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The insurance industry and climate change: A story of resilience and collapse

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"It seems that there may not be a happy end to my story of The Five Stages of Collapse, the first of which (financial, commercial, political) are inevitable, while the last two (social, cultural) are entirely optional but have, alas, already run the course in many parts of the world. Because you see, there is also the sixth stage which I have previously neglected to mention – Environmental Collapse – at the end of which we are left without a home, having rendered Earth (our home planet) uninhabitable."

Dmitry Orlov, *The Sixth Stage of Collapse*, 2013.

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English title

The insurance industry and climate change: A story of resilience and collapse

Abstract

The insurance industry's central role in assessing current and future risks faced by, what is commonly referred to as, the modern thermo-industrial civilization makes it a crucial player when discussing one of the major issues faced by humankind: climate change. Accordingly, this thesis proposes an exhaustive analysis of the industry's core resilience when confronted by such dramatic modifications within the Earth's systems. In order to do so, this paper begins by proposing a detailed examination of the industry's business model, its close relationship to global warming, as well as a detailed review of the existing adaptation and mitigation actions undertook by (re)insurances (Chapter 1). Subsequently, the document deep dives into a theoretical stress test of the sector's resilience toward, what this paper describes as, a credible "catastrophic" scenario. This scenario refers to a situation where the RCP 8.5 path is coupled with a financial/economic crisis resembling the 2007-08 event and demonstrates the insurance sector's difficulties in displaying any type of resilience. In addition, this paper proposes a philosophical analysis of the terminology and tools used by the insurance industry, such as the notion of risk or modeling (e.g., Climate, Financial, etc.), to disclose a certain irrelevance of these tools when discussing the global and profound damages caused by climate change. Further examination of this subject through the eyes of what Pablo Servigne refer to as Collapsology offers an unusual overview of the insurance sector's activities and reactions when facing a civilization collapse. The strong correlation that exists between environmental mismanagement and civilization failure is further highlighted by the study of earlier civilization collapses such as the Maya people and the Anasazi Indians, thus attesting to the possibility of such a drastic fate for any complex civilization. A further case study of our globalized and interconnected thermo-industrial civilization outlines the extreme difficulties encountered by the existing insurance industry's business model in such a collapse process (Chapter 2). Finally, a conclusive chapter contributes to opening a discussion regarding the insurance industry's future societal roles and proposes three main pillars aimed at easing this sector's voyage through a collapsing world (Chapter 3).

Keywords: Insurance industry, Climate Change, Societal Collapse.

Titre français

L'industrie de l'assurance et le changement climatique: Une histoire de résilience et d'effondrement.

Résumé

Le rôle central de l'industrie de l'assurance dans l'évaluation des risques actuels et futurs de la civilisation dite thermo-industrielle, en fait un acteur essentiel dans le débat sur l'une des problématiques majeures de l'humanité: le changement climatique. En conséquence, ce mémoire propose une analyse exhaustive de la résilience de cette industrie face à de telles modifications drastiques du Système Terre. Pour ce faire, ce document débute par une étude détaillée du modèle économique du secteur de la (re)assurance, de ses liens étroits avec le réchauffement planétaire, ainsi qu'une revue des mesures d'adaptation et d'atténuation existantes (Chapitre 1). Par la suite, ce papier propose un test de résistance (stress test) théorique de la résilience du secteur vis-à-vis de ce que ce mémoire décrit comme un scénario «catastrophique» crédible. Ce scénario fait référence à une situation dans laquelle le scénario climatique RCP 8.5 est associé à une crise financière/économique similaire à celle de 2007-08 et démontre ainsi très clairement les difficultés du secteur de l'assurance à faire preuve de résilience face à un tel bouleversement. En outre, ce document propose une analyse philosophique de la terminologie et des outils utilisés par ce secteur, tels que la notion de risque ou la modélisation, révélant ainsi un manque de pertinence de ces outils face aux dommages globaux et profonds causés par le changement climatique. Un examen plus approfondi de ce sujet à travers les lunettes, de ce que Pablo Servigne nomme Collapsologie, offre un aperçu hors du commun des activités et des réactions du secteur des assurances face à un effondrement de civilisation. Ainsi, la forte corrélation existant entre la mauvaise gestion environnementale et le collapse de certaines civilisations est mise en évidence par l'étude de cas historiques tels que les Mayas et les Indiens Anasazi, attestant ainsi de la possibilité d'un tel destin pour toute civilisation complexe dont la nôtre. En effet, l'étude de cas du possible effondrement de notre civilisation thermo-industrielle, globalisée et interconnectée, met en évidence les difficultés majeures rencontrées par le secteur de la finance ainsi que par le modèle économique du secteur des assurances lors d'un tel développement (chapitre 2). Finalement, un chapitre conclusif contribue à ouvrir le débat sur le futur rôle sociétal de l'industrie de l'assurance et propose ainsi trois grands piliers visant à faciliter le voyage de ce secteur dans un monde en collapse (Chapitre 3).

Mots clefs: Industries de l'assurance, changement climatique, effondrement sociétal.

Abbreviations

D&O	Directors and Officers liability insurance
ECB	European Central Bank
EIOPA	European Insurance and Occupational Pensions Authority
ESG	Environmental, Social and Governance (Issues)
EU ETS	European Union Emissions trading system
Fed	Federal Reserve Bank (U.S.)
FSB	Financial Stability Board
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IAIS	International Association of Insurance Supervisors
IISD	International Institute for Sustainable Development
ILO	International Labor Organisation
ILS	Insurance Linked Securities/Strategies
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
L&H	Life and Health (re)insurance
OECD	Organization for Economic Co-operation and Development
P&C	Property and Casualty (re)insurance
PPP	Public-Private Partnership
RCP	Representative Concentration Pathways
SPV	Special Purpose Vehicle
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP FI	United Nations Environment Programme Finance Initiative
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

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Introduction

In recent years, environmental issues and the perceived risk linked thereto have increasingly become of concern to the general public. The recent worldwide youth climate strike movement, led by Swedish activist Greta Thunberg and held in over hundred countries, demonstrates the amplified awareness of environmental issues on a global scale (Laville, Taylor, & Hurst, 2019). Recent alarming scientific literature also confirms that environmental problems such as climate change, biodiversity loss or ocean acidification threaten our own survival, adding pressure on both public and private sector entities. This increased consciousness about the environmental risk has also reached, to a certain (albeit limited) extent, the economic and financial sectors which progressively consider it as a menace on day to day business (Jeucken, 2001). In fact, what was once a very niche environmental discussion is now becoming a mainstream issue within the financial sector, partly as a result of recent sensitizing efforts by the United Nations Environmental Program Finance Initiative (UNEP FI) and by other international institutions such as the World Economic Forum (2019).

When taking a step back, notions such as "Anthropocene" have entered a more mainstream vocabulary following the United Nations Conference on Sustainable Development in 2012, indicating that we have entered into an era dominated by the impact of humankind (Clémençon, 2012, p. 312). This profound and alarming modification to the Earth's complex system is confirmed when looking at Rockström's planetary boundary analysis introduced in 2009 in the scientific journal *Nature* (Rockström et al., 2009) and further developed in 2015 (W. Steffen et al., 2015). This internationally recognized scientist's work indicates that crossing certain boundaries, such as climate change or ocean acidification, could force the Earth systems into a new potentially harmful state for humanity. Moreover, the *Stern Review on Climate Change* (Stern, 2007) and numerous reports from the Intergovernmental Panel on Climate Change (IPCC, 2012, 2014, 2018) convey the worrisome idea that environmental changes will deeply impact our way of life and through it our global economy. To use the words of Nicholas Stern, "*the scientific evidence is now overwhelming: climate change is a serious and global threat, and it demands an urgent global action. […] The overall costs and risks of climate change will be equivalent to losing at least 5 per cent of global GDP each year, now and forever"* (2007, p. 15).

It is shocking to note that even though the comprehension of the damaging impact of anthropogenic pollutions on our planet is not a recent discovery (refer to Rachel Carson's *Silent spring* warning in 1962 or the Meadows' *Limits to growth* report in 1972), the financial

sector's interest in the matter is very recent and dates back only to the present century (Jeucken, 2001). The now-increased involvement of the private sector in environmental issues can be visible, for instance, at the 2015 UNFCCC Conference of Parties (COP21) that took place in Paris and was considered by many as a highlight for the environmental cause. Indeed, according to the International Finance Corporation of the World Bank Group (IFC WB) "*the private sector was more visible and active at COP 21 than in any previous COP. CEOs from industries as far ranging as cement, transportation, energy, and consumer producers stepped up their efforts to address climate change, making their own commitments to decrease their carbon footprints, adopt renewable energy and engage in sustainable resource management".* The IFC adds that *"global financial institutions pledged to make hundreds of billions of investment available over the next 15 years for clean energy and energy efficiency"* (International Finance Corporation, n.d.).

Building on this increased interest of the private sector towards environmental matters, this document intends to focus on one of the most prominent members of the financial sector: the (re)insurance industry. Indeed, an analysis of human-induced climate change and its effect on our society would be incomplete without embracing the insurance industry, commonly considered as one of the world's most powerful with its global assets estimations as high as USD 30 trillion in 2018 (Swiss Re, 2019b, p. 1). The fact that this sector's ever-growing economic strength is also interpreted by some as a potential leverage towards a low carbon economy and paradigm change (Mills, 2012) renders such analysis highly interesting from a "strong sustainability"[1] point of view. The (re)insurance industry's role as a societal stabilizer due to its knowledge, pooling of risk mechanism, and due to the fact that every economic sector transfers a part of its risks to insurers, attests the importance of ensuring its long-term resilience[2] against climate change (Swiss Re, 2019b). For the sake of clarification, this document will use the terms "insurance industry", "(re)insurance industry" or "insurance sector" interchangeably, as the research completed prior to the writing of this paper has

[1] According to Dominique Bourg "strong sustainability" comes as the opposite of "weak sustainability", which is defined by Robert Solow as the idea that the destruction of natural capital - which is inevitably caused by our economic activities - can be offset by the creation of reproducible capital and therefore of various technologies. This vision of sustainability is mostly carried out by the mainstream economy. In opposition, the notion of "strong sustainability" provides a fundamentally different approach where natural capital is not technologically substitutable (Bourg, 2012, our translation).

[2] This paper will use IPCC's definition of resilience as *"the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions"* (IPCC, 2012a).

demonstrated that all lines of business, of both insurers and reinsurers, will be profoundly impacted by climate change and that, when studying reactions towards such events, insurances and reinsurances act in similar ways and can thus be considered as a sole entity. For further disclosure, it should be noted that a sizeable amount of the analysis used in this document originates from research centers within the insurance industry and entities such as the Swiss Re Institute and Munich Re, known for their extensive reporting, are actually for-profit organizations, implying that a bias may exist in the result of certain studies or definitions.

As a result to the above, the objectives of this paper are manifold. Firstly, this paper calls for a much-needed holistic, global and inclusive response including, but not limited to, economic, philosophical and environmental points of view. Secondly, it will examine the fundamental question of the potential danger caused by the perilous combination of shareholders' short-term ambitions on the one hand and the environmentalist long-term vision necessary to fight climate change on the other hand (Reynolds, 1992), and will turn to the possible means of reconciling this dual vision. Thirdly, this thesis will discuss the insurance industry's resilience to climate change and will examine whether it is resistant to a catastrophic scenario. A thorough theoretical stress test of the insurance industry involving on the one hand, an RCP 8.5 climate pathway and an *"abrupt climate change"* (IPCC, 2012a, p. 556) scenario, in which the unbridled time scale implies unexpected and drastic responses of Earth systems, and on the other hand, a 2007-08 like crises that could potentially serve as a trigger to a global disaster. Does this economic sword of Damocles coupled with the increased risk represented by climate change constitute an insurmountable threat to the insurance industry's viability? Could it potentially cause this economic sector to collapse and bring the entire human civilization with it? Are there any possible actions that would allow avoiding such a drastic and painful fate? These and many other crucial questions attest to the necessity of studying the impacts of societal collapse on the insurance sector in order to assess future risks and develop adequate answers.

In view of the above, the first chapter of this document will serve as a contextual initiation and will help to set the scene by providing an extensive overview of the insurance industry's current structure and its close relationship to climate change, before analyzing concrete examples of (re)insurance actions in the context of climate change adaptation and mitigation. The second chapter will then turn to a comprehensive review of the most probable worst-case scenario on the environmental and economic fronts, characterized by the RCP 8.5 pathway

coupled with an important financial crisis, as well as the impact of this scenario on our society. It will be demonstrated how difficult it is for any entity to show resilience in this type of circumstances and further philosophical analysis of insurance tools and terminology, based on literature from authors such as Dominique Bourg and Nassim N. Taleb, will expose the industry's robust links to a merciless paradigm where humans believe they control nature. Further examination of this subject through the eyes of, what Pablo Servigne and Raphaël Stevens refers to as, Collapsology will offer an unusual overview of the insurance sector's performances when facing a civilization collapse, while the brief review of past civilization collapses (offered by historians and anthropologists such as Jared Diamond or Joseph Tainter) will clearly demonstrate the strong correlation between environmental mismanagement and civilization failures, leading to chilling parallels for our current environmentally destructive society. Finally, the third chapter will serve as a conclusive section, opening the discussion as to the various pathways available to the insurance industry during a time where the society walks into a challenging environment and proposing three main pillars aimed at rethinking the (re)insurance business model in order to ease its walk through a collapsing world.

1. Setting the Scene: The insurance industry and climate change

How does the insurance industry function and why talk about climate change when studying this economic sector? This chapter will address these questions by providing a comprehensive description of the insurance industry's business model before exposing the current and future potential impacts of climate change on the insurance industry's different lines of business. Finally, it will provide a selection of concrete actions that are being undertaken by the insurance industry with the aim of mitigating and adapting to global warming and will examine whether they are comprehensive enough to address this global issue.

1.1. The Insurance Industry: a complex business model

To begin, this section will introduce the insurance industry, in particular its business model and economic weight, as well as the different financial tools it uses. In this regard research from the United Nations Environment Programme Finance Initiative (UNEP FI), a partnership between UNEP and the global financial sector (UNEP FI, n.d.), as well as from the International Institution for Sustainable Development (IISD), a think tank with a mission to "*promote human development and environmental Sustainability*" (IISD, n.d.) will be of the utmost interest. Reference will also be made to reports from reinsurers such as Swiss Re and Munich Re.

1.1.1. Traditional (re)insurance: Risk pooling and basic claim structure

According to the UNEP FI, understanding, managing and carrying risk are at the core of the insurance industry's business model. Indeed, "*by pricing and creating a market for risk, it enables it to be pooled, diversified, managed and reduced, thereby protecting society and supporting innovation and economic development*" (UNEP FI, 2012, p. 3). In other words, through risk pooling an "*insurance helps communities cope with the financial hardship"* associated with unexpected losses (IISD, 2015, p. 214). In his book *"Risk Society"*, the German sociologist and philosopher Ulrich Beck, even considers that the concept of risk and risk pooling is key to the *"second modernity"* we live in and observes a societal evolution where *"modernization is becoming reflexive; it is becoming its own theme. Questions of the development and employment of technologies (in the realms of nature, society and the personality) are being eclipsed by questions of the political and economic 'management' of*

the risks of actually or potentially utilized technologies - discovering, administering, acknowledging, avoiding or concealing such hazards with respect to specially defined horizons of relevance" (Beck & Ritter, 1992, p. 19-20). In these circumstances, the insurance industry and its role as a risk absorber become increasingly central to the way our society functions and perceives risk. As we will discover in the subsequent sections, certain risks such as terrorism, cyber attacks or extreme weather events are too sizeable to be born by individual insurers and should be rather spread within a global risk-sharing system involving numerous players (IISD, 2015).

The insurance industry, as an economic sector, consists of three main players: policyholders (individuals or businesses), insurance companies also called primary insurers and reinsurance companies insuring the primary insurers (see figure 1).

