitat appropriateness for Chinese fir (Zhao *et al., 2021)*. The acceptable habitats for Chinese fir were anticipated to diminish and grow more fragmented under future climatic scenarios, with a propensity to relocate to higher-altitude places. In reaction to changing climate circumstances, the study emphasizes the importance of adapting long-term preservation and management techniques for Chinese fir plantings.

**2.2.4.2** ***Catastrophe Risk Models***

A comprehensive list of diverse scholarly papers and authoritative materials about the concept of existential hazards (Turchin and Denkenberger, 2020) encompasses a range of subjects, including but not limited to artificial intelligence, nuclear warfare, biosecurity, and other conceivable menaces to the human species. The purpose of their

piece of writing is to provide a curated assortment of references that can be utilized for subsequent investigation and discourse on the subject matter of existential risks.

The risk management measures used by maize growers in Bangladesh (Adnan *et al., 2020)* polled 350 farmers from various areas, and a multivariate probit model was used to examine the relationship between producers' views on catastrophic hazards and their feelings toward risk sources. Their study also investigated the association between risk management techniques such as contract farming, growth, and precautionary savings. Their findings suggest that using one risk administration tool might affect the usage of another. Age, level of education, extension expertise, monthly household income, agricultural regions, ownership of land, and cautious nature were shown to be major factors influencing risk management strategy acceptance. Their findings are useful for decision-makers in anticipating optimal risk management measures. Table 2.4 illustrates the advantages and research gaps of Models for Measuring Climate Risk.

***Table 2.4:*** *Comparability of Models for Measuring Climate Risk (Source : Mannappan and Varadarajan 2023)*

| **Author** | **Year** | **Aim** | **Advantages** | **Research Problem** |
|---|---|---|---|---|
| Kling *et al.* | 2021 | Analyse the impact of climate sensitivity on private sector capital costs and availability of credit, with a | the link between higher loan costs for businesses and climate vulnerability. | the economic effects of climate change, focusing on developing nations and the private sector's capital costs and |

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| | | focus on developing nations. | | credit availability. |
| Tremblay *et al.* | 2020 | the need for more research to improve our understanding of drought in the area known as the Mediterranean by examining the difficulties in assessing and understanding them. | covers situations with a Mediterranean climate and several types of droughts. highlights the importance of including atmospheric evaporation in measures of dryness. | explores the difficulties in comprehending and analysing droughts in the Mediterranean, particularly in light of future climate projections. |
| 2021, Zhao *et al.* | 2021 | The goal of the study is to forecast, using climatic criteria, the ideal habitat for Chinese fir. | Factors affecting the Chinese fir's habitat appropriateness. Expect alterations in habitat appropriateness | The appropriateness of a habitat for Chinese fir and plan for future climate scenarios. |

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| | | | in light of potential future climate scenarios. | |
| Turchin and Denkenberger | 2020 | Provide a thorough index of a wide range of academic articles and reliable resources on existential risks. | offers a thorough list of sources about existential threats. | Assemble reliable resources and a variety of academic publications regarding existential threats. |
| Adnan et al. | 2020 | Examine the connection between producers' attitudes regarding risk sources and their perspectives on catastrophic hazards. | the effect of several elements on risk management methods' adoption. | Analyse the relationship between different aspects impacting the acceptability of a plan and risk management strategies. |

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### 2.2.5. Overview of Climate Change and Financial Stability

Climate change can impact an insurer's financial stability through three broader risk categories, as per Alliance (2021).

**Physical risks**

Extreme weather events and long-term alterations in climatic patterns are two physical concerns linked to climate change. The implications of these changes extend to infrastructure, human well-being, and ecosystems, all of which are exposed to risks. Coastal areas are particularly vulnerable to storm surges, while agricultural practices are influenced by the shifting patterns of precipitation. Additionally, the warmer environment facilitates the spread of infectious diseases.

The potential to cause shocks and vulnerabilities to the financial system and economy (Brunetti *et al., 2021)* emphasizes the need for further investigation and analysis to understand these risks and emphasizes the importance of transparency in revealing financial vulnerabilities. The article also highlights potential issues such as asset mispricing, higher leverage, and interconnectivity. The authors contend that climate change presents substantial risks to the stability of the financial system and necessitates immediate and focused consideration.

**Liability risks**

The financial and legal ramifications that governments, businesses, and people may face as a result of participating in environmental destruction are linked to climate

change liability risks. Lawsuits against organizations accused of inadequate emission control, environmental damage, or non-compliance with climate-related obligations are becoming more probable as climate-related damages increase. Industries such as transportation and energy, which have significant carbon footprints, may face legal action for their impacts. Liability risks emphasize the importance of effective regulatory compliance, robust climate change risk management, and legal frameworks that assign liability for climate change damages. Taking proactive measures and adopting environmentally friendly practices are essential to adapt to these risks.

Digital technology may be used to fight climate change and promote sustainable development by merging of sustainability and digital mandates, as well as the capacity of entrepreneurial entities to employ digital resources in addressing sustainability issues (George *et al., 2021)*. The article discerns six significant sustainability dilemmas and suggests six digital sustainability approaches to tackle them. Ultimately, it concludes with a research plan about digital sustainability.

**Transition risks:**

Transition risks in climate risk pertain to the financial and operational obstacles that corporations encounter while undergoing the transition towards a low-carbon economy. As societies worldwide endeavor to diminish carbon emissions and abate climate change, industries heavily dependent on fossil fuels or other activities emitting high levels of greenhouse gases may face transition risks. These risks may materialize in the form of alterations in regulations, mechanisms for pricing carbon, market preferences, and technological advancements that affect the value of specific assets or business models. Successfully managing transition risks necessitates organizations to adapt,

innovate, and align their strategies with emerging sustainability trends to remain resilient in an evolving economic landscape.

The global shift toward decarbonization will require certain industries to grow while others must contract (Semieniuk *et al., 2021)*. The stability of financial institutions may be significantly impacted by this structural shift, which might also result in asset revaluations, credit defaults, and the bursting of bubbles in developing industries. The report asserts that despite numerous studies on the risks of rapidly growing industries, there is a lack of research on contracting enterprises. To comprehend the causes, pathways of transmission and effects of the financial system's exposure to the phase-out of carbon-intensive sectors, the paper puts forth a theoretical framework. It also talks about how laws meant to safeguard the financial sector are doing.

Defaults and a drop in business profitability may result from climate change, which might be detrimental to both the financial and non-financial corporate sectors (Dafermos *et al., 2018)*. Additionally, it forecasts a reallocation of the portfolio that would result in a drop in corporate bond prices. Climate change may potentially aggravate its effects on the economy by causing financial instability, which would restrict credit growth. However, a green quantitative easing program could help mitigate global warming and minimize the financial instability brought on by climate change. The degree to which green investments adjust to fluctuations in bond yields will determine how successful this program is.

Central banks and financial authorities have difficulties in tackling climate change (Campiglio *et al.,* 2018). In evaluating the risks and possible effects of climate change on financial stability, it brought attention to the necessity of a thorough framework. Their essay delves into the function of financial regulators and central banks in fostering enhanced comprehension of climate-related financial hazards and reducing their impact.

It covered a range of possibilities, such as encouraging low-carbon investments, supporting risk disclosure, and minimizing hazards. Their paper raised open questions for more investigation and underlined how crucial it is to include these initiatives in central banks' current mandates. Ultimately, their paper urged central banks and financial authorities to give climate change issues more thought and to take stronger action.

#### *2.2.5.1 Three Broad Categories of Climate-Related Financial Risks*

Conventional methods are ill-suited to capture the features of climate risks, methodologies are required to assess the financial risks associated with climate change (Battiston *et al., 2021)*. Their essay stressed that new financial opportunities and hazards brought about by climate change are relevant to the stability of individual institutions as well as the global financial system. Stress tests and disclosure requirements were among the steps taken by financial supervisors and regulators to address climate concerns. Their paper also covered the physical and transitional hazards associated with climate change and how they can affect asset values and financial stability. Their article's overall thesis was that a thorough grasp of climate risks is necessary to guide financial risk assessment and ease the shift to a low-carbon economy.

The financial system is affected by climate change, namely the risks that banks and insurers face (Mandel *et al., 2021)*. The connection between climate change and systemic risk, the expense of natural disasters, and the effect of climate change on world wealth are some of the other subjects covered.

Increasing sea levels, harsh weather, and other environmental changes brought about by climate change had a detrimental impact on prosperity and economic progress (Fabris, 2020). Their paper made the case that central banks' and supervisors' mandates ought to take climate change into account since it presents financial risks to institutions.

A model for handling financial risks brought on by climate change was also developed in the article. All in all, it underscored the necessity of paying more attention to the financial ramifications of climate change and the possibility of both possibilities and threats.

***2.2.5.2 Adverse Climatic Conditions and Systematic Risk***

A weather-related natural disaster that damaged the balance sheets of households, corporations, banks, and insurers could cause financial and macroeconomic instability (Batten *et al., 2016)*. Secondly, an abrupt tightening of carbon emission policies could result in disorderly asset repricing and a negative supply shock. These are the two main risks that the authors identify for central banks. Assisting investors in evaluating their financial risk exposures and easing the shift to a low-carbon economy, according to the authors, are two benefits of climate disclosure. Table 2.5 illustrates the advantages and research gaps of the Overview of Climate Change and Financial Stability.

***Table 2.5:*** *Comparability of Overview of Climate Change and Financial Stability (Source : Mannappan and Varadarajan 2023)*

| Author | Year | Aim | Advantages | Research problem |
|---|---|---|---|---|
| Brunetti *et al.,* | 2021 | Explores the potential for climate change to cause financial system and economic shocks and vulnerabilities. | The importance of transparency in revealing financial vulnerabilities and addressing potential issues like asset mispricing. | The financial system's risks and vulnerabilities, including asset mispricing, higher leverage, and interconnectivity, are crucial to address climate change, |

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| | | | | requiring immediate attention and action. |
| George *et al.,* | 2021 | It is utilized to combat climate change and promote sustainable development. | The integration of sustainability and digital mandates identifies six key sustainability challenges, proposes six digital sustainability strategies, and concludes with a research plan on digital sustainability. | The use of digital technology in addressing climate change and promoting sustainability offers practical strategies for entrepreneurs to utilize digital resources effectively. |
| Semieniuk *et al.,* | 2021 | The transition to a low-carbon economy may introduce financial instability risks. | Examines the effects of global decarbonization on industries and financial institutions, highlighting potential risks like asset revaluations, credit defaults, and industry bubbles. | Explores financial exposure to carbon-intensive sectors, addressing research gaps, proposing theoretical frameworks, and evaluating laws' effectiveness in safeguarding the financial sector during |

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| | | | | this transition. |
| Dafermos *et al.* | 2018 | Explain how climate change is affecting the stability of the economy and promote green QE | Mitigation of global warming and minimization of financial instability through a green quantitative easing program. | Success hinges on how green investments respond to changes in bond yields. |
| Campiglio *et al.,* | 2018 | Draw attention to the challenges central banks face in addressing the financial system's impact from climate change. | Improved understanding of climate-related financial risks and mitigation of their effects via an extensive framework | Unanswered issues requiring additional research and inclusion in central banks' mandates |
| Battiston *et al.* | 2021 | Examine the relationship between climatic risks and financial stability. | Acknowledgment of the risks and new financial opportunities brought on by climate change. | Climate threats are not fully captured by traditional methods; a detailed understanding is required. |
| Mandel *et* | 2021 | Examine the topic of climate change and | Being aware of the financial cost and toll | Examines costs but might not offer all- |

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|---|---|---|---|---|
| *al.,* | | the financial system's related costs. | that extreme weather disasters have. | encompassing answers or suggestions for policy |
| Fabris | 2020 | Analyse how climate change is affecting the economy and financial stability. | Acknowledging how climate change affects the economy. | Stresses that supervisors and central banks must take climate change into account, but the effectiveness of the suggested methodology is not explained in depth. |
| Batten *et al.* | 2016 | Evaluate a central bank's ability to accomplish goals in light of mitigation efforts and climate change. | Risk identification includes things like the sudden tightening of carbon emission regulations and weather-related natural calamities. | Possible financial and macroeconomic volatility; advantages depend on facilitating the shift to a low-carbon economy and ensuring effective climate disclosure. |

### 2.2.6. Role of TCFD

TCFD and the extent to which the Group has followed its recommendations, and it emphasized the management's role in evaluating and controlling these risks, as well as the Board's monitoring of climate-related risks and opportunities (Board, 2017). The

Group's environmental plan, including the creation of steering groups to supervise the switch to zero-emission vehicles, is also mentioned in the article. It goes on to detail the roles and duties of various managers in identifying, evaluating, and controlling opportunities and hazards associated with climate change. Their study concluded by outlining the Group's procedures for locating, evaluating, and controlling these risks. Table 2.6 illustrates the advantages and research gaps of the Role of TCFD.

***Table 2.6:*** *Comparability of the Role of TCFD (Source : Mannappan and Varadarajan 2023)*

| Author | Year | Aim | Advantages | Research problem |
|---|---|---|---|---|
| Board | 2017 | Assess the Group's handling of climate-related risks and opportunities as well as the application of the TCFD guidelines. | Stressing the importance of management in regulating climate. | The effectiveness of the Group's procedures and their specific outcomes were not specifically discussed. |

### 2.2.7. Climate risk related Challenges in Insurance

Critics of insurance in the context of climate change put forth arguments that the current insurance models tend to disproportionately impose burdens on communities that contribute the least to carbon emissions. This critique arises from the fact that vulnerable communities, which are oftentimes found in developing nations, experience more severe impacts as a result of climate-related occurrences. Natural catastrophes, increasing sea levels, and harsh weather are some of these events. These vulnerable communities

typically possess limited resources and capabilities to adapt to or recover from such events. The determination of insurance premiums is frequently based on assessments of risk, which take into consideration factors like geographical location, historical data on climate-related incidents, and vulnerability. However, in places where climate hazards are larger, this tactic may result in higher insurance premiums. Critics argue that this exacerbates existing disparities because those who are least responsible for emitting greenhouse gases ultimately bear a disproportionate economic burden. Furthermore, detractors point out that many disadvantaged communities may not be able to pay or get insurance solutions, leaving them without enough financial security if climate change causes losses. Since individuals who commit the least to global warming are frequently the individuals who are most negatively impacted and least prepared to handle the financial fallout, this situation raises ethical questions. This criticism underscores the necessity for a more just and comprehensive approach to managing climate risks. It demands creative answers that take into account the worries of marginalized groups and make sure that the financial costs of environmental deterioration are allocated fairly. To increase resistance amid climate change, proponents of change suggest looking at other methods for spreading and managing risks and encouraging global cooperation.

The insurance industry finds itself utterly captivated by the emergence of various risks that demand unwavering attention and meticulous strategic adaptation to navigate the treacherous waters of uncertainty. The sector must constantly reevaluate risk management procedures due to the rapidly changing environment of cyber risks brought about by the quick speed of technology improvements. Moreover, the unrelenting effects of climate change provide an unparalleled obstacle, given their capacity to destabilize the foundation of the insurance sector (Figure 2.3). In light of these multifaceted challenges,

the industry must seek out innovative and forward-thinking risk management solutions that can effectively address the intricate complexities of this modern period.

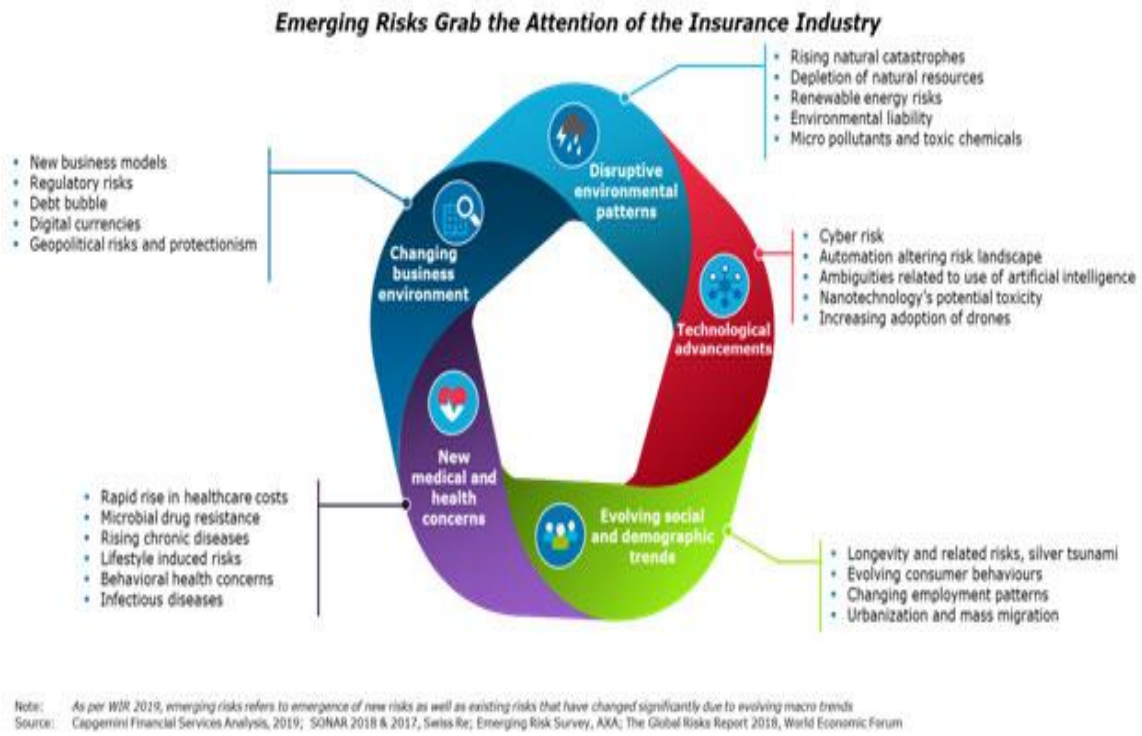


***Figure 2.3:*** *The insurance industry and emerging risks (Moneylife, 2019).*

The policies of German and Swiss banks, insurance companies, and chemical companies regarding their reporting of corporate social responsibility (CSR) to stakeholder groups is important (Lock and Seele, 2015). Their research employed quantitative content analysis of corporate social responsibility reports and compared the findings to the industry risk weighting of social and environmental issues as determined by the Sarasin sustainability rating. Their research revealed that while CSR reports from

the banking and insurance sectors fall short of the threshold, those from the chemicals industry do meet it. Although German corporations represented sector-specific risks in the banking and insurance industry, Swiss chemical producers do a good job of reporting on their industrial risks. Further standardization of CSR reporting is recommended by the study to create fair competition throughout Europe.

The difficulties that climate change poses to American agriculture and the requirement that farmers implement practical adaptation measures has examined the attitudes toward adaptation, perceived threats from weather and climate, and views about climate change among crop farmers in the Midwest of the United States (Mase *et al., 2017)*. Examined are the most popular methods for managing weather and climate risk, including acquiring more crop insurance, putting conservation measures into place, and introducing new technologies. According to their study, the most significant factors influencing adaptation are farmers' views about innovation, the risk to their farms, and attitudes toward adaptation. Table 2.7 illustrates the advantages and research gaps of Challenges in the Insurance Industry Related to Climate Risk.

***Table 2.7:*** *Comparability of Challenges in the Insurance Industry Related to Climate Risk (Source : Mannappan and Varadarajan 2023)*

| Author | Year | Aim | Advantages | Research problem |
|---|---|---|---|---|
| Lock and Seele | 2015 | Examine the CSR reporting practices of Swiss and German banks, insurers, and chemical firms, and make | Information about industry risk weighting can be obtained by quantitative content analysis of CSR reports. | Insufficient knowledge of the real CSR activities and how they affect risk management. |

| | | | | |
|---|---|---|---|---|
| | | recommendations for equitable competition throughout Europe. | | |
| Mase *et al.* | 2017 | Examine the difficulties that climate change has brought to American agriculture and the necessity for Midwest crop producers to implement workable adaptation strategies. | Examination of perspectives on adaptability and the dangers that people see from the weather and climate. | A Midwest-centric regional focus can miss more significant agricultural issues. |

### 2.2.8. Anticipated Changes in the Insurance Industry

It is anticipated that the insurance sector will undergo substantial transformations in a short time. These changes are driven by the rapid advancements in technology, the evolving expectations of consumers, and the shifting landscapes of risks. The advent of insurance companies, which is distinguished by the use of blockchain, AI, and data analytics, is a significant development in this sector. Insures holds the promise of enabling insurance companies to streamline their operations and provide personalized services to their customers. To meet the expectations of today, insurance firms are focusing heavily on customer-centricity, making improvements to their electronic interfaces, and offering coverage that is tailored to meet the requirements of individual clients. Insurers are also being prompted to create sustainable practices and reassess their

risk models by the increased public awareness of climate change Regulations are also changing, and this is affecting how insurers conduct business through the adoption of international standards, for example. Remembering that the world is becoming a more linked place is crucial as one witness these improvements. As a result, insurers will need to be proactive, strong, and resilient to effectively traverse the problems of the future. Accepting these shifts gives insurers the capacity to seize new possibilities to deal with a constantly changing environment in addition to efficiently reducing risks.

The vast majority of businesses are not incorporating climate change into their risk management strategies (Thistlethwaite and Wood, 2018). However, reinsurers are more likely to adjust their processes than primary insurers, showing that the industry's nested spatial and temporal scale causes resistance to climate change risk management. They contended that understanding and executing risk-reduction methods is critical for effective risk management in the face of climate change.

Climate change is affecting the insurance sector (Keucheyan, 2018). This study looked at how the frequency and intensity of natural disasters have grown as a result of climate change, posing new risks and difficulties for insurers. They contended that to mitigate these risks, the insurance sector is creating new financial tools and systems to shift the costs associated with the effects of climate change. The process of converting natural resources and environmental services into tradable commodities is referred to as the "financialization of nature." Their piece emphasized the trend's ramifications, such as possible inequality and the commercialization of the natural world.

#### *2.2.8.1 Technological Transformation in the Insurance Sector*

The insurance industry's response to the digital revolution through the application of Berliner's insurability criteria and Porter's value chain has proposed (Eling and

Lehmann, 2018) has proposed Four primary objectives. They were identified by their study for the industry: providing innovative products, creating improved customer experiences, streamlining business procedures, and becoming ready for cross-industry rivalry. Along with that, it outlined three major areas of change in insurability: rising system dependencies through connection, the impact of new technologies on loss frequency and severity, and knowledge asymmetry and risk pooling. Their paper outlined future research goals and examined the significance of digitization in the insurance sector.

The connection between company performance, innovation kind, and innovation capability in Sri Lanka's insurance sector sought to close the knowledge gap on innovation and innovation performance in the insurance sector (Rajapathirana and Hui, 2018). According to their findings, corporate performance and innovation efforts and capacities are significantly and positively correlated. The study highlighted the significance of efficiently managing innovation capability to enhance performance and tackle the obstacles confronting the insurance sector.

#### *2.2.8.2 Emphasis on Enterprise Risk Management (ERM)*

Enterprises must prioritize risk management systems to navigate the evolving commercial landscape. A critical aspect of ERM lies in its emphasis on acquiring a comprehensive understanding of risks. ERM promotes a holistic approach to risk management, considering how various risks may interconnect and impact strategic objectives This integrated approach helps to avoid fragmented risk management efforts, thereby fostering a more cohesive and well-informed decision-making process. ERM also promotes a forward-thinking outlook, underscoring the significance of anticipating and preparing for potential future risks. By conducting scenario analyses and stress tests,

organizations can identify emerging risks and adapt their strategies accordingly to effectively navigate uncertainties. This proactive stance enhances organizational agility and responsiveness to the ever-evolving market conditions. Moreover, ERM aligns risk management with strategic planning. Strategic decision-making can be optimized by incorporating risk considerations to achieve desired objectives by optimizing risk-taking endeavors. This alignment ensures that risk management becomes an integral part of the organization's core values, permeating throughout the entire hierarchy from top leadership to every employee. Emphasizing the implementation of Enterprise Risk Management is pivotal for organizations aspiring to not only survive but thrive in an environment characterized by volatility, uncertainty, complexity, and ambiguity (VUCA).