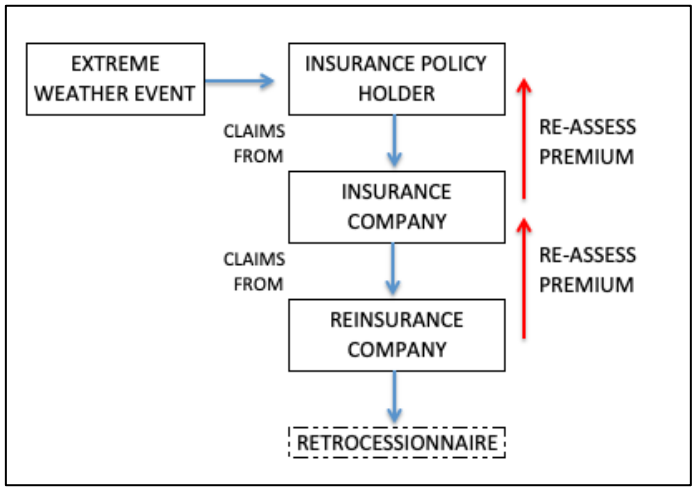

Figure 1: Basic claim structure of the insurance industry for an extreme weather event.
Source: adapted from *The Insurance Industry and climate change on the Prairies* (IISD, 2009, p. 6).

The interactions between the different entities are very straightforward. Individuals or businesses will approach insurance companies in order to spread their risks linked to a potential event. The insurance company will then agree to make the individual or business a policyholder as long as they are willing to pay the adequate premium, the price of which reflects the assessment of the risk that an event will actually take place. Likewise, the insurance company covers its own risks by paying a premium to a reinsurance company (IISD, 2009, p. 6). According to the Organization for Economic Co-operation and Development (OECD) the reasons for primary insurers to purchase reinsurance are manifold. In fact, a primary insurer signing a reinsurance treaty will be able to increase its underwriting capacity and reduce its solvency capital requirements, which will allow "*primary insurers to*

take more diverse risks with the same working capital" (Helmut Gründl, Dong, & Gal, 2016 p. 6). Finally, in certain cases, reinsurances will look to cover their own risks through a retrocessionaire (IISD, 2009, p. 5) which is defined as a transaction between two reinsurers where one of them cedes a part of its reinsurance portfolio to the other, who becomes the retrocessionaire. They do so in order to "*reduce their net liability on individual risks*" and to help *"avoid catastrophic losses, stabilize financial rations, and obtain additional underwriting capacity*" (insuranceopedia.com, n.d.).

Traditionally, the insurance industry is split into two separate entities: life and non-life insurance (see figure 2). On the one hand, the Life and Health (L&H) branch is meant to cover serious risks to human well-being and provide post-retirement income. Core life insurance products are known to include whole life insurance, term life insurance, endowment life insurance and annuities (Helmut Gründl, Dong, & Gal, 2016, p. 5) and was worth USD 2,820 billion in premiums in 2018 (Swiss Re, 2019c, p. 11). On the other hand, non-life, or Property & Casualty (P&C) insurance, was valued at USD 2,373 billion (p.11) in premiums and focuses on protecting individuals and businesses against risks to assets, loss of income and third party liability (UNEP FI, 2007, p. 14). The central role of P&C insurance is therefore to protect against fire, theft, weather perils, negligence and other *"acts and events that can result in injury to persons or property"* (Helmut Gründl et al., 2016, p. 5).

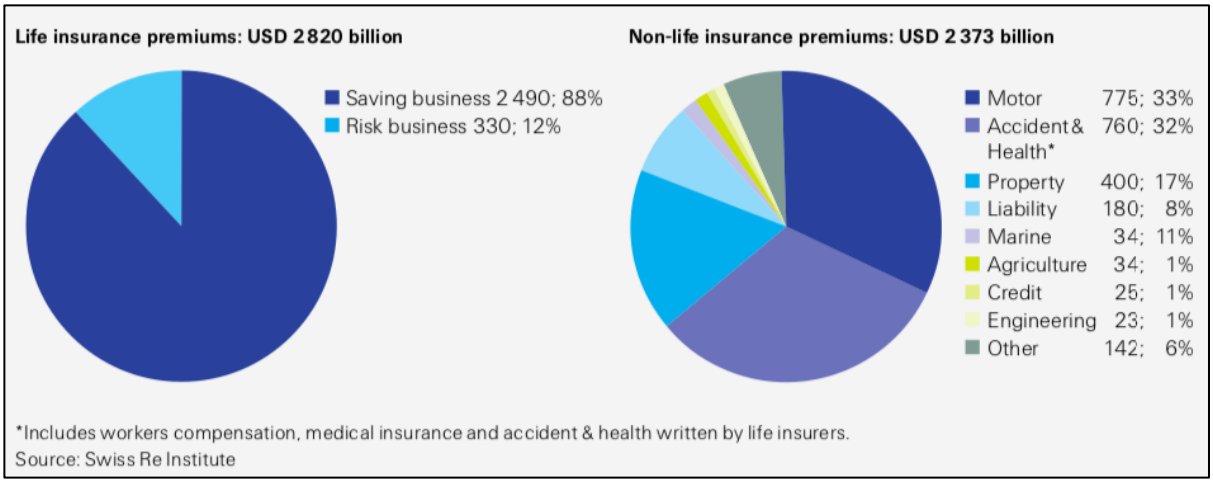

Figure 2: Line business split in life and non-life premiums (in USD billions and %), 2018.
Source: Swiss Re, 2019c.

1.1.2. The roles and weight of the insurance industry

Insurers are said to have three main roles within the financial sector. As demonstrated above, they primarily act as underwriters, but, the insurance industry also has a major role as a financial investor and as a key player in the banking sector since bank transactions usually depend on insurances to "*reduce the potential risk to a loan or investment*" (Dlugolecki, 2008, p. 71-72).

When looking at the insurance industry as a major investor in financial markets it is undeniable that the capital invested in 2014, amounting to USD 30 trillion, clearly demonstrates the massive potential of the sector (Climate Wise, 2016, p. 1). For the sake of financial weight comparison, the net assets under management in funds based in Luxembourg, the largest investment fund center in Europe (Association of the luxembourg fund industry, 2017, p. 6), were about USD 5.03 trillion in early 2019 (alfi, 2019). In addition to impressive investment capacities, the insurance industry's economic strength can also be observed through its 2017 premium volume which reached a striking USD 4.9 trillion (Swiss Re, 2018c, p. 38), representing an approximate 6.27 per cent of the world's GDP (estimated at USD 80,738 trillion by the World Bank) (World Bank, n.d.), and making the insurance sector one of the world's largest and most powerful industries (Mills, 2012). A 45/55 ratio between life and non-life premiums also shows a well-balanced and diversified industry (Swiss Re, 2018c, p. 38) and the 3 per cent forecasted growth for global non-life and life premiums for the 2019-2020 period further demonstrates an outstanding potential (Swiss Re, 2018a, p. 11). Another valuable indicator of the insurance industry's financial weight is the insurance spending in OECD countries, defined as the ratio of direct gross premiums to GDP expressed as a percentage. For instance, in 2017, the insurance spending in OECD countries was of approximately 8.9 per cent (OECD, 2019).

With regard to profitability of the insurance sector, the global insurance industry Return on Equity (ROE) saw an 8.9 per cent increase in 2018 and as estimated by Ernst and Young, the insurance net income growth was of 23 per cent for the year 2018 (Crawford, Kumar, & Russignan, 2018, p. 5), proving once again the sector's financial strength. It is also interesting to note that the global insurance penetration was of 6.3 per cent in 2016 (Crawford, Kumar, & Russignan, 2018, p. 5) leaving a huge growth potential and that the total financial portfolio for life and non life insurances equaled approximately USD 21 trillion in 2017, allocated in cash and deposits, real estate, equity, bills and bonds, loans, collective investment schemes,

private equity funds, hedge funds and structured products (OECD, 2019, p. 7). Swiss Re's recent data confirms this trend as it estimates the total non-life (re)insurance capacity to be more than USD 2 trillion at the end of 2018 proving, in Swiss Re's view, that the industry is well capitalized in regard to losses arising from extreme events (Swiss Re, 2019, p. 19).

Lastly, when evaluating financial weight of the entire sector, it can be of assistance to know who the market leaders of the insurance industry are. Indeed, the three biggest insurance companies[3] - Allianz SE (Germany), AXA S.A. (France) and Prudential Financial Inc. (U.S.) - add up to a net non-banking asset of USD 1.8 trillion, demonstrating the economic leverage of these entities (Am Best, 2017b). In regard to reinsurances, market leaders[4] are Munich Reinsurance Co. (Germany), Swiss Re (Switzerland) and Berkshire Hathaway Inc. (U.S.) (Am Best, 2017a).

From the above data, it is evident that the insurance industry as a whole possesses an important leverage linked to its investment portfolio and could, therefore, be a potential actor in setting investment trends. However, it is essential to note that, similarly to most financial entities, the 2007-08 financial crisis also had a deep effect on the insurance industry, which became subject to increasing regulations, as a result thereof (see sub-section 1.1.3).

1.1.3. Insurance regulations and the role of the State

According to Mills, *"insurance regulators have two overarching and interrelated goals: to maintain the availability and affordability of insurance for customers and to guard against insurer insolvency"* (2009, p. 349). Indeed, "*regulators have a responsibility to see that rates are adequate and that state-operated insurance pools have sufficient capacity to pay losses*" (Mills, 2009, p. 349). As an example, in Switzerland, the Swiss Financial Market Supervisory Authority (Finma), more precisely its insurance division, is in charge of supervising insurance companies, groups and conglomerates and even has an entire team dedicated to the Zurich Insurance Group and the Swiss Re Group (Finma, n.d.). On a broader scale, the European Insurance and Occupational Pensions Authority (EIOPA) was created after the 2007-08 financial crisis following a call for more integrated European supervision (EIOPA, n.d.-a). In this regard, one can note the elaboration of Solvency II, the insurance industry's equivalent to the banks' Basel III (Bank for International Settlements, 2017), which is a

[3] Based on the 2017 non-banking assets (Am Best, 2017b).
[4] Ranked by unaffiliated gross premiums written in 2017 (Am Best, 2017a).

regulatory framework reviewing the prudential regime for insurance and reinsurance undertakings within the European Union and is considered as a true benchmark for the industry's regulation (EIOPA, n.d.-b). Solvency II is based on three pillars: (i) the amount of capital an insurer must hold; (ii) internal governance and formal supervision; and (iii) public disclosure and transparency (Ralph, 2016); and pushes insurers to have sufficient capital to cope with the worst expected losses over a year. The importance of regulators in the insurance industry was also pointed out by the ACAPS, a non-profit project born from the consortium of the Norwegian Refugee Council and Save the Children (ACAPS, n.d.), which affirms that insurance regulation "*is a cornerstone for a resilient society*" since it oversees the activities of insurances, encouraging them to act in an economically sustainable manner (ACAPS, 2017).

Finally, it is interesting to mention that in certain countries, the State plays the role of the last insurer with an unlimited government guarantee for catastrophes (Charpentier, 2008, p. 100). As an example, the French insurance system consists of a public-private partnership (PPP) involving the Caisse Centrale de Réassurance (CCR), a public sector reinsurer that provides *"cedants operating in France with coverage against natural disasters and uninsurable risks*" (CCR, n.d.) and the French State intervenes with a State guarantee as a last resort to avoid any potential system failure (CCR, 2015) adding further resilience to the entire system.

While it is clear from the above that States have a crucial role to play with regard to the insurance industry's resilience, the insurance sector also uses financial markets as yet another opportunity to transfer its risks (see section 1.1.4 and sub-chapter 1.2).

1.1.4. Capital markets: The tip of the pyramid

As will be demonstrated, the insurance industry is very dependent on certain weather events. For instance, the intensity of the 1992 Hurricane Andrew shocked the whole industry by demonstrating the sector's capacity constraints at the time. As an answer to this limited capacity of the traditional insurance and re-insurance system (see previous sections), the industry turned itself to the almost "unlimited" scope of financial markets through securitization, in particular through Insurance-linked Securities (ILS) (Swiss Re, 2011, p. 7).

1.1.4.1. Andrew: The event that changed the industry

With insured losses of USD 27 billion,[5] the 1992 Hurricane Andrew is considered to be an event that fostered the present-day (re)insurance industry (Swiss Re, 2018b, p. 12-13). Indeed, according to Swiss Re, *"the losses from Hurricane Andrew far exceeded the then-estimated maximum potential cost that a catastrophe might inflict"* causing *"fundamental changes in the operations of the (re)insurance sector"* (p. 12). As a brief reminder, Hurricane Andrew hit the state of Florida (U.S.) at category 5 intensity on August 24, 1992 with winds as strong as 265 km/h (Sarkis, 2017) causing destruction and death in the States of Florida and Louisiana, as well as in the Bahamas (CNN, 2018). The storm is considered to be one of the toughest hurricanes in U.S. history causing insurance losses accounted for 9.5 per cent of the national industry capital and even driving some P&C insurers into bankruptcy (Swiss Re, 2011, p. 7). As a comparison, the 2017 Hurricanes Harvey, Irma and Maria, also known as the HIM cluster, caused respectively, 2.4 per cent, 3.7 per cent and 4 per cent insured loss of the U.S. industry capital (Swiss Re, 2018b, p. 12). According to Swiss Re, the Hurricane Andrew experience demonstrated *"the extent of financial losses that can result in coastal regions of growing population density and development which are exposed to the natural elements"* causing deep changes within the insurance industry (2018b, p. 12).

1.1.4.2. Insurance Linked Securities (ILS)

One of the numerous effects brought upon the insurance industry by Hurricane Andrew was the securitization of catastrophe risks, which developed in answer to the limited capacity of the traditional insurance system (Swiss Re, 2011, p. 7). The following sub-section will discuss the growing importance of ILS to the insurance industry and will underline both the complexity and the usefulness of these financial instruments.

a) An increasing contribution of ILS to the total risk-bearing capacity of (re)insurances

Hurricane Andrew, coupled with the Lloyd's crisis, in the 1990's (Dunkley & Jenkins, 2017), and with the asbestos linked claims, increased the industry's motivation to *"bring more risk-bearing capacity to the catastrophe reinsurance market"* (Swiss Re, 2018b, p. 13). The interest towards ILS, also referred to as alternative capital (AC), strengthened in 2005

[5] In 2017 prices (Swiss Re, 2018b, p. 12).

when Hurricanes Katrina, Rita, Wilma, Ophelia and Dennis *"contributed to what is considered as a record loss of USD 80 billion in insured losses"* pushing (re)insurers to approach the financial market's broader capital due to the constraints in their risk-bearing capacity. As a consequence, Swiss Re estimates that USD 8.5 billion of cat bonds were issued in 2007, being *"the year with the largest amount of newly issued ILS capacity"* (Swiss Re, 2011, p. 7). In this respect, figure 3 provides a good overview of the growing trend of AC during the past twenty years in comparison to the development of the global non-life (re)insurance capital. Indeed, Swiss Re estimates that 2018's total non-life insurance industry capital can be broken down to 80 per cent from primary insurers, 16 per cent from reinsurers and 4 per cent being the share of AC (Swiss Re, 2019, p. 19).

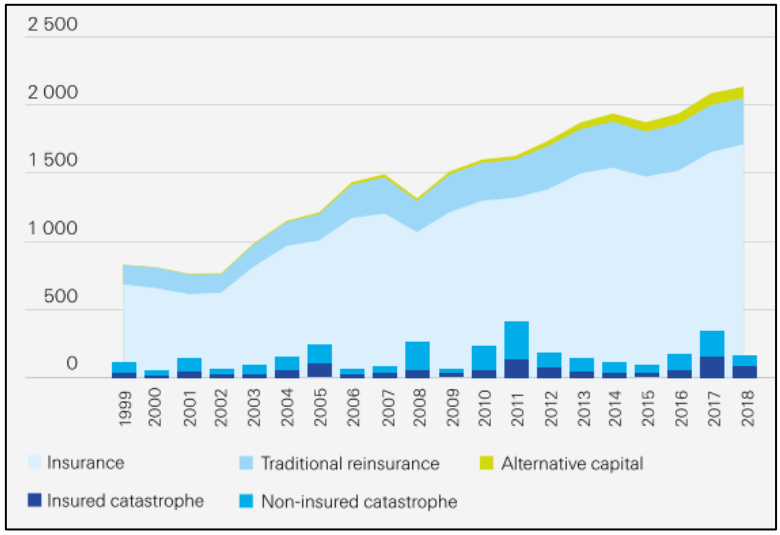

Figure 3: The development of the global non-life (re)insurance capital, and the size of insured and uninsured losses since 1999 (in USD billion).
Source: Swiss Re, Sigma report No 2/2019, p. 19.