The idea of enterprise risk management (ERM) suggests that rather than managing each risk separately, firms should address all of their hazards thoroughly and cogently (Bromiley *et al., 2015)*. They maintained that although academic research on ERM has been gaining traction in the business world, there has been little input from management scholars in the field thus far. Their evaluation of the literature on ERM highlights its shortcomings and gaps while outlining potential topics for management research to further ERM theory and practice. They underlined the significance of taking organizational culture and other variables into account while implementing ERM and the necessity of taking a comprehensive approach to risk management. Additionally, they proposed that management scholars may improve ERM research and practice by utilizing their knowledge of risk, strategy, decision-making, and organizational change.

Risk management techniques have changed over time and emphasized the need for a more proactive, integrated approach to risk management (McShane, 2018). By creating efficient risk management plans, firms can better recognize and address risks with the aid of a design science viewpoint. They emphasized in their article's conclusion

the value of continued study and cooperation in advancing risk management techniques. Table 2.8 illustrates the advantages and research gaps of Anticipated Changes in the Insurance Industry.

***Table 2.8:*** *Comparability of Anticipated Changes in the Insurance Industry (Source : Mannappan and Varadarajan 2023)*

| Author | Year | Aim | Advantages | Research Problem |
|---|---|---|---|---|
| Thistlethwaite and Wood | 2018 | Evaluating the insurance sector's performance in controlling the financial risks associated with climate change. | Uses a system that takes into account the relationships' vertical structure while assessing risk management practices. | The majority of organizations are not integrating climate change into their risk management plans, according to findings. |
| Keucheyan | 2018 | Investigating the financialization of nature and how it affects the insurance industry, with a focus on risks associated with climate change. | Investigates the increase in natural disasters as a result of climate change. | Evokes worries about potential financialization-related inequality and the commercialization of the environment. |
| Eling and Lehmann | 2018 | Examining how the insurance sector has | Establishes four main goals for the | Recognizes the possible difficulties |

| | | | | |
|---|---|---|---|---|
| | | responded to the digital revolution and how it has affected value chain procedures and insurability standards. | sector in reaction to the digital revolution. | brought on by growing system interdependence and knowledge imbalance. |
| Rajapathirana and Hui | 2018 | Examining the relationship in Sri Lanka's insurance industry between firm performance, innovation kind, and innovation capabilities. | Demonstrates a considerable positive relationship between business performance and innovation efforts. | Restricted to a single geographic area (Sri Lanka), which can reduce generalizability. |
| Bromiley et al. | 2015 | Introducing the idea of ERM, assessing its uptake, and emphasizing the necessity of an all-encompassing strategy. | Suggests using ERM to completely address all dangers. | Highlights the dearth of contributions from management academics in the ERM sector. |
| McShane | 2018 | I am promoting a | Investigates the | Might not cover |

| | | | | |
|---|---|---|---|---|
| | | proactive, integrated approach to risk management by introducing a design science method for managing risks in enterprises. | development of risk management strategies. | subtleties unique to a certain industry or range of business situations. |

### 2.2.9. Government Mandates on Climate Risk

Government regulations and practices for climate-related risk disclosure are crucial for promoting transparency, accountability, and resilience in the face of climate change. To educate stakeholders, investors, and the general public about possible dangers and possibilities, governments across the world are incorporating financial disclosures connected to climate change into business reporting. Governments and regulatory authorities are creating frameworks, like the TCFD, which offers a set of guidelines for effective disclosure, to help companies with how to disclose information connected to climate change. Some countries are even mandating the reporting of TCFD for specific sectors, aligning their disclosure practices with global standards. Best practices often encompass a thorough assessment of climate-related risks and opportunities, scenario analysis, and the incorporation of climate considerations into overall risk management and corporate strategy.

Effective disclosures typically adopt a forward-looking perspective, outlining how organizations plan to adapt to a changing climate and take advantage of emerging opportunities. The push for standardized climate risk disclosure is driven by the

recognition of the financial risks and opportunities associated with climate change. Organizations must adhere to government regulations and adopt best practices to contribute to a sustainable global economy and meet the growing demand for transparent climate-related information from investors and stakeholders.

Climate change poses a serious risk to the stability of the world economy (Christophers, 2017). and the neoliberal strategy that emphasizes risk disclosure and market discipline as the growing consensus among global financial regulators on how to handle this threat. They contended that this strategy puts regulators at risk of a "climate Minsky moment" by depending on financial market mechanisms and practices that were shown to be erroneous during the financial crisis. They expressed gratitude to the Swedish Research Council for funding their research on financial risk and climate change.

The connection between the price of private ordering and the disclosure of nonfinancial hazards study looked at how businesses reveal nonfinancial risk information and how that affects private ordering costs (Ho, 2018). According to their findings, businesses with lower costs of private ordering are typically those that disclose nonfinancial risks more thoroughly and transparently. Their study brought to light the significance of nonfinancial risk disclosure for businesses as well as the possible cost-saving advantages.

International presence and reporting experience have an impact on disclosure quality and seasoned sustainability reporters typically disclose more risks (Truant *et al., 2017)*. However, very few businesses make the connection between strategy, risk metrics, and transparency when examining particular risk-related areas. They recommended more studies and predictive models in their paper to lessen the possibility of "window dressing" and "greenwashing" in sustainability reporting. Table 2.9 illustrates the

advantages and research gaps of Government Mandates and Best Practices for Climate Risk Disclosure.

***Table 2.9:*** *Comparability of Government Mandates and Best Practices for Climate Risk Disclosure (Source : Mannappan and Varadarajan 2023)*

| Author | Year | Aim | Advantages | Research Problem |
|---|---|---|---|---|
| Christophers | 2017 | Critiquing the neoliberal approach that places a strong emphasis on risk disclosure and market discipline and advocating for greater understanding of climate change as a major threat to the global economy. | Increases awareness of the grave threat that climate change poses to the global economy. | Ignores possible advantages of the neoliberal approach in Favor of focusing on potential disadvantages. |
| Harper Ho | 2018 | Examining the relationship between disclosure and private ordering costs, with a focus on the relationship between private ordering prices and the disclosure of nonfinancial dangers. | Demonstrates the connection between the full disclosure of nonfinancial risks and the private ordering costs. | Does not offer an in-depth analysis of particular nonfinancial risk disclosure procedures. |

| | | | | |
|---|---|---|---|---|
| Truant et al. | 2017 | Highlighting the importance of sustainability risk disclosure in corporate reporting and looking into the relationships between different variables and the quality of disclosure. | Emphasizes how critical it is for business reporting to disclose sustainability risks. | Restricted to a sample of large Italian businesses that comply with GRI G4 standards. |

### 2.2.10. Climate Risk Management

Climate risk management necessitates a comprehensive comprehension of the indirect ramifications arising from natural calamities, as these secondary repercussions frequently present substantial challenges. The immediate and obvious repercussions, such as physical damage and human casualties, are evident when a natural disaster occurs, like storms, floods, or wildfires. However, the indirect consequences over the long run could be even more significant. Supply chain and vital infrastructure disruption is one important indirect consequence. Natural disasters can impair roads, ports, and other indispensable facilities, hindering the transportation of goods and services. This can result in scarcities of essential resources, impacting communities, enterprises, and entire economies. Another indirect ramification is the strain on public health systems. Natural catastrophes can result in harm, uprooting communities, and unhygienic circumstances, which can foster the spread of illness. The aftermath of disasters often witnesses a surge in health-related problems, placing additional burdens on healthcare infrastructure.

Socioeconomic disparities frequently become exacerbated by indirect effects. Vulnerable populations, including low-income communities, may encounter prolonged recovery periods, heightened unemployment, and limited resource accessibility. These disparities can amplify existing inequities, rendering it imperative for climate risk management strategies to address the differential impacts on various socioeconomic groups. Comprehending and proactively managing the indirect consequences of natural disasters are integral to constructing resilient communities and economies in the face of escalating climate hazards. Comprehensive risk management strategies should contemplate not only the immediate effects but also the intricate web of repercussions that ensue in the aftermath of natural disasters.

In today's global world, Economies, markets and industries are interlinked. The indirect effects of natural disasters can have a significant impact on them. In fact it can have a cascading effect which would amplify the direct impacts. Hence managing them effectively is very important. There are not many studies that are available today on indirect effects of disasters and hence their climate risk management is an oppurtunity to improve. There is one good study on Austrian flood risk management (Reiter et. al, 2022) which focuses on detailed stakeholder analysis of those potentially involved in indirect flood risk management and the relationships among them. This study helps to identify the current gaps and barriers in indirect effects on climate risk. This study also recommends increased efforts in data collection, modelling and understanding the interdependency between different systems. Development of similar models for handling indirect effects on climate risk is very important.

Climate change necessitates a comprehensive comprehension of its risks and their impact on society and decision-making processes (Adger *et al., 2021)*. An exhaustive comprehension of its risks and impacts is essential in the identification and evaluation of

potential consequences; however, given the dynamic nature of risk, conventional methods may not be appropriate. Adaptation strategies should focus on effectiveness and fairness, regardless of future climate changes, to effectively address new risks.

Catastrophe experience on emergency supply preparations made by households using information gathered from more than 20,000 Japanese homes (Onuma *et al., 2017)* reveals that while familiarity with disaster damage boosts readiness, the impact differs for various types of emergency supplies. Experience in evacuations is also beneficial for planning. Their research also showed that in comparison to other regions, areas with a higher future risk of large-scale earthquakes are less prepared, underscoring the necessity for policymakers to increase awareness and fight inadequate readiness.

Different elements that contribute to the susceptibility of Dhaka, Bangladesh, to natural catastrophes such as floods and earthquakes (Gain *et al.,* 2015) has emphasized the need for comprehensive early warning systems that are oriented toward people, as well as the significance of integrating social and technical views in mitigating flood risk. Their piece also looked at how Dhaka's environment is affecting the spread of illnesses like cholera and dengue. The discussion of the obstacles to and prospects for sustainable urbanization in the city came to a close.

#### *2.2.10.1 Understanding Indirect Effects and Cascading Impacts*

Indirect consequences and cascading repercussions within the framework of climate change pertain to the intricate and interconnected effects that surpass the immediate outcomes of environmental transformations. These repercussions often give rise to a sequence of events, exerting influence on various systems and sectors, thereby amplifying the overall influence of climate change. Within ecosystems, indirect consequences are made manifest through disruptions in ecological equilibrium. For

instance, modifications in temperature and precipitation patterns have the potential to induce alterations in the distribution of species, thereby impacting entire food webs. The proliferation or decline of specific species can have far-reaching consequences on others, thereby influencing biodiversity and the services provided by ecosystems. In the socio-economic sphere, indirect impacts are observable in supply chains, economies, and communities. Incidents of severe weather have the potential to cause supply chain disruptions and shortages of necessary goods and services. This in turn affects jobs, companies, and the stability of the economy. The most disadvantaged groups are frequently the ones that suffer the most from these cascading effects, having to deal with issues with infrastructure, health, and food security. Moreover, indirect effects factor into the exacerbation of pre-existing vulnerabilities. For instance, a region's health care system may be under stress from a serious storm brought on by warming temperatures, increasing the likelihood of disease epidemics. Understanding these collateral impacts is essential to developing methods that effectively adapt to and mitigate the consequences of climate change because it allows for a more holistic approach that considers the complex web of interdependencies that exists within ecosystems and human civilizations.

The effect of infectious illnesses in Europe due to climate change (Semenza and Paz, 2021) draws attention to the ways that infectious disease onset, resurgence, and dissemination, as well as the persistence and dispersal of disease pathogens and vectors, are influenced by climate change. Provides particular instances, including foodborne and aquatic illnesses, as well as vector-borne illnesses like West Nile fever and chikungunya. In order to successfully address the detrimental consequences of warming temperatures on health, it emphasizes how important it is to understand the complex linkages that exist among weaknesses, exposure patterns, and climate hazards. The European Union's

climate change adaptation plan and the need for better understanding and action to lower the risks of infectious illnesses are also mentioned in their paper.

Climate change and extreme weather events (Cianconi et al., 2020) explores how human activities have contributed to global warming and the subsequent increase in extreme events such as heat waves, floods, and droughts. The article also highlights the challenges in understanding and predicting these events, as climate change is a complex system with non-linear behavior. The potential impacts of climate change on human populations and ecosystems are discussed, including the risks to human health, food security, and biodiversity. Overall, the article emphasizes the need for further research and international efforts to address climate change and its consequences.

The insurance business invented risk layering as a technique to control hazards by dividing them into several layers (Hochrainer-Stigler and Reiter, 2021). Up to a set amount, each layer is insured by a separate insurer. The idea has been extended to several fields, such as risk management for disasters. Despite their potential to jeopardize international agendas, indirect risks—such as cascading repercussions and ripple effects—are currently underappreciated in risk management plans. According to their paper, indirect risks can be included in risk-layering, opening the door to more extensive risk management schemes. For assessing direct risks, a probabilistic method is adequate; however, for assessing indirect risks, a connectedness-based approach is more suited. Their paper stressed the necessity of new alliances and approaches to successfully manage indirect risks. All things considered, adding indirect hazards to the risk-layering process can aid in tackling the intricate problems of the twenty-first century.

The idea of "cascading" climate change impacts and ramifications, which describes how distinct stresses compound over time and affect multiple industries and domains has concentrated on the connections between New Zealand's metropolitan water

infrastructure, the financial services industry, and the effects of climate change (Lawrence *et al., 2020)*. To comprehend how the effects of climate change ripple through several sectors and what it means for governance, their research integrated network and systems analysis with qualitative data collection. Their findings made clear the necessity of developing suitable solutions and a deeper comprehension of cascading effects. They offered recommendations for more study as well as policy and practice observations in the conclusion of their paper.

The consequences of climate change's cascading effects on different systems emphasized the feedback loops that exist between socioeconomic and natural systems and their interdependence (Lawrence *et al., 2019)*. They highlighted the financial services industry, water and utility networks, and urban systems as some of the industries impacted by climate change. To safeguard community well-being and adaptive ability, their research underscored the necessity of comprehending and addressing these cascading repercussions.

The idea, source, occurrence, spread, development, and framework for evaluating systemic risk brought on by climate change made it clear that systemic risk brought on by climate change is a comprehensive danger that results from the interplay and interconnection of several kinds of isolated risks, with cascading impacts serving as its distinguishing characteristic (Hui-Min *et al., 2021)*. The significance of comprehending the systemic risk mechanism, carrying out empirical research to evaluate potential hazards, and creating countermeasures to lessen the risk was also underlined in their paper. In summary, the paper advocated for a more thorough comprehension of the systemic risk brought about by climate change as well as the creation of mitigation plans.

#### *2.2.10.2 Importance of Managing Indirect Climate Risk*

Beyond its obvious physical consequences, indirect climate risk may have indirect and cascading repercussions on a variety of systems, making it an essential component of controlling climate change. Because global supply chains are intertwined, disturbances in one area may have a ripple effect throughout the globe, hurting sectors that depend on complex networks of providers and distributors. This makes these risks especially serious. Risks related to indirect climate change can raise financial instability, raise the cost of obtaining resources, and raise the risk of asset depreciation. As investors reevaluate the risks connected with climate-related consequences on firms, financial markets may potentially become unstable. These indirect effects, which can exacerbate social inequality, lead to water and food shortages, and even spark violence and displacement, disproportionately impact vulnerable individuals in society. Additionally, the dissemination of contagious. Moreover, the proliferation of contagious illnesses and the heightened movement of individuals present difficulties to public healthcare structures and societal unity. Hence, an all-encompassing strategy towards the management of climate-related hazards, which takes into account both immediate and indirect repercussions, is paramount in fostering adaptability in global economies, societies, and ecosystems.

A disaster's impact on welfare was contingent not just on the material harm it inflicted but also on the economy's capacity to absorb shocks, bounce back, and rebuild (Hallegatte, 2015). They suggested a general method for estimating macroeconomic resilience that accounts for the length of the reconstruction, the interest rate, and a "ripple-effect" element. Both resilience-building and disaster risk reduction measures would be a part of an ideal risk management plan.

CSR plays in project funding choices (Sarfraz *et al., 2018)* and it looks into how project finance was affected by environmental plans, stakeholders, credit risk, and

corporate social responsibility assessments. According to their analysis of data from both foreign and domestic banks, the banking industry in Pakistan is putting environmental management strategies into practice. International banks have stronger incentives for CSR initiatives. Cultural disparities may have an impact on how managers view policies about environmental risk management. According to their research, environmental risk management and project funding decisions are influenced by CSR. Their conclusions offered policymakers and financial institutions recommendations. Table 2.10 illustrates the advantages and research gaps of Climate Risk Management - Indirect Effects of Natural Disasters.

The connection between the danger of climate change and the stability of the banking and investment fund industry was examined (Roncoroni *et al., 2021) and* by adding market variables like the rate of recovery and volatility in asset prices to the framework of climatic stress testing. The mechanics of indirect transmission between investment funds and banks are also taken into account. The paper investigates the effects of market circumstances and climate policy shocks on financial stability by applying the model to a special supervisory dataset. The findings imply that more aggressive climate measures may be implemented without raising financial risk under stronger market circumstances. This article emphasizes the significance of climatic testing and its economic consequences, offering analytical conclusions and empirical data for the Mexican banking system. Though the effects of the below examples talk about a localized problem for each of the scenario, their impact on climate risk can be indirect and cascading.

***Table 2.10:*** *Comparability of Climate Risk Management - Indirect Effects of Natural Disasters (Source : Mannappan and Varadarajan 2023)*

| Author | Year | Aim | Advantages | Research Problem |
|---|---|---|---|---|
| Onuma *et al.* | 2017 | Using information from Japanese houses, examine how disaster experiences affect the emergency supplies that households prepare for. | Gives information on how a disaster experience affects a household's emergency supply planning. | Restricted to Japanese household situations; may not apply to other contexts. |
| Gain *et al.* | 2015 | Identify factors that make Dhaka, Bangladesh more vulnerable to natural disasters and stress the importance of integrated social-technical perspectives and extensive early warning systems. | Identifies the factors that make Dhaka more vulnerable to natural disasters. | Restricted to the particular setting of Bangladesh's Dhaka. |

| | | | | |
|---|---|---|---|---|
| Semenza and Paz | 2021 | Examine how the changing climate is affecting infectious diseases in Europe. | Determine the ways that illness onset, resurgence, and distribution are impacted by climatic change. Draw attention to particular cases, such as vector-borne, aquatic, and foodborne infections. Stress how crucial it is to comprehend how exposure patterns, vulnerabilities, and climatic threats are related to one another. | The negative impacts of rising temperatures on health. Stress the importance of fully understanding the complicated relationships between vulnerabilities, exposure patterns, and climate hazards. The European Union's climate change adaptation plan emphasizes the need for enhanced understanding and action to mitigate infectious disease risks. |

| | | | | |
|---|---|---|---|---|
| Cianconi *et al.,* | 2020 | The frequency of extreme weather events and the escalating issue of climate change. | Explains the difficulties in comprehending and forecasting these occurrences because of the intricate, nonlinear dynamics of climate change. Highlights the necessity of more study and global initiatives. | Addressing the difficulties associated with understanding and forecasting these occurrences because of the complexity of climate change. highlighting the possible effects on ecosystems, biodiversity, and human populations. highlighting the necessity of further study and global cooperation. |
| Hochrainer-Stigler and Reiter | 2021 | In disaster risk management, introduce the idea of risk layering and draw attention to the undervaluation of indirect hazards in risk management strategies. | Presents the idea of risk-layering as a means of reducing dangers. | To fully grasp, one may need to have a solid understanding of risk management concepts. |

| | | | | |
|---|---|---|---|---|
| Lawrence *et al.* | 2020 | Provide the notion of "cascading" the effects of climate change on several New Zealand industries, combining qualitative data collection with network and systems analysis. | Combines systems and network analysis to provide a thorough insight. | Particular to New Zealand; might not be applicable elsewhere. |
| Lawrence *et al.* | 2019 | Stress how various systems are affected by the cascading effects of climate change and emphasize how important it is to comprehend and deal with these implications. | Emphasizes the feedback cycles that exist between natural and societal systems. | Focusing exclusively on certain industries could restrict generalizability. |
| Hui-Min *et al.* | 2021 | Describe the concept, origin, incidence, dissemination, evolution, and framework for assessing the systemic | Presents the idea of climate change-related systemic risk. | Demands a thorough comprehension of the ideas around systemic risk. |

| | | | | |
|---|---|---|---|---|
| | | risk associated with climate change. | | |
| Hallegatte | 2015 | Introduce the concept of macroeconomic resilience and a broad approach to measuring it that takes the length of reconstruction, interest rate, and a "ripple-effect" component into account. | Explains the idea behind macroeconomic resiliency. | Assumes, without providing substantial empirical support, that the suggested strategy is generally applicable. |
| Sarfraz *et al.* | 2018 | Explain how corporate social responsibility (CSR) affects project financing, emphasizing how environmental planning, stakeholders, and CSR evaluations affect project funding. | Examines the impact of corporate social responsibility (CSR) on project financing in Pakistan's banking sector. | Particular to Pakistan's banking sector; may not be broadly applicable. |
| Roncoroni *et al.* | 2021 | Consider the relationship that exists | Combines examination of | In the context of the Mexican banking |

| | | | | |
|---|---|---|---|---|
| | | between the threat posed by the changing climate and the stability of the banking and fund of investment sectors. | financial stability with climate change risk. Takes into account indirect transmission mechanisms and market factors for a thorough evaluation. Increases relevance by applying findings to a particular supervisory dataset. | system, how do market conditions and climate policy shocks affect financial stability?<br>In stronger market conditions, is it possible to take more severe climate actions without increasing financial risk? |

### 2.2.11. A regional based approach to Climate risk

There is a good study on how to customize the climate risk management for a region (Kc et. al, 2021). In this study, for the years between 2040 to 2049, climate risk for the entire US is accessed. This study covered every county in US with a climate risk index which was covering multiple climate calamities and exposures. This study analyzed the exposures of living and non-living things to multiple hazards including sea level rise and storm surges. This study found that Florida, California, the central Gulf Coast, and North Atlantic at high climate risk in the future. However, the contributions to this risk vary regionally. A similar approach can help climate risk management specialists to target high risk area and create adaptation strategies to reduce exposure to climate risk impacts.

### 2.2.12. Climate risks and a best practice to disclose it.

One of the successful work to manage climate risks is followed by the UK Government. This can be easily replicated by other governments as well. The UK Government has mandated all companies to disclose their risks associated with Climate and this went live in April 2022. UK disclosure regulations mandates companies to categorize climate-related risks as short term, medium term and long term in alignment with the TCFD recommendations (Sessa, 2021). This kind of disclosure clearly helps informed decisions to be made by business leaders and develop their short to mid-term to long-term strategic investments based on their organization's risk management practices. They also consider multiple different future climate possibilities and impacts and create strategies to mitigate damage to their assets. They follow a simple four step approach to set time horizons for their business:

**Step 1**: Identify business continuity risks. For example,

- Due to climate related events or calamities their day-to-day operations can get impacted. It could be to their assets or a disruption to their supply chain. This can have a direct impact on their revenue.

**Step 2**: Identify time horizons in which their business can get affected due to assets which can be affected during this time. For example,

- Issue could be as trivial as a power disruption to run their business operations during the daytime.

**Step 3**: Create knowledge around climate risks across the different timeframes and their potential impact.

- This step is to analyze the climate risks in different time frames and how they would evolve over the different timeframes.

**Step 4**: Identify and prioritize the most significant climate risks and classify them.

- Obviously, one cannot create mitigation plans for all the risks in the business. But it is important to have a mitigation plan for key climate risks which would impact the companies in the short to medium to long term and create risk management strategies for them.