The Swiss reinsurance company also believes that despite a slight loss of investors' appetite in 2018 due to *"disappointing price increases"* and *"gradually escalading loss numbers"*, AC are here to stay on the long run, since alternative capital has *"matured into an integral player in the growing market of catastrophe risks"* (Swiss Re, 2019, p. 19). Swiss Re's CEO, Moses Ojeiskhoba, confirms the appetite for ILS by stating that "*ILS are set to play a meaningful role within global risk markets, as insurance and reinsurance risk and exposure expand"* (Evans, 2019). Indeed, as shown in figure 4, 2018 was a very active year on the ILS primary market with a total issuance of USD 9.7 billion, placing the year "*as the second highest year of issuance volume since the market's inception, and only 8% down from 2017's USD 10.5 billion"* (Swiss Re, 2019a, p. 4).

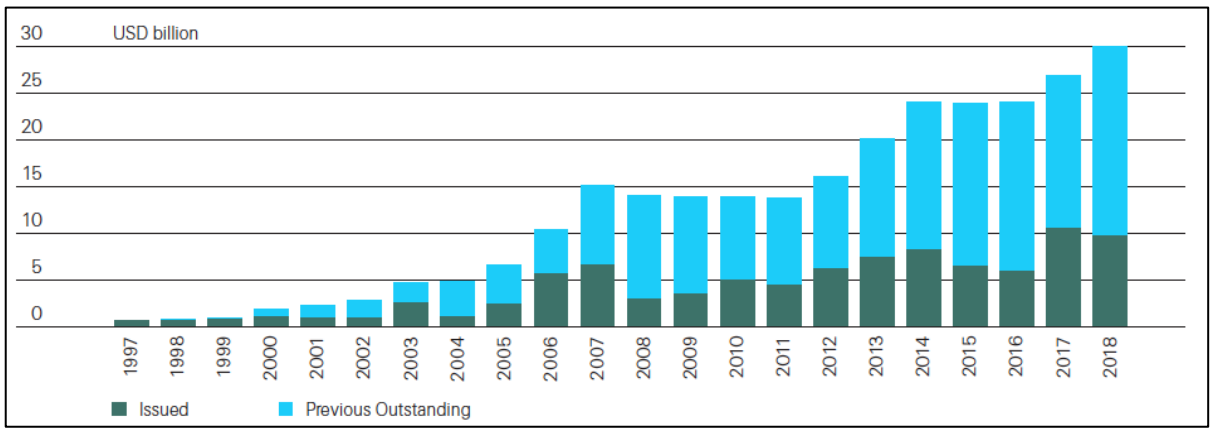

Figure 4: Yearly issuance and outstanding ILS bonds.
Source: Swiss Re, 2019a, p. 4.

Finally, it is assumed that the insurance industry demand will expand faster than economic growth due to a *"dynamic industrial growth and urbanization in emerging markets, and also as the increasing value of assets located near coastal areas in mature markets, which are often vulnerable to natural hazards"* (Swiss Re, 2019, p. 20), thus proving the potential growth of the whole sector as well as the share of ILS within the overall industry capital.

b) What are Insurance Linked Securities?

Having established that ILS are here to stay and that their share of the total insurance industry capital will continue to grow on a long term basis, it is now necessary to understand what these financial tools are and how they are used.

Credit Suisse's Insurance Linked Strategies team (CSILS), defines ILS as an *"innovative niche asset class allowing investors to gain exposure to reinsurance catastrophe risks and earn returns largely uncorrelated to traditional and alternative asset classes"*. The Swiss bank adds that ILS's added values are a *"low correlation to traditional and alternative asset classes"* as well as an *"attractive return potential"* (Credit Suisse, n.d.). Going further into details, ILS instruments can be classified into different types: Industry Loss Warranties (ILWs), sidecars and catastrophe bonds (Cat bonds) (Michel-Kerjan & Morlaye, 2008, p. 157).

Industry Loss Warranties

As most of the just mentioned financial tools, an Industry Loss Warranty (ILW) aims at protecting the insurance industry from severe losses incurred by extreme events and comes in

the form of a contract in major part written by reinsurance companies or hedge funds (Michel-Kerjan & Morlaye, 2008, p. 157). Lane Financial L.L.C, a consulting firm focusing on the intersection of reinsurance and finance defines ILWs as *"a double trigger*[6] *instrument, one trigger of which is some level of indemnity loss that will be activated fairly easily, combined with a second trigger based on industry loss"*. In other words, if losses caused by a specific event in a covered territory are below a predefined trigger, the writer keeps the premium and collateral is returned. But, if the losses are above the trigger, the ILW buyer gets to keep the writer's collateral (Lane & Beckwith, 2018, p. 4). Kerjan and Morlaye add that ILWs *"are similar to excess of loss reinsurance but where the insurer now has some basis risk"* (2008, p. 157), and therefore do not come as a first choice to use as a hedge (Lane & Beckwith, 2018, p. 4). For the sake of clarification, the term "basis" in the investment environment refers to *"the difference between the current spot price (that is, the price of the asset for immediate delivery) and the future price (that is the purchase price stated in the futures contract)".* The expression "basis risk" refers to *"the risk of the basis narrowing or widening, causing gains or losses to investors"* (Sharpe, 1990, p. 60). Therefore, when citing basis risk, the insurance industry refers to *"the mismatch between losses to the reinsured portfolio and the recovery provided by the ILS instrument"* (Swiss Re, 2011, p. 8) or in other words, *"the difference between the expected recovery from a risk transfer mechanism and the actual recovery of the cedant"* (WiIlis Towers Watson Securities, 2017).

Reinsurance sidecars

The second set of financial instruments approached in this document is reinsurance sidecar. This tool, also referred to as a "sidecar" or a "reinsurance sidecar vehicle", is a financial structure created to allow investors to take on the risk and *"benefit from the return of specific books of insurance or reinsurance business"* (Artemis.bm, n.d.). In short, a sidecar is a "special purpose company" or "Special Purpose Vehicle" (SPV) providing reinsurance coverage exclusively to its sponsors by issuing securities to investors based on quota-share reinsurance. Quota-share reinsurance is defined as a pro rata reinsurance contract in which insurers and reinsurers share premiums and losses according to a fixed percentage (Kagan, 2019b) and differs from excess-of-loss reinsurance that is characteristic for ILWs and cat bonds (Michel-Kerjan & Morlaye, 2008, p. 163), which is triggered when an event exceeds a specific limit (Kagan, 2019a). Sidecars are known to be complex financial transactions

[6] For a more comprehensive explanation of the different triggers available please refer to the paragraph on catastrophe bonds in this sub-section.

requiring a large investment and are usually of a shorter duration if compared to catastrophe bonds (Michel-Kerjan & Morlaye, 2008, p. 163). As examples, Mt. Logan Re Ltd owned by Everest Re, and Concord Re Ltd held by AIG, are sidecars with USD 1,028 billion and USD 730 million of assets respectively (Artemis.bm, 2019b).

Catastrophe bonds

The most commonly used financial instruments in the insurance industry are catastrophe bonds or cat bonds (Artemis.bm, 2019a), defined as *"bonds whose coupon and principal payments depend on the non-occurrence of a predefined catastrophic event, the performance of an insurance portfolio or the value of an index of natural catastrophe risks"* (Swiss Re, 2011, p. 7). As shown in figure 5, a cat bond transaction commonly involves three parties: a sponsor, an SPV and investors, who are most commonly large institutional buyers. Similarly to ILWs and sidecars, cat bonds exchange structures are complex but can be simplified as follows. A company located within the Cayman Islands, Bermuda or Ireland shelters an SPV, protecting it from the potential bankruptcy of its sponsor. Investors purchase securities from the issuer creating a complex link between investors, issuers and the ceding company (Swiss Re, 2011, p. 7). Finally, cat bonds usually have a term ranging from one to four years and if no trigger occurs, the *"SPV returns the investment to the investor with the final coupon payment"*. However, *"if a covered natural catastrophe does occur, the SPV pays the ceding company according to the terms of the reinsurance contract"* (Swiss Re, 2011, p. 7).

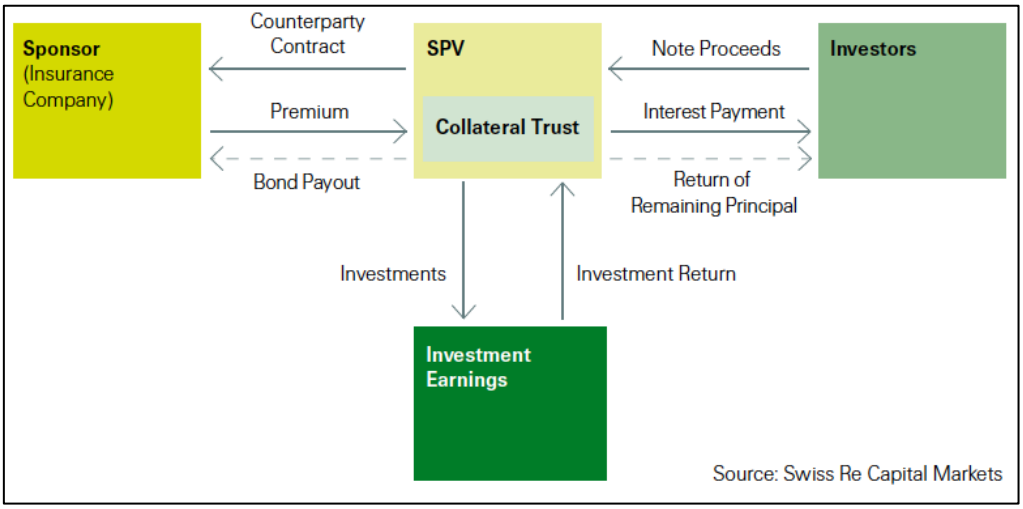

Figure 5: Catastrophe bond payment structure. Source: Swiss Re, 2011, p. 7.

Trigger mechanisms

Since ILW and Cat Bonds transactions are linked to a specific trigger that will determine whether a natural catastrophe qualifies for coverage, understanding trigger mechanisms is key to these financial instruments. As presented in Swiss Re's trigger comparison matrix (see figure 6), there are commonly five types of triggers offering different levels of basis risk to sponsors and transparency to investors (Swiss Re, 2011, p. 10): indemnity, pure parametric, parametric index, modeled loss and industry index.

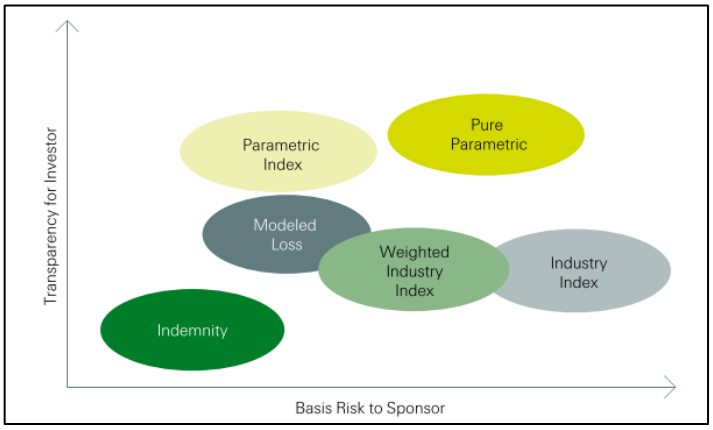

Figure 6: Illustrative trigger comparison matrix.
Source: Swiss Re, 2011, p. 10.

The first cat bonds issued in the 1990s where mostly based on indemnity triggers (Swiss Re, 2011, p. 10), which are a *"base recovery on the actual losses of the sponsor"* (WiIlis Towers Watson Securities, 2017, P. 7). In other words, cat bonds become active "*only if the ceding company incurs a predetermined level of losses"* (Swiss Re, 2011, p. 10). On the one hand, indemnity triggers are not subject to basis risk as they are directly linked to the company's losses, but on the other hand, they are widely exposed to the operational risks of the ceding company and rating agencies, and therefore *"tend to require additional stress testing, which may result in lower ratings"*, hence, creating an opportunity for additionally transparent trigger categories.

In the search for increased transparency towards investors, the "pure parametric" and "parametric index" triggers are considered to be on the forefront. Indeed, a sponsor's recovery in the case of a "pure parametric" trigger (also referred as "physical triggers") depends solely on the geographical location and strength of an event (Swiss Re, 2011, p. 12) and physical parameters taken into consideration are, for instance, wind speed, earthquake magnitude and death toll (WiIlis Towers Watson Securities, 2017, p. 7). One of the

disadvantages of this trigger is its significant basis risk for the ceding company as *"the geographical distribution of its book of business varies from that of the cat bond"* (Swiss Re, 2011, p. 13). To address this issue, parametric index triggers come as an alternative to pure parametric triggers, as the former contains lesser basis risk. Essentially, the parametric index trigger *"refines the pure parametric trigger by using a greater number of locations and applying different weights to each location to reflect the ceding company's exposure to events in the area"* (Swiss Re, 2011, p. 13).

In addition to theses physical based mechanisms, the (re)insurance industry also proposes triggers based on *"estimated insured industry losses"* (WiIlis Towers Watson Securities, 2017, p. 7). These mechanisms commonly known as "industry index" and "weighted industry index" triggers are based on industry indexes proposed by independent companies such as the Pan-European Risk Insurance Linked Services (PERILS) and PCS (Swiss Re, 2011, p. 10). Indeed, the PERILS which is based in Zurich, Switzerland, proposes an Industry Loss Index relying on a detailed industry loss database covering events ranging from bushfires to extra tropical cyclones in various geographical locations (PERILS.org, n.d.). One of the advantages of the weighted industry index is that it proposes a lessened basis risk option as it applies *"weighted calculation factors to various sub-regions of the covered area"* allowing the sponsor to obtain *"a coverage that more closely aligns with its own portfolio of risks"* (Swiss Re, 2011, p. 12).

And last but not least, "modeled loss" triggers are characterized by basing the transaction loss payout on a modeled estimation. To put it simply, physical parameters of a catastrophe are entered into a third-party model to project losses to a ceding company's portfolio (Swiss Re, 2011, p. 14).

It is interesting to note that the different types of triggers mentioned in this sub-section do not represent an equal share of ILS in 2018. In fact, Artemis, a leading web-based analyst on risk transfer intelligence, estimates that the outstanding cat bonds and ILS capital based on an indemnity trigger represent 65.7 per cent of the overall capital, followed by industry loss index triggers with a 17.9 per cent share and 5.1 per cent for parametric triggers (Artemis.bm, 2018).

To sum up, sub-chapter 1.1 has demonstrated that the traditional risk pooling and basic claim structure of the (re)insurance system does not suffice in the occasion of extreme events such as Hurricane Andrew in 1992. Therefore, the insurance industry has progressively turned to

securitization through financial markets, having recourse to instruments such as cat bonds and ILWs to increase their risk bearing capacities, but at the same time rendering the industry increasingly dependent on capital markets (see figure 7 for a comprehensive summary of the insurance industry value chain). This sub-chapter also demonstrated that by virtue of its economic weight the insurance industry possesses a strong leverage and could therefore be considered as a potential player when discussing ecological transition. It is in this context that the next sub-chapter will focus on the close relationship between the insurance industry and human induced-climate change.