### 2.3. Research Gaps

Despite the growing recognition of the impact of climate risk within the insurance business, there remains a research vacuum in understanding its complex dynamics and practical ramifications. Although recent research frequently highlights the broad challenges, there aren't many detailed examinations of the steps insurers have taken to reduce and adjust to these risks. Moreover, little research has been done on how climate risk interacts with other insurance markets, including health, property and liability, and life insurance. Furthermore, not much study has been done on how well regulatory frameworks operate to help the insurance industry manage climate risk. There are also significant gaps in our knowledge of the attitudes, views, and actions of policyholders and insurers about climate risk. An understudied area is the creation of novel insurance products and financial instruments geared toward mitigating climate risk, as well as the insurance industry's role in promoting greater climate resilience. Closing these gaps is essential to developing focused and successful initiatives that improve the industry's capacity to navigate and address climate change-related concerns.

## 2.4. Summary

Climate risk is a complex matter that impacts natural systems, social structures, and economic landscapes, encompassing both physical and socioeconomic consequences. It reveals vulnerabilities across various industries. Corporations are increasingly compelled to adopt proactive measures in response to the escalating perils posed by climate change, precipitating a paradigm shift in corporate strategies. The TCFD reporting framework holds the potential to fundamentally transform sustainable accounting and reporting practices, necessitating the development of novel techniques for evaluating climate-related scenarios and conducting academic research to enhance its tangible impact. A comprehensive approach to assessing climate risk entails the utilization of "storylines" as a tool to heighten awareness of risks, enhance decision-making processes, and explore the boundaries of plausibility. The notion of existential threats, such as artificial intelligence, nuclear warfare, and biosecurity, is extensively examined in scholarly publications and authoritative sources.

Clearly a study on insurance business reveals that only a small section of the insurance business has the means to handle climate risk (Singh and Madaan, 2023). Hence an approach to manage climate risk in the Insurance industry is the need of the hour. There are many climate models available in the industry. Hence a **study on these models** and their applicability to the Insurance industry is very important. Also, the insurance industry needs to develop a common **strategy to disclose climate risk** and have a strategy to **manage their assets and liabilities** efficiently ("Go Green" support initiatives can be an important step in it) to stay ahead of the business. Climate risk is also showing **new revenue opportunities** for the insurance industry. The insurance industry needs to make some quick changes for managing climate risk and not get overwhelmed by the big bold moves that it has to take. It is a perfect opportunity for the insurance

industry to demonstrate once again to the world on why it is a leader for many industries to grow their business by leaning on insurance industry to run their business fearlessly.

# CHAPTER III:

# RESEARCH METHODOLOGY

## 3.1. Overview of the Research Problem

Climate change is a reality of the world and is affecting many industries including the insurance industry. Climate change is impacting corporations either directly or indirectly by damage to assets and disruption to their supply chains. Hence there is a growing focus to manage climate change. Most of the literature available on Climate change and climate risk primarily points to the public sector's role in it. Mostly, the Private sector (Corporations) plays a secondary role in managing climate risks by funding research related to Climate change and its associated risks. Clearly, two important immediate actions are emerging on Corporations to manage climate risks.

- Corporates have to divert their financial investments to more climate friendly and low-carbon economy products. They also have to spend a lot of money related to green projects.
- Corporations have to disclose their climate risk exposures in their financial statements. This is being mandated by all countries. Their financial and assets exposure to climate risk would determine their capital management strategy also.

## 3.2. Methodological Approach

Our research philosophy is Interpretivism, and research approach is mostly Qualitative based on the text-based data available in the public domain and in open

literature to explore the richness and to appreciate the complexity of this research topic. Over a period of 18 months have also done informal interviews with key leaders from Global Insurance Industry on their readiness to handle climate risk and the associated strategy of their organizations for the future. Due to Non-Disclosure Agreements, unable to give those references here. But the findings and observations from these discussions are used for this research and the recommendations made for future research are also based on these interviews.

### 3.3. Research Purpose and Questions

As stated earlier, Insurance industry is impacted a lot by climate change as the company assets and liabilities have a huge exposure to climate change related calamities (Climate Change, 2022). Also to comply with regulatory and compliance changes, Insurers need to define their own Net Zero strategy, sustainability policies, and the steps they are taking to achieve it. Financial and economic impacts of climate change are not integrated into core insurance business. This has to be integrated and only recently, these impacts of climate change are getting defined under physical, liability and transition risks. This helps organizations to monitor these risks and also quantify their impact. They are now getting integrated into the core insurance business as well (Climate change, 2022).

Also, like many industries the focus is shifting from looking at these risks not as just a cost but as a revenue generating opportunity. Insurers who are able to integrate these risks into their current business models are able to differentiate them from other companies and they in fact are looking at growing their business with a new revenue opportunity. This is the key purpose of this research. For adapting the business models,

insurers need data on transition risks for sectors and insurers, and then need strategy to deploy the capacity and expertise into sectors that are likely to benefit from the transition to a low-carbon economy. Hence the purpose of this research also is to obtain data on transition risks.

Insurers are already experiencing increased financial losses from catastrophic weather events. To help understand and mitigate these losses, the insurance industry has depended on sophisticated Catastrophe risk models, but these do not currently take into account the threats from a changing climate. Climate risk models have emerged to estimate how temperatures will evolve in the future. Rather than rely on historical, backward-looking data, climate models provide forward-looking simulations of the interaction between energy and matter in the ocean, atmosphere and land based on levels of greenhouse gas emissions. So, the question at hand is to how to leverage both these models to estimate the climate risk better. Any insurer who is able to adapt their business models for the climate risks are most likely to capture the growth opportunities and mitigate the financial losses that they incur due to their lack of preparedness to handle climate risk.

### 3.4. Climate Model in Insurance Industry- Analysis

There are many models available to measure the Climate risk. The important ones are listed below.

#### 3.4.1. Climate Scenario Models

Climate scenarios (Beddow, 2022) are analytical tools. They analyse the potential impacts of climate change under different conditions. They take Greenhouse gas emissions and their Representative pathways as inputs and do different scenario analysis and come with a view of

financial risks. IPCC has made a recommendation to the organizations to use three possible scenarios to understand their exposures to climate risk. Also, they recommend to study and analyse these risks over a period of time to come with a trend analysis. This trend analysis would help organizations to handle the climate risks over a period of time and also give an early indication to any climate hazards so that organizations can be proactive about handling them. IPCC suggests using the below 3 possible future scenarios:

i. **Worst case scenario: Business as usual** (If no one acts on Greenhouse gas emissions, then temperature would continue to raise throughout the 21st century with a mercury going up by 5 degrees Celsius.)
ii. **Most likely scenario: Emissions peak in 2040** (Based on the commitments made by different countries and organizations and also by policy interventions, Greenhouse gas emissions would hit the peak by 2040 and thereafter would remain flat or reduce from then.)
iii. **Best case scenario - Paris-aligned** (Greenhouse emissions are reduced in an aggressive manner in line with the Paris Agreement. This would mean the world temperature increase by 2 degrees Celsius only or even may surprise us with a less than 2-degree Celsius increase)

By using different climate scenarios, businesses would be able to understand their physical and transition risks much better. This would also equip them to make critical decisions about their asset allocation strategies. With better management of their case

reserves they can be more profitable and also create new growth opportunities for the business by enhancing their product base.

Climate scenarios fall into two main categories, **Climate physical risks** and **Climate transition risks** and they are modelled differently.

a. Climate physical risks occur based on the extreme climate related events such as flooding or heat waves or increase or decrease in sea levels. These risks are analysed by Intergovernmental Panel on Climate Change (IPCC)on specific projects and programs. For ex, The Scenario Model Intercomparison Project (ScenarioMIP) (Tebaldi *et al.,* 2020) (climate scenarios developed by well-known science or industry experts) defines and coordinates the main set of future climate projections, based on concentration-driven simulations, within the Coupled Model Intercomparison Project phase 6 (CMIP6). Scenarios developed by ScenarioMIP, take an earth system modelling approach covering the full spectrum of climate-related outcomes.

b. Climate transition risks are based on the disruption caused by political, social, and economic shifts arising from decarbonization. As part of Go Green initiatives and also for transitioning to a low carbon economy, companies have to spend a lot of money and this in turns transfers out to be a business risk. These are modelled based on simple climate model and improvised for future complexities. For ex, The scenarios developed by the International Energy Agency (IEA) and the Network for Greening the

Financial System (NGSF), use a simpler climate model but incorporate models of how energy markets function into their scenarios.

### 3.4.2. Global Climate Models

A global climate model (GCM) is a complex mathematical representation of the major climate system components (atmosphere, land surface, ocean, and sea ice), and their interactions. Earth's energy balance between the four components is the key to long-term climate prediction. They are three-dimensional in that they represent physical processes in three dimensions, including the atmosphere, oceans, land, and the cryosphere, or sea ice and glaciers on land. Compared to the other types, these models can predict climate over longer time scales of several 10,000 years or glacial years. There are Five basic types of climate model.

i. Energy Balance Models (EBMs)
ii. Radiative-Convective (RC) or Single-Column models (SCMs)
iii. "Dimensionally Constrained" models.
iv. Global Circulation Models (GCMs)
v. Earth System Models (ESMs). There are many examples of successful implementation of Global Climate models. For ex,

- "Using six HighResMIP multi-ensemble GCMs (both the atmosphere-only and coupled versions) at 25 km resolution, the Tropical Cyclone (TC) activity over the Bay of Bengal (BoB) is examined in the present (1950–2014) climate" (Akhter *et al.,* 2023).

- "Performance of a set of regional high-resolution simulations of the 1982–2005 seasonal mean climatology of daily precipitation and precipitation distribution over land are compared to observations from different sources (i.e., in situ-based and satellite-based) (Nguyen *et al.,* 2022).
- Historical simulations of 15 Global Climate Models (GCMs) of the Coupled Model Intercomparison Project phase 6 (CMIP6) in replicating annual and seasonal rainfall climatology, their temporal variability and trends in Bangladesh for the period 1979–2014 is evaluated" (Kamruzzamman *et al.,* 2022).
- "Three generations of global climate models (GCMs), Coupled Model Intercomparison Project version 3 (CMIP3), CMIP5, and CMIP6, are evaluated for performance simulating seasonal mean and annual-to-decadal variability of temperature and precipitation in the Upper Colorado River Basin" (Pierce *et al.,* 2022).
- "Skill of 28 GCMs and 16 RCMs, and more importantly to assess the ability of RCMs relative to parent GCMs in simulating near-surface wind speed (WS) in diverse climate variable scales (daily, monthly, seasonal and annual) over the ocean and land region of the South Asian (SA) domain is evaluated" (Lakku and Behera, 2022).

### 3.4.3. Coupled Model Intercomparison Project (CMIP)

CMIP (Tebaldi *et al.,* 2020) is a project of the World Climate Research Programme (WCRP)'s Working Group of Coupled Modelling (WGCM). CMIP has led to a better understanding of past, present and future climate change and variability in a multi-model framework. CMIP has developed in phases, with the simulations of the fifth phase, CMIP5, now completed, and the planning of the sixth phase, i.e. CMIP6, well underway. Based on the CMIP many regional based models are developed. For ex,

- "The ability of 42 global climate models from the Coupled Model Intercomparison Project Phase 6 (CMIP6), consisting of 20 low resolution (LR) and 22 medium resolution (MR), are evaluated for their performance in simulating mean and extreme precipitation over Indonesia" (Kurniadi *et al.,* 2023).
- "The ability of 11 climate models from Coupled Model Intercomparison Project Phase 5 (CMIP5) and Phase 6 (CMIP6) to simulate the sea ice seasonal cycle in Antarctica in terms of area (SIA) and concentration (SIC), as well as the improvements in the most recent models' version, submitted to CMIP6" (Casagrande, Stachelski and de Souza, 2023).
- "Precipitation variability (Sein *et al.,* 2022) over Myanmar at the annual and seasonal scales was compared against 12 model outputs from the Coupled Model Intercomparison Project Phase 6 (CMIP6) with gridded observational data provided by the Global Precipitation Climatology Centre (GPCC) from 1970 to 2014".
- "The concurrence of the two extremes, compound wind and precipitation extremes (CWPEs), may cause even larger impacts than

the univariate counterparts. Using Coupled Model Intercomparison Project (CMIP6) models, changes of CWPEs in the mainland of China in the future were assessed" (Meng *et al.,* 2023).