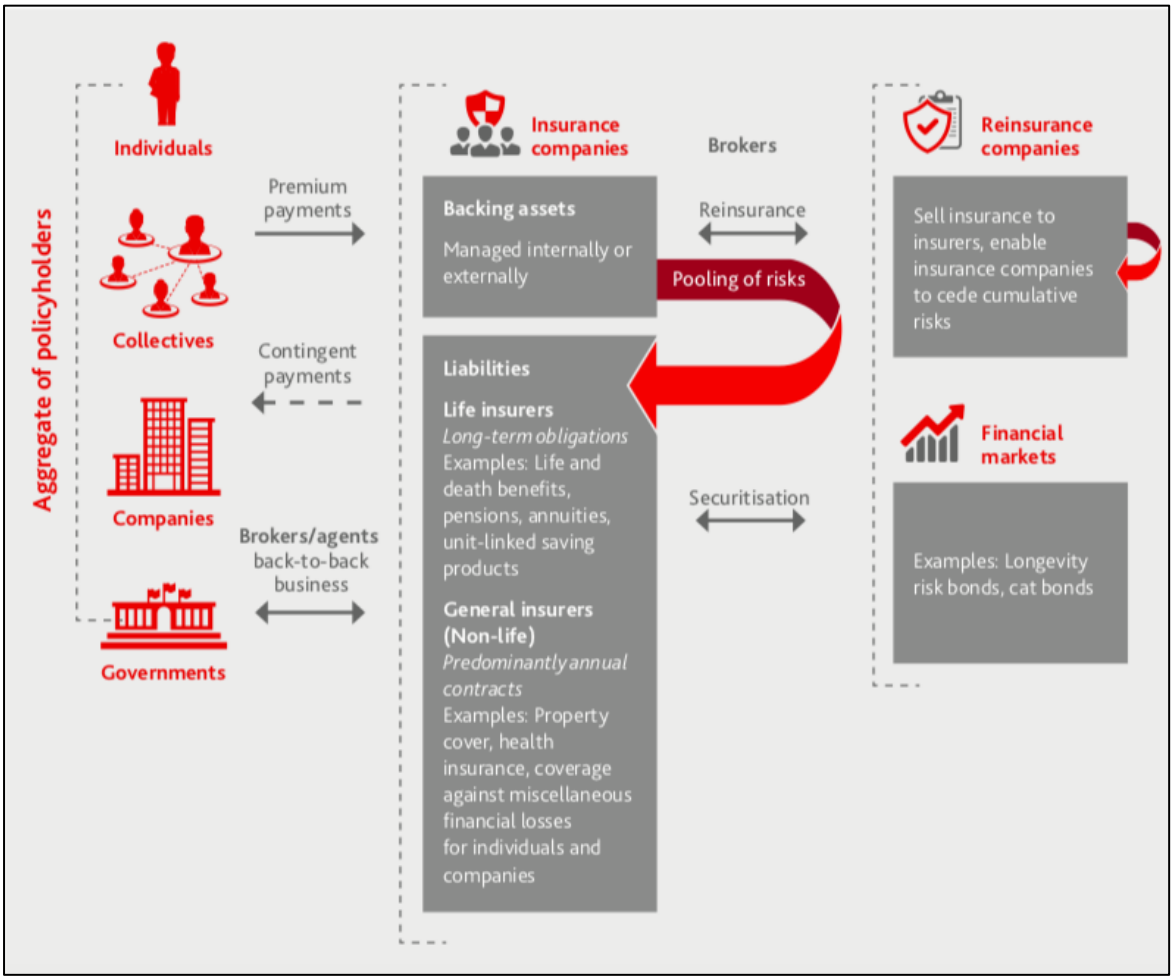

Figure 7: The Insurance Industry value chain.
Source: The Geneva Association, 2018, p. 39.

1.2. The intertwined relationship between the insurance industry and climate change

The following sub-chapter will lay out the current environmental setting in which the insurance industry operates and will explain the strong link that exists between the industry and climate change. Indeed, recent reports from international organizations, such as the IPCC (2012, 2014 & 2018), or institutions like the World Economic Forum (WEF, 2017, 2018, 2019), have been increasingly drawing attention to the potential effects of global warming on our socio-economic resilience. More precisely, the WEF Global Risks Report 2019, a joint report from the World Economic Forum and the Zurich Insurance Group, suggests that the top risks for the year 2019 are *"extreme weather events, failure of climate change mitigation and adaptation and natural disasters"* (World Economic Forum, 2019, p. 5), thus demonstrating the amplified consideration of environmental issues by various branches of the economic sector. It should be clarified that the words "climate change" and "global warming" are used in this paper to describe the same phenomenon, defined by the IPCC as *"a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer*" (IPCC, 2012a, p. 557). It is important to note that *"climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use*" (IPCC, 2012a, p. 557) and it is precisely this human-induced modification of climate that will be addressed here.

Accordingly, to delve into this topic, this sub-chapter will briefly expose the various types of extreme climate events and the relevant impacts of such climate change on the insurance industry (section 1.2.1) before examining the notion of climate risks and the question of their insurability (section 1.2.2).

1.2.1. Extreme events, secondary perils and relevant impacts of climate change

Even though this document does not aim at extensively reviewing the science of climate change, it is crucial to have an understanding of how it influences extreme events and their relevant impacts on the insurance industry. The term "relevant" refers to the most recurrent aspects of climate change impacting the insurance industry that came out during the research for this paper on the basis of different IPCC reports (2012, 2014, 2018).

Swiss Re defines a natural catastrophe as an "*event caused by natural forces*" resulting in a large number of individual losses involving insurance policies. The reinsurer also mentions that "*the scale of the catastrophe depends not only on the severity of the natural forces concerned but also on man-made factors, such as building design, or the efficiency of disaster control*" (Swiss Re, 2019, p. 27). Furthermore, "extreme (catastrophic) events", also known as "peak perils" carry a heavy risk of increased property damage and a linked rise in insurance claims (Maynard, 2008, p. 1). In fact, the 2012 IPCC special report of working groups I and II (also known as SREX), which focused precisely on the management of risks linked to extreme weather events, mentions potential future change in the distribution, frequency and intensity of those risks within the climate system (IPCC, 2012b). In this regard, data gathered by reinsurers and insurers during the past decades are key to understanding past trends in the occurrence of extreme events. For instance, when looking at data from the past forty years gathered by Munich Re, one can observe the upward tendency of weather catastrophes worldwide and a drastic increase of meteorological events (storms), hydrological events (floods, mass movements) and climatological events (extreme temperatures, drought, forest fires) (see figure 8). In 2018, Munich Re recorded 359 meteorological events, 382 hydrological events and 67 climatological events.

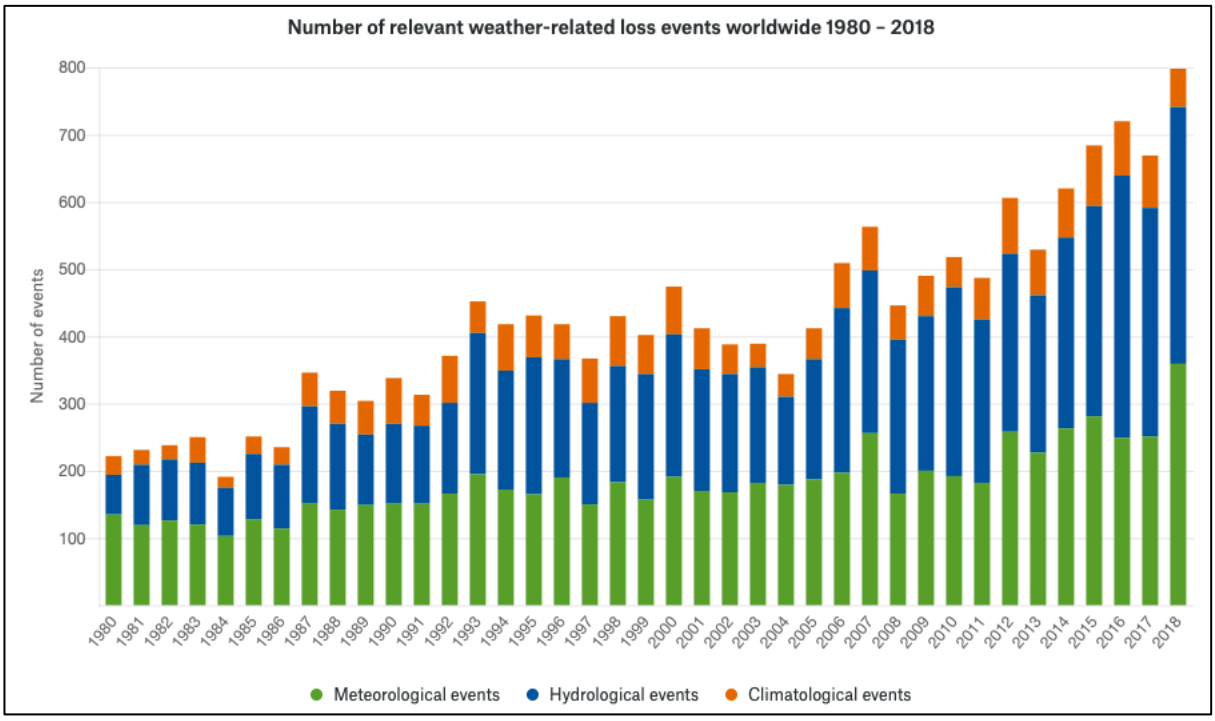

Figure 8: Weather catastrophes Worldwide 1980-2018, Number of relevant weather-related loss events.
Source: Munich Re, Geo risk research, NatCat SERVICE – as of April 2019.

Importantly however, it is not only the increasing number of weather events, but also their worldwide distribution that can be a cause of worry for the insurance industry. In fact, when looking at the global overview of weather events during the past decade (2008-2018) (see figure 9) it can be noted that weather events are taking place all over the world, hence increasing the possibility of hitting several areas of a (re)insurance company's portfolio at the same time. On the one hand, international diversification of the industry's business model is key to its resilience as the *"erosion of the ability to diversify risk internationally is unwelcome for the industry and costly for society and economies. For example, without risk diversification provided by re/insurers operating globally, the cost of providing necessary protection from natural catastrophes could become prohibitive"* (Swiss Re, 2018c, p. 38). On the other hand, a series of extreme weather events spread over several geographical locations within the same timeframe could become a heavy burden to the industry's operations and solvency (McHale, Leurig, & Logan, 2012. p. 5).

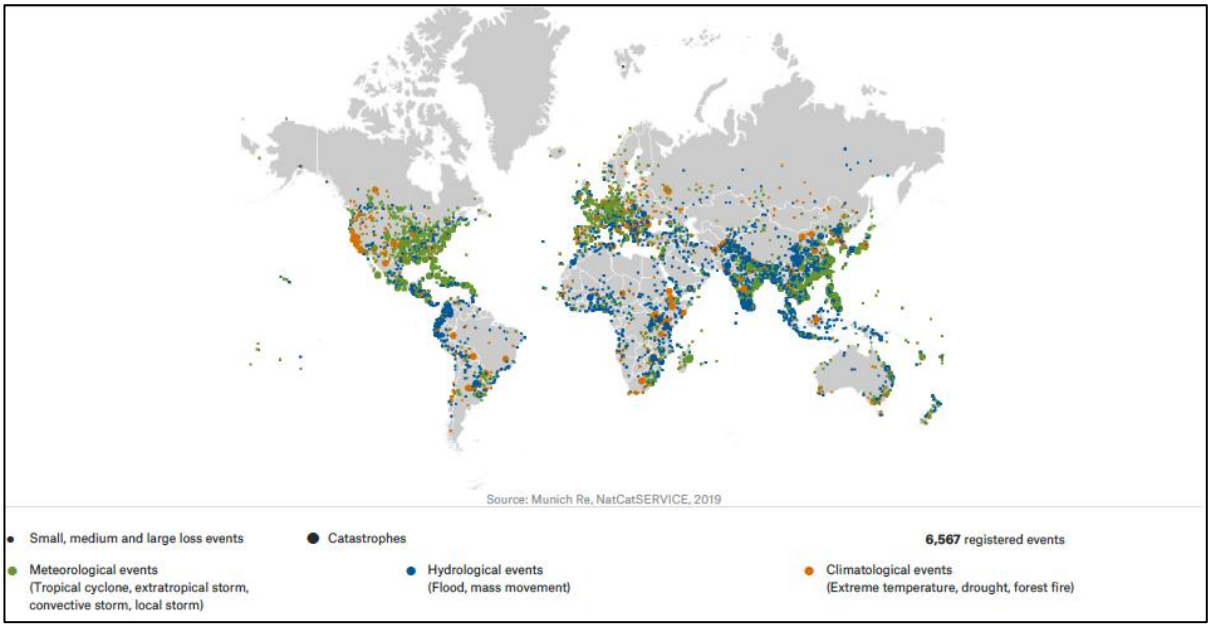

Figure 9: Geographical overview, relevant weather related loss events worldwide, 2008-2018.
Source: Münchener Rückversicherungs-Gesellschaft, Geo risk research, NatCat SERVICE – as of April 2019.

In addition to extreme events, Swiss Re clarifies in a recent report that *"the natural catastrophe theme of 2018 was the occurrence of many secondary peril events across the world". "*Secondary perils" are defined as "*independent small to mid-sized events*" that are "*often not modeled"* and receive little monitoring by the industry, for example precipitation and storm surges induced by hurricanes. Effects of such secondary perils should however be

taken into consideration as they may cause heavy casualties and costly material damages (Swiss Re, 2019, p. 7). According to Swiss Re, *"the world is getting warmer, leading to more occurrence of extreme weather conditions and associated secondary perils and secondary effect perils"* and this trend is expected to continue *"due to the ongoing urbanization, growth in concentration of assets in exposed areas, and the long-term climate change projections"* (Swiss Re, 2019, p. 1) .

Moreover, the 2018 IPCC Summary for Policymakers from working groups I, II and III, on the impacts of global warming of 1.5°C above pre-industrial levels (IPCC, 2018) does not bring a brighter picture. Indeed, it affirms with *"high confidence"* that *"impacts on natural and human systems from global warming have already been observed"* and that *"many land and ocean ecosystems and some of the services they provide have already changed due to global warming"* (IPCC, 2018, p. 7). The report also mentions that climate-related risks to health, livelihoods, food security, water supply, human security, and economic growth are projected to increase with global warming of 1.5°C and grow even further with 2°C (p. 11). Finally, the Reasons for Concern (RFCs) related to extreme weather events are deemed to be high, indicating severe and widespread impacts/risks (p. 13).

It is clear from the above that global warming is a strong driver of change and uncertainty. In this context, we will now take a closer look at the most relevant weather events impacting the insurance industry.[7]

Tropical cyclones, severe convective storms and floods

Meteorological events including tropical cyclones and severe convective storms are having an increasing impact on our society and on the insurance industry in particular. For instance, the previously mentioned IPCC (SREX) report of 2012 states that although the global frequency of tropical cyclones will remain unchanged, the average cyclone maximum speed is likely to increase (IPCC, 2012, p. 11). Indeed, Dominique Bourg, professor at Lausanne University (UNIL), suggests in his recent book that cyclones Haiyan in the Philippines (2013), Pam in Vanuatu (2015) and Irma in the Antilles (2017) have had gusts of wind reaching 340 km/h and even 379 km/h, a *"speed approaching the blow of a conventional bomb"* (our translation, Bourg, 2018). This growing destructive potential of cyclones is commonly regarded as a risk to infrastructure, thus strongly impacting P&C insurances.

[7] Please refer to sub-section 1.2.2.2 for overall and insured loss data resulting from these extreme events.

Since global warming also has a deep impact on our oceans, it leads to increasing evaporation from warmer ocean surfaces, growing water-holding capacity and a vertical extension of the warming troposphere, which translate into an increasing amount of precipitable water accumulated during tropical cyclones or local convective storms (Niehoerster, Aichinger, & Murnane, 2013). Stronger winds and precipitation may both increase coastal floods and storm surge risks, further impacting infrastructures and businesses in these geographical locations (p. 12). IPCC's latest report confirms this trend suggesting that with an increase in temperature of 2°C, compared to 1.5°C, tropical cyclones will be associated with higher precipitation (IPCC, 2018, p. 9). Finally, a report from the Geneva Association covering the connection between ocean warming and the insurance industry mentions an increased uncertainty due to the non-stationary behavior of cyclonic activity in both the Atlantic and the Pacific Oceans. This report further indicates that the rising level of oceans may cause additional losses to the insurance industry as the impact of storm surges related to cyclones may become greater. While there is no direct correlation between tsunamis and climate change, one should keep in mind the growing impact they may have in the context of increasing ocean levels (Niehoerster et al., 2013, p. 14).

Drought and wildfires

Climate change has a direct impact on precipitation, making it higher in some regions while decreasing it in others and leading to droughts. The IPCC 2012 report mentions with a *"medium confidence"* that droughts will intensify in the 21st century due to reduced precipitation and increased evapotranspiration (IPCC, 2012, p. 11) and the 2018 IPCC report concludes the same (IPCC, 2018, p. 9).

Furthermore, a recent analysis from Munich Re claims that climate change is a strong contributor to the rising wildfire risk in California (Munich Re, 2018, p. 42) and data covering the period from the 1980's indeed demonstrates an increase in large individual fires (see figure 10). The largest wildfires recorded in California since the 1930s have mostly occurred in the new millennium, in high correlation to years with *"exceptionally high temperatures and unusually dry conditions"* (Faust & Steuer, 2019). Interestingly, Swiss Re considers the biggest catastrophe insurance loss-event of 2018 to be Camp Fire in California with an estimated insured loss of USD 12 billion (Swiss Re, 2019, p. 1). However, the occurrence of wildfires is not geographically limited to California and recent studies confirm that an increase in the environmental conditions favoring wildfires can be seen in other parts

of the world such as the European Mediterranean and parts of Australia (Faust & Steuer, 2019).

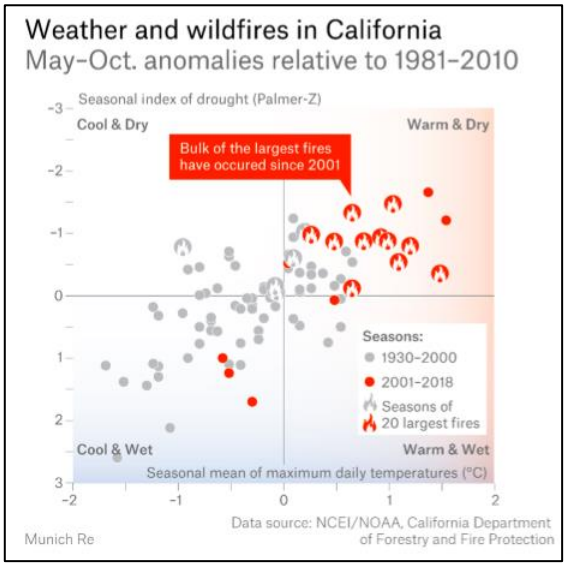

Figure 10: Weather and wildfires in California, anomalies relative to 1981-2010.
Source: Munich Re, Faust & Staeur, 2019.

Agriculture and late frosts

On the colder side, late frosts are also affected by climate change and for this reason are carefully monitored by the insurance industry. Indeed, in recent history, a violent series of spring frosts occurred between April and May 2017, touching twenty European countries and causing up to 80 per cent of fruit crop losses, hence deeply impacting the continent's agriculture production. In fact, it is estimated that the financial losses due to the event were of approximately € 3.3 billion of which only € 600 million were insured (Munich Re, 2018, p. 25). Munich Re also states that *"there are very clear indications that climate change is bringing forward both the start of the vegetation period and the date of the last spring frost"* (p. 29). A recent article published in *Nature* confirms this trend as the authors consider that *"while climate warming reduces the occurrence of frost events, the warming-induced lengthening of the growing season of plants in the northern hemisphere may actually induce more frequent frost days during the growing season"* (Liu et al., 2018).

These statements are equally confirmed by the Swiss long-term series of phenological observations on the horse chestnut tree in Geneva since 1908. In fact, Météo Suisse indicates that there is "*a clear trend towards earlier event dates since 1900. Global climate change, as well as structural modifications in the surrounding area and greater warming in the city, are all factors at play here"* (Météo Suisse, n.d.). Munich Re further explains that Europe is

composed of different climate zones, thus causing regional variations in the start of the vegetation period and the date of the last spring frost. As an example, spring frost in the Luxembourg region will diminish by 40 per cent between 2021 and 2050 when compared to the 1961 to 1990 period, hence reducing the risk of frost (Munich Re, 2018, p. 29). Germany, however, will see an increase in the number of spring frost days, therefore increasing the risk of losses related thereto (Chmielewski, Blümel, & Henniges, 2010).

While it is true that the exact future impact of climate change on spring frost remains an area of uncertainty and further studies are needed to provide clarification on the subject, spring frosts remain a potential threat to the insurance industry due to their (insured) economic impact on agriculture (Munich Re, 2018, p. 26).

Human Health

In addition to the direct physical impact of weather events on the insurance industry, this economic sector is also touched by the effects of climate change on human health. Indeed, there is near unanimous consensus that anthropogenic greenhouse gas emissions will change Earth's climate which will in turn affect human health (McMichael, Woodruff, & Hales, 2006). As early as 2005, an article published in the scientific journal *Nature* mentioned that the WHO estimated that modifications in climate patterns for the past three decades have caused over 150,000 deaths annually (Patz, Campbell-Lendrum, Holloway, & Foley, 2005, p. 1). A more recent article claims that climate change is *"expected to cause approximately 250,000 additional deaths per year, from malnutrition, malaria, diarrhea and heat stress"* (WHO, 2018). It is said that *"many prevalent diseases are linked to climate fluctuations, from cardiovascular mortality and respiratory illness due to heat waves, to altered transmission of infectious diseases and malnutrition from crop failure"* (Patz, Campbell-Lendrum, Holloway, & Foley, 2005, p. 1). Finally, the WHO estimates the future cost of climate change on human health to be between USD 2 and 4 billion per year by 2030 (WHO, 2018), demonstrating the strong and concrete impact climate change could have on L&H branches of the insurance sector.

Directors & Officers Liability

One of the recent trends in the insurance industry linked to the impacts of climate change is the significant increase in the activity of liability insurers. Indeed, the potential liability of corporate directors and officers (D&O) for their actions, or lack of action, regarding global warming risks began to appear in the early 2000's and has been reflected within insurance

policies since then (Mills, 2009a). According to Dr. Evan Mills (2009), a former staff scientist at the U.S. Department of Energy's Lawrence Berkeley National Laboratory, most large (re)insurers, including Zurich, Liberty Mutual, and Munich Re, have launched products targeted at covering boards of directors in the event of climate change litigation. More precisely, a director's and officer's liability, also known as D&O coverage, is an insurance policy that offers liability cover for company managers to protect them from claims which may arise from the decisions and actions taken within the scope of their regular duties. As such, *"D&O insurance has become a regular part of companies' risk management"* (Allianz, n.d.) and Trevor Maynard (2008) confirms that the potential for third-party liability claims from climate change has a big chance to impact the insurance industry. Indeed, "*the huge economic and social impact of climate change will inevitably lead to accusations, claims and lawsuits over attribution of causation, which will impact on liability classes."* (Maynard, 2008, p. 141). In fact, it can easily be imagined that D&Os could be sued when demonstrated that their actions have not properly anticipated their company's contribution or exposure to climate change (p. 141).

1.2.2. Climate risks: definition and insurability

Following the presentation of numerous extreme weather events and the impact of climate change on the insurance industry, it is imperative to analyze a key element of the sector's vocabulary in regards to climate change: *climate risks*. Indeed, the notion of climate risk and its potential un-insurability has recently grown to become a major concern within the insurance industry and a cause for extensive debates. As a matter of fact, the United Nations Office for Disaster Risk Reduction (UNDRR, formerly know as UNISDR) indicates that by 2025, due to an increased magnitude of extreme weather events, climate risks might become "*too high for the pool of premium available*" (Warner et al., 2009, p. 12). But what makes an extreme weather event become a "climate risk"? And why are they difficult to insure? The next sub-sections will provide the insurance definition of a climate risk (1.2.2.1), study the question of their insurability and discuss the protection gap linked to these issues (1.2.2.2).

1.2.2.1. What are climate risks?

Climate risks are most commonly understood as risks induced by climate change, including *"health issues due to new diseases (or resurgence of diseases that were supposed to have disappeared) or the impact of climate on economics (agriculture or energy)"*

(Charpentier, 2008, p. 91). Understanding how natural disasters are evaluated and categorized as such by the insurance industry is key to this document. According to Wolfgang Krone, a Munich Re expert on risk communication, the definition of "a risk" is very precise in the context of natural disasters and "*the scientific community agrees that risk is the product of the probability of a hazard and its adverse consequences*" (Munich Re, 2015, p. 20). Furthermore, it is understood that "*where there are no people or values that can be affected by a natural phenomenon there is no risk. Similarly, an event is only termed a disaster if people are harmed and/or their possessions damaged*" (p. 20). Therefore, the overall risk linked to a natural phenomenon is said to be composed of three variables as highlighted in the box below:

$$R = H \times E \times V \ (\times I)$$

The risk calculation formula is composed of Hazard (H), representing the full range of intensities of natural phenomena including their probabilities of occurrence. The second factor is Exposure (E) being the total value exposed or at risk. The third value is vulnerability (V) being the lack of resistance to damaging forces, or the ratio of exposure that can potentially be damaged. Finally, if looking at the insured risk, a fourth factor, the Insurance penetration (I) representing the insured proportion of the value at risk, will be added (Munich Re, 2015, pp. 22-23). Interestingly, one of the outcomes of this risk formula is that some of the factors such as exposure, vulnerability or insurance penetration, can be influenced by societal changes in order to construct a population that is more resilient to natural phenomena.

1.2.2.2. Are climate risks insurable?

Having covered the insurance industry's definition of climate risk, one must further examine the essential question of whether these risks are insurable.

a) Insurability criteria

The first interrogation that comes to mind when discussing the insurability of climate risk is to know what makes something insurable. According to Arthur Charpentier (2008), there is a specific list of criteria that must be followed to make sure that a risk can be insured. The author suggests that the first aspect of a risk to look into would be its "legal insurability"

described as: *"judicially, an insurance contract can be valid only if the claim occurrence satisfies some randomness property"*(p. 95). The second concept presented by Charpentier is the "actuarial insurability" of a risk, defined by the fact that the "*maximum possible loss should not be huge with respect to insurer's solvency*", "*the average cost should be identifiable and quantifiable*" and "*risks should be pooled so that the law of large numbers can be used*" (p. 95). And last but not least, a risk should respect "economic insurability", meaning that "*there should be no moral hazard, and no adverse selection*" and *"there must exist an insurance market, that is, the supply and the offer should meet, and an equilibrium price should arise"* (Charpentier, 2008, p. 95). For the sake of clarification, "adverse selection" refers to a situation in which buyers possess more information than insurances (or vice versa), hence creating a situation of asymmetric information resulting in a lack of efficiency when fixing the price of premiums (Nickolas, 2019). A "moral hazard" situation is one where a party has "*not entered into the contract in good faith or has provided false details about its assets, liabilities, or credit capacity*" (Nickolas, 2019).

Similarly to Charpentier's work (2008), an article written by Trevor Maynard, Manager of Emerging Risks at Lloyd's of London, also describes the concept of risk insurability. Indeed, the author believes that an insurable risk should be: (i) *quantifiable*, indicating that a risk should be well understood and largely constant over the period of insurance. (ii) *Diversifiable*, implicating that one type of risk can be offset against another. (iii) *Fortuitous*, indicating that it may or may not happen and (iv) *economically priced* and therefore affordable to the policy holder (Maynard, 2008, p. 141).

b) Increasing "overall and insured" losses

In respect of the insurability criteria, one of the key elements is to ensure that the maximum possible loss must not exceed an insurance's solvency. It is therefore of an evident interest to briefly examine recent data related to "*overall and insured loss*" in the insurance industry. For the sake of clarity, the present paper will use Swiss Re's definitions of "total economic losses" and "insured losses". The first notion, "total economic losses" also called "total damages" is defined as the "*financial losses directly attributable to a major event"* including "*losses due to a business interruption as a direct consequence of the property damage"*. It comprises all insured and uninsured losses and Swiss Re warns that the numbers should be taken as indications only, since losses are estimated and communicated differently

from one entity to another. The second notion of "insured losses" is defined as *"all insured losses except liability"* and *"life insurance losses"* (Swiss Re, 2019, p. 27).

When looking at the global warming issue, the recent significant upward trend in "insured losses" caused by extreme events has been alarming. Indeed, data gathered by the NatCat service of Munich Re, clearly shows the ever-climbing statistics related to weather catastrophes (see figure 11).

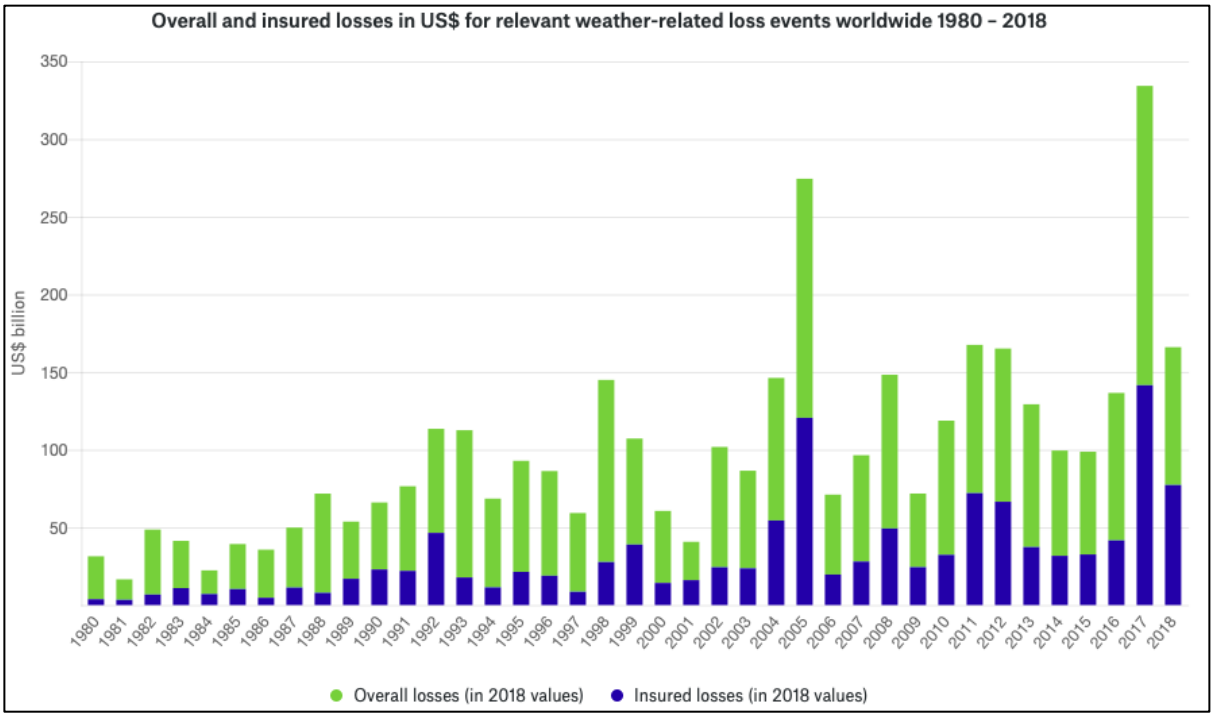

Figure 11: Weather catastrophes Worldwide 1980-2018, Overall and insured losses in USD.
Source: Munich Re, Geo risk research, NatCatSERVICE – as of April 2019.

In fact, the reinsurer observes that 2018 was the fourth costliest year for the insurance industry since the 1980s with an approximate overall economic impact of USD 160 billion of which 80 billion were insured (Munich Re, 2019). It is also noteworthy to compare these numbers with the inflation-adjusted overall loss average of the past 30 years, which equals to USD 140 billion, and the insured loss of 41 billion, clearly demonstrating the difference of impact recent years have had on the insurance industry (Munich Re, 2019). Similar data published by the Swiss Re Institute in 2019 confirms the trend of increasing losses due to natural catastrophes, as the reinsurer estimates a total economic loss of USD 155 billion of which 85 billion where covered by insurances during the year 2018 (Swiss Re, 2019, p. 1).