- "Performance of global climate models (GCMs) from the family of the Coupled Model Intercomparison Project Phase 6 (CMIP6) in the historical simulation of precipitation and select the best performing GCMs for future projection of precipitation in Pakistan (Abbas *et al.,* 2022) under multiple shared socioeconomic pathways (SSPs) was evaluated".
- "How rainfall may change in the future over the Sahel, Savannah, and coastal zones of the Volta River Basin (VRB), the trends and changes in rainfall between 2021–2050 and 1985–2014 under the Shared Socioeconomic Pathway (SSP2-4.5 and SSP5-8.5) scenarios were analyzed after evaluating the performance of three climate models from the Coupled Model Intercomparison Project Phase 6 (CMIP6) using Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) as observation" (Dotse *et al.,* 2023).

### 3.4.4. Third party Climate model tools

There are also third-party climate models like EarthScan (Cervest, 2023). These models basically use the best practices from different models and create more customization to the needs of their customer. These models have a built-in feature to travel back and look at historical data. They also have access to current data through the integration with other models. They can also travel forward and give a predictive view of the climate risk and its impact on physical

assets. This flexibility to travel in multiple ways and also to integrate with multiple components helps these third-party models to baseline, monitor and forecast risk across the entire portfolio.

### 3.4.5. **Catastrophe Risk Models**

Catastrophic weather events are known business risks in the Insurance business and because of them businesses and investors are already experiencing increased financial losses. The insurance industry has relied on sophisticated catastrophe risk models, (Pielke *et al.,* 1999) to manage and mitigate these financial losses. Catastrophe models which are based on historical and past data (Grossi, Kunreuther and Windeler, 2005), matured and already in use for many years. The limitation of the catastrophe model is that it does not take into account the threats from futuristic disasters like a changing climate.

### 3.4.6. Climate risk models

Climate Risk models help us to predict how temperatures will evolve over time. Unlike Catastrophe models which rely on historical data, climate models rely on future data. They take Greenhouse gas emissions level as an input and simulate interaction between energy and matter in the ocean, atmosphere and land. There is a phenomenal book which covers the climate model in depth (Gettelman and Rood, 2016). Authors of this research work are strongly recommending anyone who is trying to create a climate model for any industry to understand this book before they start their work, as it captures many of the nuances of climate model in depth.

### 3.5. Research Design

The impact of climate is analyzed by two widely accepted models here.

1. **Representative Concentration Pathways** (**RCP**) based model: The future of the climate conditions in the world depends a lot on Greenhouse gas (GHG) emissions. Hence controlling them within permissible limits is extremely important for our survival in this world. To measure and control Greenhouse gas emissions, Intergovernmental Panel on Climate Change (IPCC) scientists developed four **Representative Concentration Pathways** (**RCP**). RCPs are based on the projected temperature increases expected in the coming years. The below chart shows the 4 RCPs and their potential increase to the world temperature. It also talks about a worst-case scenario (RCP 8.5) of increase in temperature of more than five degrees Celsius (Wolf, 2020) if the world doesn't act on GHG emissions today. This can be a very disastrous situation for the world.

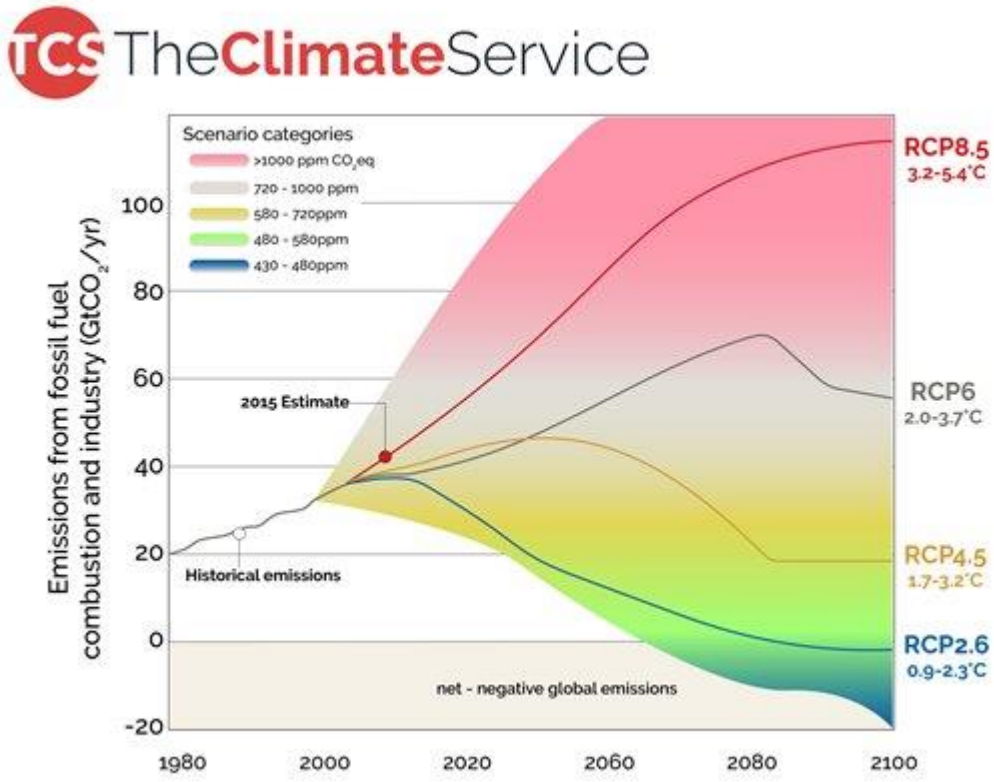


***Figure 3.1**: Global Carbon Budget (*Fuss *et al.,* 2014*)*

Using these RCP scenarios, different risk analytics providers have modeled the impact of the climate risk. The one depicted above is a model by a climate risk analytics provider TCS (The Climate Service). They have analyzed the financial impact of hazards including extreme temperature fluctuations, wildfire, drought, flooding and many other climate change related calamities. Many similar models can be developed and customized for insurers needs including an approach to measure the region-based climate risks.

2. **Physical laws**-based model: Physical laws-based models are based on existing physical laws like the law of conservation of energy which are proven and tested many a times. For example, Basic processes describe the source and

loss terms in equations, subject to basic laws of conservation. As one knows the temperature energy to the earth comes from the Sun. Greenhouse gases (Water vapor, Carbon dioxide, Methane etc.,) alter the flow of energy in the atmosphere (Sensoy and Demircan, 2010). This leads to more temperature energy entering the earth's climate system due to the law of conservation of energy. This phenomenon can be modeled through Climate model. A climate model is a computer program (Fahys, 2019). Generally, each component, such as the atmosphere, can be run as a separate model, or coupled to other components: often as a coupled climate model. Simple to complex physical laws-based models exist. Climate models' complexity is based on how each component of the earth is represented in it and also on how they have a combined effect on each other. Climate model complexity would continue to evolve with the development of more advanced computers.

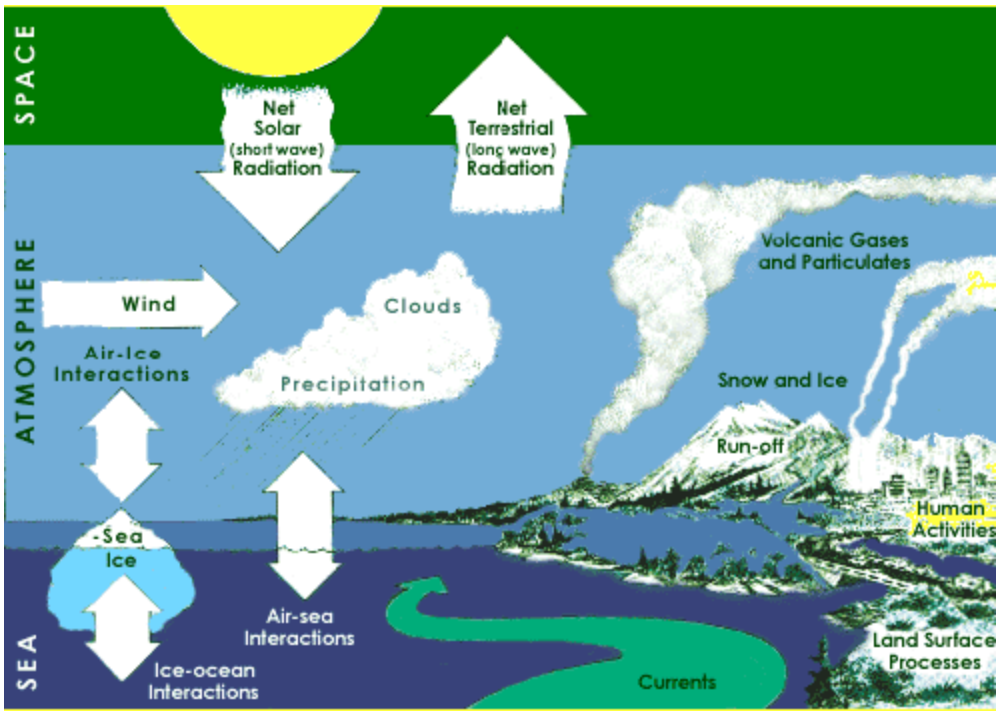


***Figure 3.2**: Major elements of the climate system (Sensoy and Demircan, 2010)*

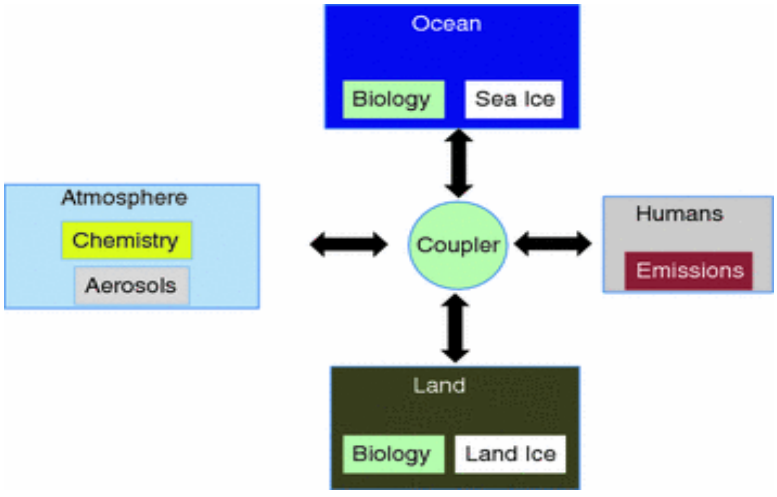


***Figure 3.3**: Coupled climate model (Fahys, 2019).*

The key to developing climate risk model is to combine the climate risk data exposures with the exposures that the insurers assets have. This helps them to quantify the financials losses of an asset. This can be extended to any property which is exposed to climate risk and can be customized for any region or location in the world. By integrating many such climate models, forward-looking climate risk data can be estimated. This data can be used by underwriters, engineers and financial analysts to improvise and improve upon the climate risk management initiative.

### 3.6. Research Design Limitations

When this research work was started not many work related to climate models were available in the public research domain. Now, one can see more and more work related to climate risk are being developed across many industries with active participation and funding by specific Countries, Industries, and top institutions. Some are getting published now more as an approach document. Still the work related to Climate risk in insurance industry is not much in public domain yet. Any advancements in it may pave way for more Climate models than the climate models discussed here. Hence this research work is giving an approach on how to integrate the existing risk models with a few available Climate Risk models to have better prediction on the impact of climate risk in insurance industry and this research design is limited by the fact that it is in no means an exhaustive analysis of all the available or potentially to be available Climate Risk models.

### 3.7. Recommendations

Our recommendations are.

- In the insurance industry, since climate models are in it earlier stages, it is better to start with integrating physical laws based base models with Catastrophe based models and expand it to more complex models later.
- In every region, a certain aspect of the climate would be predominant. It would be more appropriate to look for these regional based climate models and integrate them with Catastrophe models for better results.
- In places where climate risk is greater, climate risk itself can be a new product for the insurance industry generating a new revenue stream. New climate models and products can be developed in line with vertical and horizontal integration of services in the insurance industry.
- Underwriting and claims specialists must be trained more on climate risk with associated models for them to serve this industry better. Specific recommendations must be developed for selling Property and Casualty insurance and Life and Annuity insurance.
- Also, Private insurance plays a role in addressing long-term risks. A public–private partnership, where government intervention contributes to overcoming both the supply and demand barriers of long-term insurance development, would be an optimal choice in practice (He and Faure, 2023).
- Like the UK government, all governments should mandate the disclosure of climate risks. This is very important for business-like insurance which is heavy on regulatory and compliance related changes. The impact of climate risk in insurers is more and hence this best practice can go well

with protecting the interest of all stakeholders involved in it. In the US, the Securities and Exchange Commission (SEC) has recently proposed rule changes to enhance and standardize climate-related disclosures for investors.

- Some of the big insurance players understand the need to be ready for climate risks and are investing in key dedicated resources to manage them. They are also strictly governed and controlled by the regulators and have eagerness to stay good in front of their stakeholders. The challenge would be for the small insurers who don't necessarily have the money to invest in it or have the expertise to handle it.
- In the future, Insurers must create climate risk models which are consistent and compliant to international standards. Their current climate risk models which are internal to their organizations would be subjected to more scrutiny as the expertise in the area is evolving. Insurers ability to defend these models also would be very limited as regulators may not appreciate inconsistencies across many companies in these important topic of the globe.

Our recommendations for the future are:

- More focused work on climate models for each climate risk zone needs to happen which can help to plan for the climate risks better.
- Global communities on climate risk to be formed to promote knowledge sharing on this topic which will be evolving in the coming years.
- Technical advancements like computing power and Gen AI can help to accelerate the models to get refined further without causing too much cost for the company or additional premium for the consumers. Focused

research on the technical disruptions to be encouraged by Governments and insurance companies.

- Climate risk impact on assets in the long term would be a topic of key interest in the future. It is recommended that insurers have to invest in key personnel who stay up to date with the relevant standards and regulations related to climate risk as climate risk is very complex from a modeling point of view.
- Monitoring and recalibrating climate risk strategies are important. Hence insurers have to develop key metrics and scorecards which are standardized across all insurance companies so that they can monitor them closely. They should also create an action plan based on these metrics and KPIs to recalibrate the guidelines and act on them when they are not within the acceptable limits.
- Insurers would face the operational challenge of collecting the data for the key climate risk metrics. This requires a lot of investment from the companies in the resources needed to collect them and also systems in place to automate this data collection as it is subjected to error if it depends on manual data collection. This means bringing in a lot of discipline within their organizations to capture them correctly and within key timelines. This data would be subjected to auditing and any misses in it can bring reputational risk for the business including penalties to be paid for not complying with Low carbon economy goals.
- The insurance community also needs to develop a reporting engine which is accepted across the industry and is widely accepted by different stakeholders like rating agencies, climate risk agencies, regulators and

policy holders. The need for this report and the complexity and volume of this report would only increase from now and hence a dedicated team of experts to be invested in this important activity. The moment they master this art this can bring in a lot of confidence from the different stakeholders and can turn out to be a differentiator for them. There could be rating agencies which would give ratings to different insurers based on how they monitor, define, collect and report these climate risk metrics in the future.

# CHAPTER IV:
# RESEARCH OBSERVATIONS, RESULTS AND DISCUSSION

## 4.1. Research Goal

Climate risks have a huge cost impact to the organizations, but they also provide new revenue opportunities. To the financial market players and operating companies, both physical and transition climate risks can provide huge revenue avenues, while their associated cost impact cannot be ignored, and they must be manged as well. Their goals include:

- **Strategy Objectives** – Climate risk related challenges brings in innovation to Business models and hence helps organizations to find competitive products.
- **Operational Performance** – Climate risk can result in supply chain disruptions and employee management. Hence operational efficiency is important to stay competitive else the business would be exposed to vulnerabilities.
- **Financial Management** – Climate risk management involves a capital expenditure for the company and hence their cash flow. Hence managing corporate finance needs to factor this also.
- **Reputation and Stakeholder Engagement** – Climate risk related regulatory requirements including emission goals for the corporates and countries are on the raise. Also, social and corporate awareness on climate change is more now. Hence driving climate changes have a direct correlation to the

stakeholder engagements and their reputation risks as they may lead to climate-related litigation issues.

Insurance industries which are governed by regulatory, and compliance related changes need to have a well thought out strategy to handle Climate risk. In every part of the world, every business sector is facing climate risk in some form or other. This risk is threatening the existence of many companies, and this risk is increasing every day as climate change is increasing every day and is very visible from news that one can gather in the world today.

- A report on Weather, Climate and Catastrophe Insight by AON (He, 2023) says that in 2021 alone, extreme weather events caused USD 329 billion in economic losses – 45% higher than the 21st-century average.
- A report from McKinsey (Climate risk and response, 2020) claims that of the 105 countries it assessed (representing 90% of the world's population), all "are expected to experience an increase in at least one major type of impact on their stock of human, physical, and natural capital by 2030. The McKinsey report also adds that the socioeconomic impact of physical climate risk increases between roughly two and 20 times by 2050 versus today's levels.

A detailed study on Physical Climate Risk and Firms Adaptation Strategy (Li X, 2023) says that most firms do not adapt to different climate change exposures. Hence the ability of the organizations and governments to understand climate risk and take effective adaptation actions to reduce it would help their sustainability. This is the important goal of this research.

Based on the review of literature done so far, it is evident that the Climate insurance industry is not fully equipped to manage the risks associated with Climate change yet. Hence the research problem is to

- find the gaps in insurance industry to handle climate risk.
- focus on the data and models that are available today to manage the climate risk and make recommendations on how to manage climate risk in insurance industry for the future and also
- make recommendations for the future research on this topic.

### 4.2. Observations from this research

**The insurance industry** is impacted a lot by climate change as the company **assets and liabilities have a huge exposure to climate change related calamities** (Climate Change, 2022). Also to comply with regulatory and compliance changes, Insurers need to define their **own Net Zero strategy**, sustainability policies, and the steps they are taking to achieve it. Financial and economic impacts of climate change are not integrated into core insurance business. This **has to be integrated** and only recently, these impacts of climate change are getting defined under physical, liability and transition risks. This helps organizations to monitor these risks and also quantify their impact. They are now getting integrated into the core insurance business as well (Climate change, 2022).

Insurance business is split into two major sub-domains Property and Casualty insurance and Life Insurance. Life insurers have already incorporated ESG-C (Environmental, Social, Corporate Governance and Community) guidelines into their investment decision making process. P and C (Property and Casualty) insurers who take

less investment risk and tend to hold liquid, highly rated assets, have lagged behind life insurers in terms of integrating ESG-C factors into their operations. However this is quickly changing recently as P and C insurers also face business pressure to incorporate ESG-C into their decision-making processes.

The focus has shifted from looking at **ESG-C purely from a downside/defensive point of view to a forward looking, revenue generating point of view**. Many P and C insurers, particularly those involved in corporate specialty P and C insurance, are becoming more vocal about the revenue opportunities that ESG-C brings to the marketplace. **Green infrastructure and renewable energy projects** which support the transition from a high carbon to low-carbon economy should present new risks and premium opportunities for P and C insurers.

For adapting the business models, insurers **need data on transition risks** for sectors and insurers, and then need strategy to deploy the capacity and expertise into sectors that are likely to benefit from the transition to a low-carbon economy. Majority of investors (89%) surveyed for the most recent EY Global Institutional Investor Survey said they would like the reporting of ESG performance, measured against a set of globally consistent standards, to become a mandatory requirement (Constructing Climate Pathway, 2022).

Insurers are already experiencing increased financial losses from catastrophic weather events. To help understand and mitigate these losses, the insurance industry has depended on sophisticated **catastrophe risk models**, but these do not currently take into account the threats from a changing climate. **Climate risk models** have emerged to estimate how temperatures will evolve in the future. Rather than rely on historical, backward-looking data, climate models provide forward-looking simulations of the interaction between energy and matter in the ocean, atmosphere and land based on levels

of greenhouse gas emissions. **Any insurer who is able to adapt their business models for the climate risks are most likely to capture the growth opportunities** and mitigate the financial losses that they incur due to their lack of preparedness to handle climate risk**.**

### 4.3. Recommended climate risk models

The insurance industry already has sophisticated Catastrophe models to handle scenarios which have happened in the past and they have a solid database around it. But climate risk is a new area which needs an insight into future data to model it well. Catastrophe risk models typically provide a sophisticated understanding of potential insured loss over the next 12 months, while climate risk models can project economic losses decades into the future.

A few approaches on how to come up with climate risk models for insures are discussed in this research. There are many climate models available in the industry. Hence a study on these models and their applicability to the Insurance industry is very important. Catastrophe and climate models both have unique and valuable attributes. Based on the research conducted on Climate risk in insurance industry it can be **concluded that while Catastrophe based models are well matured and integrated with insurance business there are opportunities to improve in managing climate risk**. Once these climate risk models are developed, they can be integrated with the existing risk algorithm of insures by supplementing the catastrophe models with the findings from climate risk models. This can bring in a lot of balance to the climate risk management of insurers with the view of the past and a good prediction to future climate

data. Also, catastrophe risk and climate risk combined outputs can unlock a range of analytical opportunities.

### 4.4. Research Question 1 – Gaps to handle climate risk.

Insurance industry has many gaps to handle climate risk. Key ones are listed below.

- Net zero strategy and Sustainability policies are not consistent in Insurance companies. They need to take quick steps to achieve it so that there won't be any anomalies in a regulated industry like insurance.
- Financial and economic impacts of climate change are not integrated into core insurance business. This has to be integrated.
- Insurers' decision-making process, particularly in their investment portfolios, is not having ESG-C needs to it. This has to be incorporated.
- ESG performance reporting is not consistent today. ESG performance reporting has to be benchmarked against a set of widely accepted global standards. This also has to be reported as a mandatory requirement across insurance companies.
- Insurers in their journey to transform their organization from high carbon to low carbon economy have a big gap in process maturity among themselves. To close this gap, they should implement green infrastructure and renewable energy projects quickly. These projects would also give competitive advantage for the insurers.

The insurance industry, like any other industry, is limited by the resources it has, including knowledgeable workforce that are available to help its transition from high

carbon to low carbon economy. Hence deploying its available resources and also leveraging the expertise of its workforce into the right area to move their organizations to a low carbon economy is extremely important.

### 4.5. Research Question 2 – Future models to measure climate risk.

The insurance industry needs the below data and models to handle climate risk.

- transition risks related data is not readily available for insurers to make informed decisions. Insurers have to focus on developing this data with some focused investments from their side.
- As stated in earlier sections, Climate risk models are based on how temperatures will evolve in the future. Hence more and more work related to the development of climate models is important.
- In the insurance industry, since climate models are in it earlier stages, it is better to start with integrating physical laws based base models with Catastrophe based models and expand it to more complex models later.
- Regional based climate models' development is critical to handle the variations associated with regions.
- In places where climate risk is higher, new climate models and products can be developed in line with vertical and horizontal integration of services in the insurance industry.

# CHAPTER V:

# SUMMARY AND RECOMMENDATIONS

## 5.1. Summary

### 5.1.1. Climate change and Climate risk

**Climate Change** is a new reality of the world and is affecting every living and non-living thing in the world. Climate change is altering the way industries are run and it is an interesting transition period for every business. If the business world is not sensitive to this important transition and develops the ability to manage **climate risk,** it can hurt their business in a big way, and they may go out of business also. Hence identifying solutions to this universal problem is important. Every industry approaches this problem in a unique way. Climate change can affect financial stability of an insurer (Alliance, 2021) through three broader risk categories Viz,

- **Physical risks**: Physical risks such as floods and storms have an immediate (TODAY) impact on the insurance company and also on its and customer assets which are exposed to climate change.
- **Liability risks**: Liability risks such as Compensation to be paid by insurance companies in the near future (TOMORROW) if the customers suffer damage to their properties due to climate change.
- **Transition risks**: Transition risks such as financial risks to the company to implement GO Green Projects to meet low carbon economy guidelines can happen immediately (TODAY) or in the near future (TOMORROW) also.