It is also interesting to take a step back and look at the year 2017, which witnessed a very strong hurricane season including a cluster of category 4+ hurricanes composed of Harvey, Irma and Maria (HIM) that hit the Northern Atlantic and caused damages of about USD 92 billion (Swiss Re, 2018b, p. 1). In addition to the tropical storms, the year 2017 "*will pass as the costliest year for wildfire losses ever, globally*" (Swiss Re, 2018b. p. 7). Certainly, the Tubbs fire in the Sonoma and Napa counties (California) led to USD 7.7 billion in insured losses making it the costliest wildfire recorded by Swiss Re (2018b. p. 7). Altogether, the record breaking total economic losses were estimated to be around USD 337 billion making an all-peril global catastrophe protection gap of USD 193 billion and "*more than 11,000 people lost their lives or went missing in disasters, while millions were left homeless*" (Swiss Re, 2018b, p. 1). Furthermore, the latest Swiss Re *Sigma* report mentions that "*the combined insured losses for 2017 and 2018 resulting from natural catastrophes were USD 219 billion, the highest ever for a two- year period*" and that "*the global all-catastrophe protection gap of the past two years combined was also impressively large at USD 280 billion*" (Swiss Re, 2019, p. 21).

The statistics mentioned above, combined with the fact that the insurance industry is present in most of our business and private activities through L&H, P&C and D&O insurances generates an interrogation as to its long-term sustainability and resilience to continuous shocks caused by climate change. As previously stated in the introduction to this paper "*every sector of the economy telegraphs climate risks to its insurers*" making this sector a key actor with regards to economic resilience and it is therefore crucial that climate risks remain insurable (Mills, 2012).

c) A growing difficulty to insure

The combination of the above statistics and the non-stationary environment linked to climate change, as revealed by IPCC reports, raises the question of a potential insolvency of the insurance industry. In this regard, Maynard concludes that climate change can affect all of the insurability criteria (quantifiable, diversifiable, fortuitous and economically priced[8]), and *"our understanding of risk is reduced when conditions are changing; many regions around the world are affected at the same time, reducing the amount of diversification; climate change will happen, and in some regions extreme events may become annual occurrences;*

[8] See sub-section 1.2.2.2 (a).

the level of losses may increase to such an extent that insurance premiums become higher than policyholders are prepared to pay"(Maynard, 2008, p. 142).

Charpentier also fully covers the different features of catastrophic events and climate change responsible for the brittleness of the insurability of climate risks (2008, p. 96). The first point raised by the author is the question of the *actuarial insurability* (as explained within the sub-section 1.2.2.2) and in particular the problem of large and non-diversifiable risks. Indeed, the economic impact of natural catastrophes can be extremely large, putting a huge weight on the insurance industry and therefore "*jeopardizing the solvency of insurance and reinsurance markets*" (Charpentier, 2008, p,96).[9] On the same subject, Insurance Europe, the European insurance and reinsurance federation based in Brussels, mentions that it is difficult to provide coverage for natural hazards due to the size of the risk and the limited pool of policy holders (Insurance Europe, n.d.). Furthermore, the profound impact of a natural catastrophe within a specific geographical location may induce a strong correlation among the losses of insurance and reinsurance portfolios (Charpentier, 2008, p. 97). In such cases, *"thousands of policies are hit, for several lines of business: property, car insurance, life insurance for casualties, business interruption, etc."* (p. 97) widely complicating the risk diversification[10] of an insurance portfolio. Undeniably, the required non-correlation criteria, implying that items in a portfolio should respond differently, or in opposing ways to their environment, becomes at risk if global Earth system modifications and natural catastrophes hit several insurance business lines at the same time and in the same geographical location (Charpentier, 2008, p. 97). Finally, natural catastrophes and global warming also come as a challenge to *economic insurability*. Indeed, adverse selection can be seen as a complication because severe weather events can be covered only when pooling a large number of insured. On this point, Charpentier adds that the insurance industry should factor in that "*risks are hardly homogeneous*" and that, for example, non-coastal regions are less risky (Charpentier, 2008, p. 97). Lastly, the fact that *"many individuals perceive the probability of a disaster as a very low-probability event, and therefore find it unnecessary to invest in protective measures*" further increases the difficulty to find an equilibrium and fair price accepted by both the insured and the insurer (Charpentier, 2008, p. 99).

[9] See also the "overall and insured loss" statistics presented by Swiss Re (2018b) and Munich Re (2019) in sub-section 1.2.2.2.

[10] Diversification is a risk management strategy aimed at mixing a variety of investments within a (re)insurance portfolio in order to *"smooth out unsystematic risk events, so the positive performance of some investments neutralizes the negative performance of others"* (Investopedia, 2019) and there is no doubt that it is being challenged by natural catastrophes and climate change.

The preceding lines have exposed the difficulties in adequately insuring natural catastrophes as they strongly challenge the different insurability criteria. In addition, the deep uncertainty inherent to climate change represents a serious threat to the insurance industry as it challenges the understanding and modeling of the frequency and strength of extreme weather events. Indeed, the *Catastrophe modeling and climate change* report from Lloyd's of London (2014) states that it is of the utmost importance for insurers to understand what the future trends will be and that "*many of the effects will become apparent over the coming decades and anticipating them will require forward projections, not solely historical data*" (p. 4). Charpentier also reflects this observation in his work when he quotes Warren Buffet saying that *"catastrophe insurers can't simply extrapolate from the past"*(2008, p. 101). In the same line, Niheoerster concludes that the non-stationary environment linked to global warming makes it impossible to use historical data-driven or climatological approaches to estimate the risk of severe events as they do not adequately incorporate climate change uncertainty (2013, p. 5). To sum up, one can observe that the difficulty in insuring climate risks is becoming more and more challenging and is further reinforced by a phenomenon well known to insurers: the protection gap.

d) The protection gap

In recent years, the insurance industry has published an extensive amount of reports aimed at addressing both the "classic insurance protection gap" and the "natural catastrophe protection gap". The Geneva Association, an insurance industry think tank, defines the "classic insurance protection gap" or "underinsurance" as *"the difference between the amount of insurance coverage that is economically beneficial and what is actually purchased"* (Schanz, 2018, p. 6). It is significant to emphasize that, in the case of property catastrophe insurance, the definition is slightly different as it refers to "*the share of uninsured losses to total economic losses*" (p. 9). The "classic insurance protection gap" phenomena *"leads to a severe lack of societal resilience in many developing and emerging countries, where insurance today plays hardly any role in mitigating the impacts of, for example, natural disasters"* (Genevaassociation.com, n.d.). In an extensive 2018 report on the insurance protection gap, the Geneva Association mentions that the size of the gap differs depending on the line of business and the general maturity of the insurance market (Schanz, 2018, p. 6). Another interesting fact mentioned is that *"historically, uninsured natural disaster losses were at the root of the protection gap discussion and they are still among those that make the*

headlines most frequently and spur the most intense debates" (p. 6). As for the "natural catastrophe protection gap", the data gathered by Munich Re revealed in figure 12 reflects a slight reduction over the past thirty years (2019), passing "*from 78 per cent to 70 per cent, and from 0.3 per cent to 0.2 per cent of the world's GDP*" (Schanz, 2018, p. 6). Nevertheless, this positive trend does not cancel-out the massive protection gap remaining due to the fact that only 30 per cent of catastrophe losses were insured in 2017 (p. 6). Also, there is a large disparity within high, upper middle, lower middle and low-income countries with regards to the natural catastrophe protection gap. Indeed, while the natural catastrophe protection gap considerably decreased in countries considered as high income group, lower income countries saw no progress in this respect, with a protection gap as high as 95 per cent (see figure 12) (Schanz, 2018, p. 10).

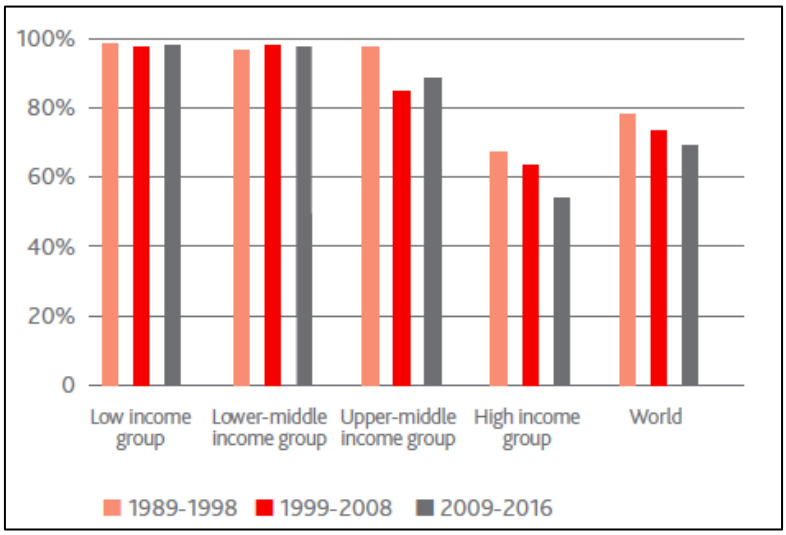

Figure 12: The natural catastrophe protection gap for different country income groups, 10 year moving average, 1989-2016.
Source: Schanz, 2018, p.10.

Due to its large impact on societal resilience and on the whole insurance structure, the issue of the natural catastrophe protection gap comes as a huge challenge to the insurance industry. Since climate change will impact future trends in the occurrence of extreme weather events (IPCC, 2012), it is crucial that emerging countries work towards narrowing this gap so that it can play its role in mitigating the impacts of natural disasters or pandemics brought by global warming (Genevaassociation.com, n.d.).

To conclude this sub-chapter, one can see that climate change is expected to have a deep impact on multiple business lines of the insurance industry such as P&C, health and D&O liability. Indeed, the potential increased frequency and strength of certain weather events (IPCC, 2012, 2014, 2018) will impact insurability, hence affecting (re)insurance premiums

due to greater incurred losses and risks (Charpentier, 2008). This growing struggle concerning the insurability of climate risks, coupled with the protection gap phenomena could substantially modify the future of the insurance industry and therefore requires a concrete reaction from the sector itself.

1.3. The insurance industry's reaction to climate change

Throughout its history, the insurance industry has been a major force in reducing societal risks. Indeed, when looking at examples of previous crisis, such as cigarettes and car safety, the insurance industry has always brought solutions so as to promote future insurability and build a resilient society (McHale et al., 2012, p. 6). Considering that climate change carries the possibility of disrupting the entire insurance industry's business model, hence challenging the sector's fundamental resilience, insurers and reinsurers are forced to take appropriate actions. How resilient and ready is the insurance industry in the case of a catastrophic scenario? In order to tackle this fundamental question this sub-chapter will provide an overview of such actions which will allow the reader to understand what activities are currently being undertaken by the industry to increase its resilience and whether they are sufficient to achieve this purpose.

1.3.1. Mitigation and adaptation measures

According to Dlugolecki, a former chief author of IPCC's Financial Services 1995 Assessment Report, *"climate change affects insurers in two ways, through the impacts of changing weather patterns and environmental conditions on its clients and its own operations, and through the regulations and other actions aimed at curbing the emissions of GHG. Strategies to deal with the first are referred to as adaptation, and those concerned with emission reduction are called mitigation"* (Dlugolecki, 2008, p. 72). The terms of mitigation and adaptation are indeed often brought forward when discussing the economic sector's action (and reactions) to climate change. The IPCC's 2014 report (AR5) explains that *"many adaptation and mitigation options can help address climate change, but no single option is sufficient by itself"* and adds that *"adaptation and mitigation are constrained by the inertia of global and regional trends in economic development, GHG emissions, resource consumption, infrastructure and settlement patterns, institutional behavior and technology"* (IPCC, 2014, p. 94). The UNEP FI's Climate Change Working Group (CCWG) also confirms that the insurance industry should be working on both adaptation and mitigation measures, clarifying,

on the one hand, that adaptation is a very important issue for the insurance industry as *"the pace of change in extreme events is already fast and the scale of losses could reach USD 1 trillion in a single year by 2040"* and highlighting, on the other hand, the significant status of mitigation action with regard to the industry's long term resilience (UNEP FI, 2007, p. 19).

1.3.2. Examples of concrete actions

The following section will offer examples of existing mitigation and adaptation measures based on research from the Geneva Association, Ceres, UNEP FI, Climate Wise and sustainability reports from major players within the industry. Reference will be made to the classification and nomenclature proposed by Mills (2009b) as it serves as a comprehensive and well-designed basis. As we further detail the industry's responses to climate change, it is important to keep in mind that these represent *"best in class"* reinsurer and insurer actions and do not reflect a universal stance, since *"there are thousands of insurers, many of which have no activities"* with regard to climate (Mills, 2009b, p. 1).

Improving data collection and contributing to research on climate change

As previously mentioned and confirmed by Mills, *"the insurance industry has a history of helping society understand and adapt to emerging risks"* (Mills, 2009b, p. 16) and a failure of climate change mitigation and adaptation can be perceived as a growing threat to societal resilience (WEF, 2019. p. 5). Therefore, having a more comprehensive grasp of what climate change actually encompasses becomes a key element for the insurance industry. In this regard, some insurers and reinsurers are using their expertise in data collection, catastrophe modeling and risk analysis as a form of involvement in the research towards understanding the details of climate change (Mills, 2009a. p. 338). A perfect example of this increased engagement is the contribution of Munich Re and Tokio Marine Holdings as authors within the IPCC (Mills, 2009b, p. 16). There are also numerous examples of insurers and reinsurers funding research in top shelf universities such as Zurich Insurance's and Swiss Re's strategic partnership with the ETH Zürich Risk Center (ETH Zurich, n.d.).

A further concern to the insurance industry when looking at the uncertainty of climate change is its strong dependency on catastrophe modeling (CAT Modeling). Indeed, the 2014 Lloyd's *"Catastrophe modeling and climate change"* report exposes the intensive use of CAT modeling technology by the insurance industry "*to perform activities such as risk selection and underwriting, reserving and ratemaking, development of mitigation strategies, design of*

risk transfer mechanisms, exposure and aggregate management, portfolio optimization, pricing, reinsurance decision-making and capital setting" (p. 4). In addition, AIR, a CAT modeling firm mentions that *"models are the basis for understanding and quantifying risk"* and *"applications today go far beyond those within the insurance industry"* (AIR, n.d.-a). Unfortunately, a major issue encountered by CAT modeling systems is the fact that they were developed using probabilistic data based on historical events and therefore have difficulties incorporating the uncertainty of present and future climate change (Mills, 2009b, p. 17). As an answer to this deficiency, CAT modeling firms, such as AIR, have worked with scientists to better integrate the risks induced by global warming into their models (AIR, n.d.-b). Nowadays, by virtue of ongoing research and adaptation, catastrophe risk modeling systems offer a more realistic overview of climate change and its related risks to the insurance industry and actively contribute to public policy discussions, thus broadening business opportunities (Mills, 2009b, p. 18).

Promoting loss prevention

The second group of measures taken by the insurance industry to address the risks caused by climate change is related to loss prevention. Indeed, working on the reduction of losses caused by catastrophic events falls within the core of the insurance industry's activities. As Mills further suggests, *"managing risks and controlling losses is central to the insurance business and is evident in the industry's history as founders of fire departments and advocates for building codes"* (Mills, 2009a, p. 338). Unfortunately, it seems that the insurance industry has mostly turned to a reactionary approach and *"the scale and breadth of insurers' efforts in all of these areas remain extremely modest in the context of their overall business operations"* (Mills, 2009a, p. 339). Nevertheless, some insurance industry activities in climate change loss prevention have been witnessed in different sectors, including land-use planning, energy management, forestry and agricultural management, post-catastrophe "rebuilding" strategies and green technologies research (Mills, 2009b, p. 18-24).

Aligning terms and conditions with risk-reducing behavior

In recent years, insurances have seen a correlation between green customers and low profile risks. Indeed, *"a growing number of insurers perceive a "halo effect" in which adopters of climate-change mitigation technologies are viewed as low risk customers"* (Mills, 2009b, p. 27). Recognizing this specific correlation should enable the insurance industry to adapt premiums to a specific green customer segment as it already does for *"good*

drivers" with the *"pay-as-you drive"* model. In short, this model refers to the correlation between accident risks and the distance driven and proposes premium discounts for good drivers (Mills, 2009a, p. 339).

Other examples of such alignments for climate change mitigation purpose could be observed within the D&O liability line of business as directors executing riskier management strategies could see their premiums increase exponentially (Mills, 2009b, p. 27).