Risks to financial stability will be maximized if the world doesn't correct its high carbon emission activities and in that case the impact could be as high as a 5 degree increase in world temperature. On the other hand, financial stability risks will be

minimized if the transition to a low carbon economy begins early and follows a predictable path, thereby helping the market anticipate the transition to a Two degree or even a better 1.5 Degree world.

Adverse climatic conditions have created greater systematic risk for companies throughout the global economy (Carney, 2015). Firms which are in countries which have severe climate risks would be controlled by strict government policies which would govern their cash reserves. Since these firms would be asked to have more cash to cover their risks, they would be constrained to have less money to invest and hence their ability to make profits would also be constrained.

The Global Climate Risk Index (CRI) developed by Germanwatch ( Huang, Kerstein and Wang, 2018) analyses quantified impacts of extreme weather events. The Global Climate Risk Index 2021 indicates a level of exposure and vulnerability to extreme weather events. Countries should use this data to their advantage and prepare themselves to handle these events in the future as expected to be more frequent in nature from now onwards.

Physical risk is the basis for liability and transition risks. Hence studies were attempted to understand the physical risks from a changing climate over a period of time. There is a good attempt made to understand the nature and extent of physical risk from a changing climate over the next one to three decades (Eckstein,  Künzel, and Schäfer, 2021). Also the need to Raise awareness on climate changes and conduct research to help shape future policies and regulatory dialogues (Woetzel, Pinner, and Samandari, 2020) is stressed.

The need for a task force to standardize the climate changes related disclosure was felt by all stakeholders.  In this regard, the Financial Stability Board established an industry-led task force: the Task Force on Climate-related Financial Disclosures (TCFD

Task Force). This Task Force made a recommendation to preparers of climate-related financial disclosures to provide climate change related disclosures in their annual financial filings. This is a huge step in the right direction, and this is helping organizations to follow common ground. The Task Force structured its recommendations around four areas that represent core elements of how organizations operate: governance, strategy, risk management, and metrics and targets (Golnaraghi, 2018). These disclosures are helping the investors, lenders, asset managers and insurance underwriters to appropriately assess the climate risks and create a mitigation mechanism for it. This also gives new revenue opportunities for them.

### 5.1.2. Climate risk insurance

Climate risk Insurance is a kind of insurance developed by insurance communities to handle the financial and other risks associated with climate change and the calamities that it can cause (Hermann, 2016). Climate risk insurance is also seen as a vehicle needed for reducing the impact the poor and developing communities would face due to climate risk (Schäfer, 2016; Russell, 2018; Surminski, 2016). Climate risk insurance provides coverage for the assets which are likely to get affected by climate risk. It also covers relief for post-disaster impacts, reconstruction measures and is designed to encourage proactive measures which are needed to manage climate risk including investment in green energy projects. Climate risk also controls insurers to have good underwriting and reinvestment strategies as the liabilities associated with climate risk are very high.

Clearly a study on insurance business reveals that only a small section of the insurance business has the means to handle climate risk (Singh, and Madaan, 2023).

Hence an approach to manage climate risk in the Insurance industry is the need of the hour.

### 5.1.3. Climate Risk – Response from Insurance Industry

Critics of the insurance say that insurance places the bulk of the economic burden on communities responsible for the least amount of carbon emissions (Russell, 2018). For low-income countries, any insurance program can be expensive due to the high start-up costs and infrastructure requirements for the data collection (Warner *et al.,* 2013). It is theorized that high premiums in high-risk areas experiencing increased climate threats would discourage settlement in those areas (7 things you need to know, 2017). These programs are also usually timely and financially inadequate, which could be an uncertainty to national budgets (Warner e *et al.,* 2013). A considerable problem on a micro-level is that weather-related disasters usually affect whole regions or communities at the same time, resulting in a large number of claims simultaneously (Hermann, Koferl and Mairhofer, 2016). This means that it **needs to be sold on a very large, diversified scale**. However, a well-designed climate risk insurance can act as a safety net for countries while improving resilience (Surminski, Bouwer, and Linnerooth-Bayer, 2016) (Kreft *et al.,* 2017).

The international community invested in developing further support for this kind of insurance through the InsuResilience Global Partnership launched at COP23. (Russell, 2018). That group **supports regional programs** such as Climate Risk Adaptation and Insurance in the Caribbean (CRAIC) and international organizations like the Munich Climate Insurance Initiative (Russell, 2018). The ACT Alliance published a guidebook

for equitable and climate justice-oriented model for climate risk insurance in 2020 (Alliance, 2021).

There are several changes that are expected in the insurance industry to manage the climate risk. Key ones are listed below.

- On the technology side, insurance industry is very slow to adopt to the new technical advancements (de Ferrieres, 2021). This study (de Ferrieres, 2021) also talks about the opportunity for the existing incumbent Insurers to work closely with new entrants (InsurTechs) to find possibilities to accelerate the digital transformation. **Digital transformation would also pave way for newer approaches to handle climate risk in insurance industry**.
- InsurTechs should partner with incumbent insurers to gain insurance knowledge, their approach to handle climate risk and leverage incumbents' years of knowledge in the insurance industry to come up to speed on the market needs. Similarly, **insurers should learn the newer technology developments from InsurTechs** and find opportunities to implement them in their companies. Until then, the industry will transform slower than other industries, and the incumbents will remain the leaders of such transformation.
- Methodological approaches currently applied to study climate insurance reach their limits when applied independently (Will *et al.,* 2022). Hence a proper **synergy** among these can make climate insurance products more effective under changing climatic conditions.
- To manage climate risk, insurers need to increase their focus, attention and their spending on capital and human resources. **Capital and human resources availability** will continue to be a problem as more and more scrutiny would be placed. Insurers would be asked to disclose their climate

risk exposures both on the underwriting and asset management side (Mills, 2009).

- Insurers exposures to **liabilities** will be scrutinized more.
- Enterprise Risk Management (ERM) will become an important framework to address climate risks.
- **Green projects** in insurance would flourish. Any insurance company that brings in innovative green products and services to scale, would be the leader in the industry and hence conformance to green initiatives would become hygiene for the insurance industry in the future.
- Any company which is doing Green Projects just as a tick in the box would be exposed soon and they would lose prominence. They also will be subjected to more audit and compliance related checks in the future.
- New insurance companies will continue to enter the insurance market. Some of the new players (with innovative climate risk solutions) can enter from outside insurance sector also.
- To deliver innovative climate change solutions, governments, non-governmental organisations, energy companies, etc. – will continue to seek innovative partnerships as they cannot channelize their resources around it. They would focus a lot to buy these skills thru partnerships than building them.
- Insurers need to spend more money on **research activities** on climate risk including regional based climate risk models, insurance sub-domain-based climate risk models, integration of various climate modelling, Go Green initiatives, efficient underwriting and asset management policies.

- **Sustainability and disaster-resilience** are linked initiatives. As a leader of the industry when it comes to regulatory and compliance adherence, insurers would take a lead to unify the low carbon economy needs and disaster-resilient practices across many domains (construction, energy, agriculture, land use).

### 5.1.4. Recommendations for the insurance industry

Insurance industry needs to develop a common **strategy to disclose climate risk** and have a strategy to **manage their assets and liabilities** efficiently ("Go Green" support initiatives can be an important step in it) to stay ahead of the business. Climate risk is also showing **new revenue opportunities** for the insurance industry. With a better understanding of the real estate assets, investors can model the expected return on investment and incorporate climate risk into investment decision. The insurance industry needs to make some quick changes for managing climate risk and not get overwhelmed by the **big bold moves** that it has to take. It is a perfect opportunity for the insurance industry to demonstrate once again to the world on why it is a leader for many industries to grow their business by leaning on insurance industry to run their business fearlessly.

Insurers have to focus on a few **long-term strategic investments** in adaptation measures such as green roofs to mitigate extreme temperature impacts or stormwater best management practices to mitigate flooding to name a few. They should incentivize businesses and their customers who are taking these proactive measures to have better premiums for their insurance products. Insurers have to enable corporations to identify locations with **high climate risk** and plan their key personnel to manage the climate risk. Also they should invest more to make the investors understand the climate risk. The

sooner businesses and investors understand their climate related financial risks, the better placed they will be to weather the gathering storm and seize opportunities as they emerge.

### 5.1.5. Summary of Findings

To Summarize, insurance companies need to develop more **consistent and comprehensive strategy on ESG-C** and implement models that would address the climate risk. **Climate models which are Regional based** and product lines which are aligned to **integration of services in insurance industry** are the need of the hour and hence more future research work is expected in this area. Climate models need to start as **simple models and mature to a more complex models** and this has to be in line with the evolution of the insurance industry maturity to handle the climate risk.

Catastrophe and climate models are unique in their coverage of risks. They also have attributes which can be leveraged across. Based on the research conducted on Climate risk in insurance industry, it can be concluded that while Catastrophe based models are well matured and integrated with insurance business there are oppurtunities to improve in managing climate risk. Models associated with Climate risk can be developed and integrating them with Catastrophe model would bring in the desired results for the business and the consumers. Different climate scenarios and its related climate hazards would bring in additional complexities. To understand these complexities, their financial implications and to manage them, **a combined climate risk analysis approach which encombasses catastrophe modeling, climate risk modeling and organizations well matured risk management model can yield robust results**. In turn, this enables more holistic preparation for the threats and opportunities that the future may present.

Also, **insurance community has to raise awareness among all stateholders** on the climate risk. They also have a **resposibility to invest in research** related to shaping up future policies and regulatory norms related to climate risk.

### 5.2. Recommendations for Future Research

In the first research paper (Climate Risk and its impact in insurance industry Part 1) presented and published by the authors on this research topic (Mannappan and Varadarajan, 2022), the topic of climate risk and its impact in insurance industry was discussed. The second research paper (Climate Risk and its impact in insurance industry Part 2) presented and being published by the authors (Mannappan and Varadarajan 2023) discussed about one Climate model and how to make it relevant for insurance industry. In the final paper (Climate Risk and its impact in insurance industry Part 3) on this research topic, authors (Mannappan and Varadarajan 2023) discussed,

- the various climate risk models available in the world,
- challenges of the insurance industry to manage climate risk and
- how to leverage two specific climate risk models for the insurance industry and come up with meaningful business inferences from it.

Our recommendations for the future research on this topic are:

- Different climate scenarios and its related climate hazards would bring in additional complexities. To understand these complexities, their financial implications and to manage them, a combined climate risk analysis approach which encompasses catastrophe modeling, climate risk modeling and organizations well matured risk management model can yield robust results.

In turn, this enables more holistic preparation for the threats and opportunities that the future may present.

- Climate models need to start as simple models and mature to more complex models and this has to be in line with the evolution of the insurance industry maturity to handle the climate risk.
- More focused work on climate models for each climate risk zone needs to happen which can help to plan for the climate risks better.
- Climate models which are Regional based and product lines which are aligned to integration of services in insurance industry are the need of the hour and hence more future research work is expected in this area.
- The need for insurers to continuously evolve along with the changes related to climate risk are high. Hence insurers have to invest more in research activities related to climate risk.
- They should also invest in building regional based climate risk models, insurance sub-domain-based climate risk models and integration of climate modelling and catastrophe modelling.
- Insurers need to spend more on green projects and “low carbon” technologies as well.

- Global communities on climate risk to be formed to promote knowledge sharing on this topic which will be evolving in the coming years.
- Many under privileged people who are in climate risk zones need to be provided with climate insurance coverage so that they don’t lose their livelihood.  Private Insurance has a role to play in it.

- Also the insurance community has to raise awareness and conduct policy-industry relevant forward-looking research in policy-industry to help shape future policies and regulatory dialogues.

- Technical advancements like computing power and Gen AI can help to accelerate the models to get refined further without causing too much cost for the company or additional premium for the consumers.
- Focused research on the technical disruptions to be encouraged by Governments and insurance companies.

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