Crafting innovative insurance products and services

There are a number of innovative insurance products at the disposal of the insurance industry to increase its resilience. For instance, the much needed energetic transition aimed at decarbonizing the generation of electricity (IPCC, 2014, p. 20) provides many business opportunities to the insurance industry (Mills, 2009b, p. 29), which has thus developed new products, including energy savings insurance, renewable-energy project insurance and green building/equipment insurance (Mills, 2009b, pp. 29-33).

Furthermore, a variety of insurance products meant at narrowing the insurance gap have been developed during the past decade, such as microinsurance. Also known as impact insurance, this form of insurance is considered as a division of microfinance that has allowed a beneficial growth in insurance penetration (Micro Insurance Network, 2017). The International Labor Organisation's (ILO) Impact Insurance Facility defines microinsurance as *"insurance specially designed for low-income people, with premiums and benefits to match their needs. It is particularly important for those in the informal economy who tend to be underserved by mainstream commercial and social insurance schemes"* (Impact Insurance Facility, n.d.-b). In other words, microinsurance consists of providing customized insurance products to modest families and businesses, particularly in developing countries where traditional insurances are inexistent or inefficient (Kagan, 2018). The UNEP FI however mentions that microinsurance should not be seen as an answer to *"environmental risk, but for social and economic vulnerability"* (UNEP FI, 2007, p. 21). In recent years, microinsurance products and services offered by commercial insurers have grown consequentially. Indeed, the ILO explains that in 2011, 33 of the world's 50 largest insurance companies proposed microinsurance products, demonstrating a notable increase from the 7 companies that were on a similar list in 2005 (Impact Insurance Facility, n.d.-a).

Offering carbon trading risk management

During the past decades, the reduction of GHG and especially carbon dioxide has become an increasingly important matter on the international level. One of the answers to this issue proposed by mainstream economists is carbon trading through global carbon markets. In simple words, carbon trading installs a scenario where *"companies buy and sell the right to pollute from each other"* in order to reach a specific emission-reduction target (Hartmann, 2017). Indeed, examples such as the European Union Emissions trading system (EU ETS) have grown throughout the world, bringing with them a certain amount of risks (Carchman, 2018). In reply, the insurance industry saw this growing market as a business opportunity and developed a considerable amount of *"mechanisms for participants to better manage carbon risks"* (Mills, 2009a, p. 342). An example of such insurance mechanism is the Tokio Marine Kiln's underwriting of the first product to cover carbon eligibility risk linked to carbon credits or Certified Emission Reduction (CERs) developed under the Kyoto Protocol of 1992 (TokioMarine Kiln, 2011).

Direct Environmental, Social and Governance (ESG) investments

As previously mentioned in section 1.1.2, the insurance industry is considered to be a significant actor in financial markets with over USD 30 trillion in invested capital (Climate Wise, 2016, p. 1). Certainly, this economic impact allows the industry to be a potential influencer in terms of ESG investments, as well as a facilitator of the transition towards a low carbon and climate resilient economy (Mills, 2009b, p. 43). In this regard, one can take a closer look at the Allianz Group 2014 Sustainability Report which provides a concrete example of the Group's investment of € 2 billion in renewable energy projects, as well as € 117.4 billion in Sustainable and Responsible Investments. Compared to the Group's €600 billion total assets, its ESG investment could be further multiplied and the growth potential in this regard remains important (Allianz Group, 2014, pp. 3-75). Looking at a broader scale, a recent insurance industry report from BlackRock states: *"our 2018 survey findings point to the growing relevance of ESG investing across the insurance sector. Globally a strong majority (83 per cent) of insurers indicate that an ESG investment policy is important to their firm, with a majority (80 per cent) already having one in place or planning to adopt one within the next year",* thus demonstrating the growing interest of insurers toward ESG investments (2018, p. 9).

Building awareness and participating in the formulation of public policy

As mentioned by Mills, *"insurers regularly engage in proactive public policy discussions, whether concerning terrorism, public health or natural hazard"* and "*it is in the business interest of insurers to support public policies that reduce and make risks more predictable"* (2009b, p. 47). The Climate Wise initiative, an insurance industry "lobby" regrouping over 30 insurers and reinsurers with the *"shared commitment to reduce the impact of climate change on both society and the insurance industry"* is a concrete example of the insurance industry's global engagement in public policies (Climate Wise, 2016). Similarly, the previously mentioned UNEP FI offers a good audience for the insurance industry and constitutes a communication platform, allowing direct contact with policy makers (Mills, 2009a, p. 344).

Leading by example

Even though the insurance industry is not considered to be a huge polluter when compared to other sectors, such as "Oil & Gas" or the automotive industry, Mills estimates that in 2009, the insurance industry emitted 12 million metric tons of carbon dioxide equivalent to "*2.5 million U.S. cars*" (2009a, p. 344). As for Allianz Group only, its total GHG emissions where of 322,529 metric tons in 2014, demonstrating that there is much room for improvement (2014, p. 3). In this regard, *"insurers are increasingly recognizing the importance of addressing their own carbon footprints"* (Mills, 2009a, p. 344) and are developing several tools and programs to turn their companies into examples to be followed. These tools include Corporate Social Responsibility (CSR) reporting, such as Swiss Re's 2017 CSR Report, which comprises items like responsible investments strategies and environmental footprint reduction programs, for example the CO_{you2} meant at encouraging the firm's employees to reduce their own environmental impact (Swiss Re, 2017, p. 58). Additional actions taken by insurers and reinsurers regarding their own operations focus on improving their in-house energy and carbon management. Indeed, "*insurers generate greenhouse gas emissions through the energy consumed in buildings they occupy or lease, business travel, IT processes, and materials they consume at various points throughout their supply chain"* and it comes as a challenge to reduce these emissions (Mills, 2009b, p. 52). As a fact, Swiss Re mentions in its CSR report that reducing the company's environmental footprint is a *"key target for the group"*, thus confirming the shift towards a more sustainable way of operating their businesses (Swiss Re, 2017, p. 50).

Climate risk disclosure

The Grantham research Institute on Climate Change and the Environment of the London School of Economics (LSE) defines Climate Risk Disclosure as a *"recognition of the risks climate change could pose to businesses"* and adds that *"there is a growing call for companies to disclose the risks they are facing from both the physical impacts of climate change and the transition to a low-carbon economy"* (Grantham Research Institute on climate change and the environment, 2018). Such disclosure has a twofold end goal, the first is to help insurers and reinsurers evaluate impacts of climate change and allowing them to make the required adaptations to their business model and the second to enable investors to assess whether a particular company is worth investing in (Mills, 2009a, pp. 345-346). On this matter, the work of the Financial Stability Board's (FSB) Task Force on Climate-related Financial Disclosures (TCFD) is of considerable influence and their latest report proposes recommendations around four core elements: governance, strategy, risk management, and metrics (2017). The TCFD recommendations also deeply influence the industry, which can be seen through the latest ClimateWise report (2018). Indeed, this independent review led by PricewaterhouseCoopers (PwC) and meant at evaluating the performance of ClimateWise participants[11] towards a selection of seven key principles[12] was recently updated on the basis of TCFD's recommendations. Another concrete disclosure program worth mentioning is the CDP (formerly Climate Disclosure Project) running a *"global disclosure system that enables companies, cities, states and regions to measure and manage their environmental impacts"* (CDP, n.d.).

To summarize, this sub-chapter has confirmed that some players in the insurance industry are running concrete actions towards mitigating and adapting to climate change. These activities range from gaining additional knowledge on the subject of climate change to disclosure of climate related risks. Fortunately, according to ClimateWise 2018 principles' review, a positive trend can be observed as the financial service industry, which includes the insurance industry, increasingly incorporates *"climate change risks and impacts"* in their business strategy and planning (2018, p. 5). While, it is important to keep in mind that most of the activities mentioned above are done on a voluntary basis, a growing public interest in the

[11] Climate Wise members include insurers and brokers such as Allianz, AON, Zurich, and reinsurers such as Swiss Re, Renaissance Re and XL Caitlin (ClimateWise, 2018, p. 2).

[12] The 2019 ClimateWise principles are meant at increasing the transparency and sustainability of the insurance industry and include criteria such as accountability, impact reduction, transparent reporting and incorporating climate-related issues into strategies and investments (ClimateWise, 2018, p. 11).

subject adds pressure on these companies making them increasingly aware of their duty to act as game changers (ClimateWise, 2018, p. 6).

2. Catastrophe and collapse: our society in dangerous waters

Chapter 1 has confirmed the insurance industry's intimate relationship to both the environment, with its exposure to extreme events, and to the financial/economic sector due to its dependency on financial markets and Insurance Linked Securities. It also demonstrated that extreme weather events already have a deep systemic impact on the industry (Hurricane Andrew and the HIM cluster being perfect examples) and that, unfortunately, this trend is not predicted to change in the future. It has been shown that some weather events resulting from global warming will profoundly impact several lines of business of the insurance industry, hence creating an environment of uncertainty.

To recall, the objective of this paper is to propose a theoretical stress test of the insurance industry's resilience towards a probable[13] worst-case scenario and to analyze whether it is realistic to believe that industry "experts" and "professionals" could develop a long-term vision within the current economical and political environment characterized by short-term decision-making. As a result, the following chapter will analyze the reactions of the insurance industry's business model to climate change through what is considered to be the most credible worst-case scenario, and will investigate whether our *"risk society"*(Beck & Ritter, 1992) is as resilient as it would like to be. Therefore, this chapter will be divided in three main sub-chapters: Firstly, we will carefully examine what environmental scientists and finance professionals consider to be the most credible worst-case scenarios and look at its effects on the insurance industry (see sub-chapter 2.1). Secondly, we will deep dive into a more philosophical approach and question the adequacy of the notion of "risk", as well as the way we perceive and model the probability of extreme events (see sub-chapter 2.2). We will finally close this chapter by discussing the potentiality of a societal collapse as brought forward by authors such as Jared Diamond (2005), Dmitry Orlov (2013) and Pablo Servigne (2015) (see sub-chapter 2.3).

2.1. The (not so improbable) worst case scenario

As previously mentioned, anthropogenic climate change is predicted to have a very deep impact on our lifestyles. Indeed, severe events such as extreme temperatures (high and low), increasing sea levels, permafrost decrease and rainfall variations (droughts and floods) will

[13] The notion of probability will be discussed in further detail in section 2.2.2, when addressing the issue of Black Swan events.

bring deep and tangible impacts on our societies. According to the IPCC AR5 Report (2014), these societal impacts may include, amongst many others, an increase in hunger and water crisis, health risks from rising temperatures and heat waves and further spread of pests and pathogens (IPCC, 2014). Our economy and financial sectors will also be deeply impacted by the effects of climate change, hence triggering reactions from the insurance industry (as exposed in sub-chapter 1.3). The *Stern Review on climate change*, confirms the potentially strong impact of global warming on the economy and Sir Nicholas Stern mentions that *"if a wider range of risks and impacts is taken into account the estimates of damage could rise to twenty per cent of GDP or more"* (Stern, 2007. p. XV).

Having these catastrophic predictions in mind, how could the most credible worst-case scenario look like? Is this really it, or are we moving towards a much darker future? In order to answer these questions, we will discuss the worst *"planned"*[14] scenarios on both the environmental and economical fronts, as we believe these two sectors are those where the insurance industry could receive the hardest hit, thus strongly disrupting its short and long-term resilience. Finally, we will also study the highly improbable (but not impossible) case of a temporal correlation between the two scenarios.

2.1.1. We live in a global, connected and VUCA world

Although a handful of societal collapses can be found throughout our human history, these examples remain focused on specific geographical areas, such as the Easter Island, Greenland Viking settlements or the Mayas (Diamond, 2005) (see sub-chapter 2.3). In this section, we are about to uncover that since humankind has developed into a global and interconnected power through its different phases of globalization, it has created a volatile, uncertain, complex and ambiguous environment also known as VUCA. VUCA is an acronym developed by the U.S. army during the 1990s and its four elements can be helpful in understanding the current environment caused by climate change. To begin, Philippe Vallat, former Colonel within the Swiss Army defines "volatility" as the "*nature and dynamic of change (amplitude, strength and speed)"* that *" provokes fear, risk aversion and a back to basic approach to life"* (2014, p. 49, our translation). The second item of the VUCA environment is "uncertainty" defined as *"the degree of unpredictability inherent to a situation or an event. She causes paralysis by creating a tendency to invest in an excessive*

[14] Inverted commas around the word *planned* are of importance, since, as we will examine in sub-chapter 2.2 humans often believe it is possible to predict and model the future, while this is not necessary the case.

and futile way in the gathering and analysis of data" (p. 49, our translation). As a quick parenthesis, it is worth to mention the parallel between this "futile" data-gathering and the astonishing amount of reports from various origins (i.e., (re)insurances, banks, Governments, etc.) encountered during the research for this paper, which clearly demonstrates the deep uncertainty of our environment. Undeniably, the paralysis effect of uncertainty is extremely relevant in the case of global warming. The third element of the VUCA equation is "complexity" which can be understood as *"the degree of dependency and interactions between multiple factors. It induces trivialization, desire to find a unique cause to a problem (scapegoat) and simple solutions that are most often false"* (p. 49, our translation). And last but not least, "ambiguity" is *"the degree of diversity of interpretation that one can do on the basis of available data. It induces doubt, mistrust and comes as an obstacle to decision-making and change"* (p. 49, our translation). While a VUCA environment constricted to a specific geographical location or a specific economic sector would not be a cause of global stress, the "Great Acceleration"[15] (Will Steffen, Broadgate, Deutsch, Gaffney, & Ludwig, 2015) (see figure 13), shows that we have become a global force impacting the complex Earth system on a worldwide scale and in an exponential way.

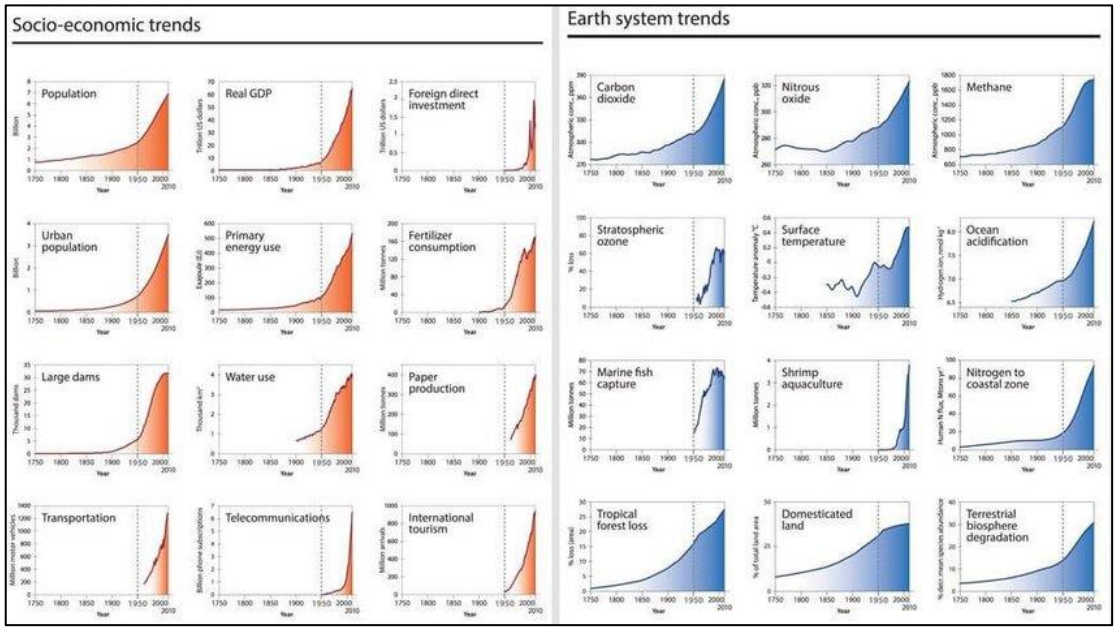

Figure 13: The "Great Acceleration" in human activity from the start of the industrial revolution in 1750 to 2010, and the subsequent changes in the Earth system.
Source: IGBP, 2015.

[15] This term was developed by the International Geosphere-Biosphere Programme and the Stockholm resilience Centre.

In this regard, it is worth highlighting that the exponential growth represented by the "Great Acceleration" is a lot more problematic for human beings to comprehend when compared to "linear growth" (Servigne, 2015, p. 30). Indeed, exponential growth is "*counter intuitive"* and *"when the effects of this growth are visible, it is very often too late"* (p. 31, our translation). Consequently, this exponential growth rate may be one of the explanations for our slow pace (or lack of) answers to environmental issues, as humans tend to believe there is always a lot more time then there really is. The most commonly used example is the *"water lilly equation"* (or *"équation du nénuphare"*) where the expansion of water lilies follows an exponential rate, hence doubling everyday. In this famous case study, the plant coverage passes from half of the pond to the entire pond in just one day, which is something very hard for human beings to apprehend (Jacquard, 2000).

In order to understand the global influence of humankind on both socio-economic and environmental fronts, it is necessary to analyze the concept of globalization. In this regard, one may look at the literature originating from the World Economic Forum (WEF),[16] which has an innovative approach to globalization. It was during the 2019 WEF Annual Meeting that Klaus Schwab, the institution's founder and executive chairman, mentioned that *"globalization 4.0 has only just begun, but we are already vastly under-prepared for it"* (Schwab, 2018). The terminology of *Globalization 4.0*[17] created by the WEF is of particular interest when studying the interconnectivity of the world we live in. Indeed, according to Schwab, we are currently entering a fourth wave of globalization, reaching a strength of connectivity never seen before throughout human history (Vanham, 2019). When looking at a brief history of globalization, the WEF describes four specific globalization waves: (i) the first wave, dating back to the 19th century and ending in 1914, witnessed the British Empire's world domination through technologies such as the steam engine and the industrial weaving machine. Undeniably, steamships and trains enabled humans to transport goods across continents and helped Britain *"attack a huge and rapidly expanding international market"* (Vanham, 2019). (ii) A second wave of globalization, with the United States as the leading power, started post-World War II and was led by the second industrial revolution[18]

[16] The World Economic Forum is an international institution for public-private cooperation and is renown for its publications and views on globalization.

[17] Globalization 4.0 was the theme of the 2019 World Economic Forum annual meeting held in Davos.

[18] In his latest book, *The Fourth Industrial Revolution* (2016), Klaus Schwab develops a theory suggesting that we are currently in the fourth industrial revolution. Both the fourth industrial revolution and Globalization 4.0 are strongly correlated as each industrial revolution brings with it new technologies creating a new wave of globalization.

technologies such as cars and airplanes (Schwab, 2016, p. 7). (iii) In a third and explosive wave, new technologies, such as the Internet, connected humans to each other in an even more direct way. For example, global exports during the 2000 era *"reached a milestone, as they rose to about a quarter of the global GDP"* (Vanham, 2019) indicating the rising global impact of world trade in correlation to increased interconnections (see figure 14).

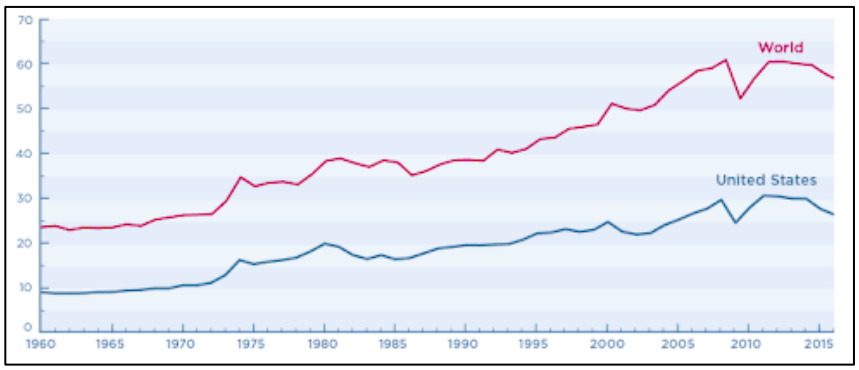

Figure 14: World and US trade as a percentage of GDP.
Source: Vanham, P. 2019. Data from World Bank Databank.

(iv) Finally, the end of the 2010s brings us to the fourth wave of globalization with two global powers, the US and the Democratic Republic of China, and a world where *"the new frontier of globalization is the cyber world"* (Vanham, 2019). Indeed, new tools such as e-commerce and digital services have been vastly enhanced by artificial intelligence (AI) and demonstrate the grasping impact of humankind on its surrounding. This history of globalization helps us understand that we have truly become a global society and that we evolve in an interconnected world. For this reason, this paper will approach our society, environment and economy as global and interrelated systems. The Princeton Institute for International and Regional Studies (PIIRS) of Princeton University (U.S.) confirms and strengthens this position by indicating that *"the interdependence of massive global interactions and structures has caused systemic risk*[19] *to increase exponentially in recent times. Tangible risks—in systems as diverse as energy exploration and production, electricity transmission, computer networks, healthcare, food and water supplies, transportation networks, commerce, and finance—now threaten global political, economic, and financial systems that affect citizens of every nation"* (PIIRS, n.d.).

From the above, it is clear that, due to globalization, human society and Earth systems should be considered as global and that the environment we live in should be regarded as vulnerable,

[19] The notion of systemic risk will be extensively covered in sub-section 2.1.3.3.

uncertain, complex and ambiguous (VUCA) as climate change affects the entire planet in a systemic manner. Having this global systemic approach in mind, we will now develop what is believed to be the future worst-case scenarios on both the environmental and the economic fronts.

2.1.2. Towards an environmental nightmare

What may the future look like from an environmental point of view? According to the IPCC's 2014 (AR5) report, there are different modeled pathways available to humanity. In order to provide a detailed and comprehensive flow of information, this section will begin by briefly introducing the IPCC's 2.6, 4.5, 6.0 and 8.5 Representative Concentration Pathways (RCPs) in order to approach the, what we believe to be, idealistic goals of the Paris Agreement. It will then turn to the, not so pleasant but probable, alternative path, presupposing that we do not manage to achieve the Paris objectives and keep on living in a "business as usual" fantasy.

2.1.2.1. Understanding the Representative Concentration Pathways

In its 2014 (AR5) report, the IPCC based its climate modeling and research on four different scenarios called Representative Concentration Pathways (RCP). In short, there are four different scenarios, namely RCP 2.6, 4.5, 6.0 and 8.5, labeled after a range of radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 W/m2). In other words, RCPs are *scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover"* (IPCC, 2014, p. 126). To recall, radiative forcing, measured in watts per square meter (W/m2) is the *"change in energy flux caused by a driver and is calculated at the tropopause or at the top of the atmosphere"* (p. 126). In addition, it is interesting to mention that the word "Representative" highlights the fact that each selected RCP *"provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics"* (IPCC, 2014, p. 126). It is also important to note that RCP scenarios do not represent forecasts as *"scenarios are devices for analyzing situations in which outcomes are uncertain"* and *"the goal of working with scenarios is not to predict the future but to better understand uncertainties and alternative futures, in order to consider how robust different decisions or options may be under a wide range of possible futures"* (IPCC, 2019). Finally, as seen in figure 15, the different RCP scenarios are

correlated to the total anthopogenic CO2 emissions hence causing a specific rise in temperature compared to pre-industrial values (1861–1880).

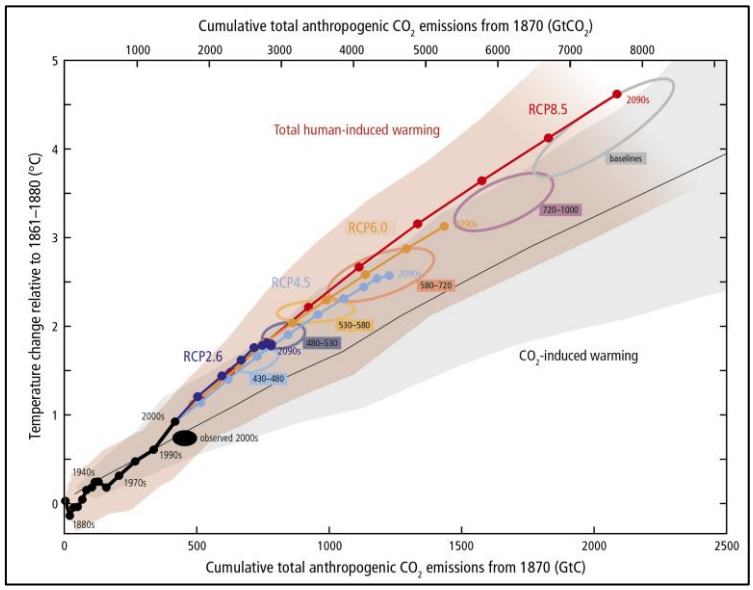

Figure 15: Summary of IPCC RPC scenarios 2.6, 4.6, 6.0 and 8.5. Global mean surface temperature increase as a function of cumulative total global CO2 emissions. Multi-model results from a hierarchy of climate carbon-cycle models for each RCP until 2100 are shown in colored lines. Dots indicate decadal averages. Ellipses show total anthropogenic warming in 2100 versus cumulative CO2 emissions from 1870 to 2100. Black filled ellipse shows observed emissions to 2005 and observed temperatures in the decade 2000–2009. Source: IPCC, 2014, p. 63.

2.1.2.2. The Paris Agreement: an unrealistic bet?

It was during the 21st UNFCCC Conference of Parties (COP 21) held in Paris in 2015 that participating States developed the so called "Paris Agreement" (UNFCCC, 2015) aimed at keeping global temperature rise in 2100 well below two degrees Celsius above pre-industrial levels and *"pursue efforts to limit the temperature increase even further to 1.5 degrees Celcius"* (UNFCCC, 2018). In short, the ultimate goal of this agreement is to limit the potential impacts of climate change and is represented by RCP 2.6 on the IPCC range of scenarios. Unfortunately, recent literature and research does not paint a very optimistic picture of achieving these goals, it is in fact all the opposite. Indeed, scholars and scientists increasingly mention that reaching the Paris Agreement would require a very deep and long societal transition including major changes to our consumption habits, the way we produce and use energy, as well as our approach to economic growth and prosperity (Jackson, 2009). Of course, the aim of this paper is not to dive deeper into the undesirable environmental and social impacts of economic growth, but authors such as Tim Jackson (2009), Ivan Illich (1975) and economists from the heterodox Ecological Economics branch provide an extensive literature on the subject. The key message to remember is that the Paris Agreement goal seems very unrealistic when taking into consideration the required rate of societal and

technological modifications mentioned by the IPCC (IPCC, 2018) and the current inertia of political and economical processes.

With regards to technological changes, it is interesting to mention that achieving the Paris Agreement goal would necessitate humanity to develop and massively spread a technology called Carbon Dioxide Removal (CDR) (also known as Carbon Capture and Storage: CCS), (see figure 16). This new technology should be able to remove CO_2 directly from the atmosphere, and this in a very short time period (IPCC, 2018, p. 16).

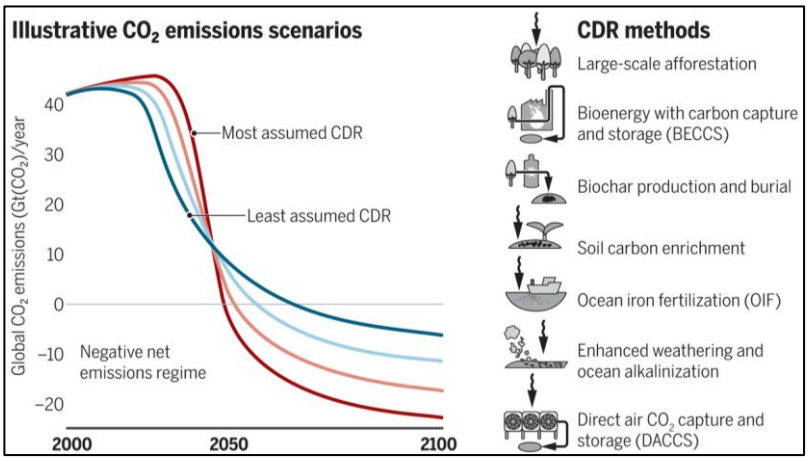

Figure 16: How hypothetical technologies shape climate scenarios. Most climate model scenarios rely on carbon dioxide removal (CDR) technologies to limit future temperature rises. Reliance on these technologies in models is problematic because they remain untested at the required scales.
Source: Lawrence & Schäfer, 2019, p. 830.

But, alas, an increasing amount of scientific sources have been publishing warnings on the potential risks linked to such technologies. Indeed, the 2016 Swiss Re Emerging Risks Insights report mentions that large-scale geoengeneering, which includes CDR, *"has potentially huge liability exposures due to unintended side effects"*(Swiss Re, 2016, p. 33). However, it is also important to mention that such technologies, representing new risk, could also open new opportunities for the insurance industry, as these would need to be covered (e.g., liability, Casualty, etc…). In addition to the risk allocated to such technologies, questions have been raised about the feasibility of developing and scaling up such technologies in a short time period.[20] Indeed, a recent article published in the scientific review *Nature* states that *"investigating, testing, and developing any of the techniques up to a climate-relevant scale would take decades, and large-scale use might not ever be feasible because of scientific, technical, and societal constraints"* (Lawrence & Schäfer, 2019, p. 829). Furthermore, Rob Jackson, Professor of Earth system science at Stanford University (U.S.) mentions that *"such technology has never existed at industrial scales"* (Meyer, 2019)

[20] As a reminder, the first targets of the Paris Agreement are set for 2030.

and Sir David King, Chief Scientist to the UK Government, adds that *"the scale of CCS required to hit the Paris climate targets is equivalent to burying the total volume of liquid (oil, gas and water) handled today by the entire global oil industry"*. The Chief Scientist further considers that *"without CCS, countries with the highest emissions would need to cut them to zero within around 30 years"*(CRO Forum, 2019, p. 21) which seems problematic when looking at the current trend of carbon emissions (see figure 17). In fact, a total of 400 billion metric tons of carbon have been released to the atmosphere and half of it has occurred since the late 1980s. It is also interesting to note that the 2014 global fossil-fuel carbon emission estimate is of 9,855 million metric tons, representing an all-time record (Boden, Marland, & Andres, 2017).

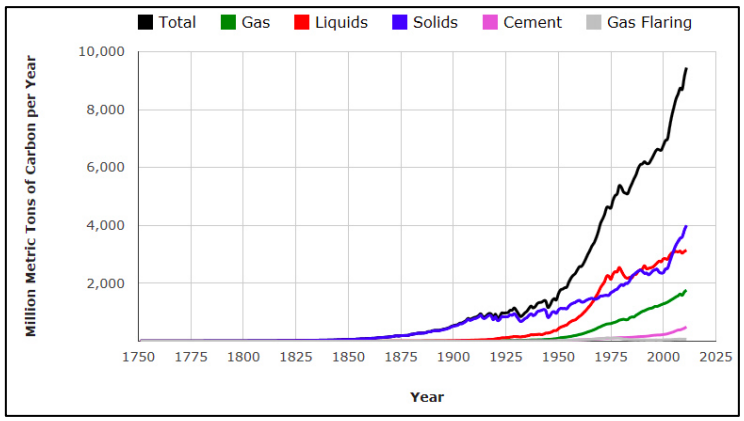

Figure 17: Global and individual contributors to Carbon emissions from 1900 to 2018.
Source: Boden, Marland & Andres. 2017.

On a more recent note, a 2019 report from British Petroleum (BP) indicates a Carbon Dioxide growth rate of one percent for the 2007-17 timeframe and of two percent for the year 2018, being the fastest growth for the past seven years (BP, 2019b). Spencer Dale, group chief economist at BP adds that this two percent growth is *"roughly the equivalent to carbon emissions associated with increasing the number of passenger cars on the planet by a third. This number is material. This increase stems pretty much directly from the growth in energy demand"* (BP, 2019a). In fact, the report refers to a global energy consumption increase of 2.9 percent in 2018, being the strongest since 2010 and almost doubling the ten-year average. It also provides a comprehensive overview of world energy consumptions and demonstrates the importance of oil, natural gas and coal to our economy and the still very low contribution of renewables (BP, 2019c p. 10) (see figure 18).

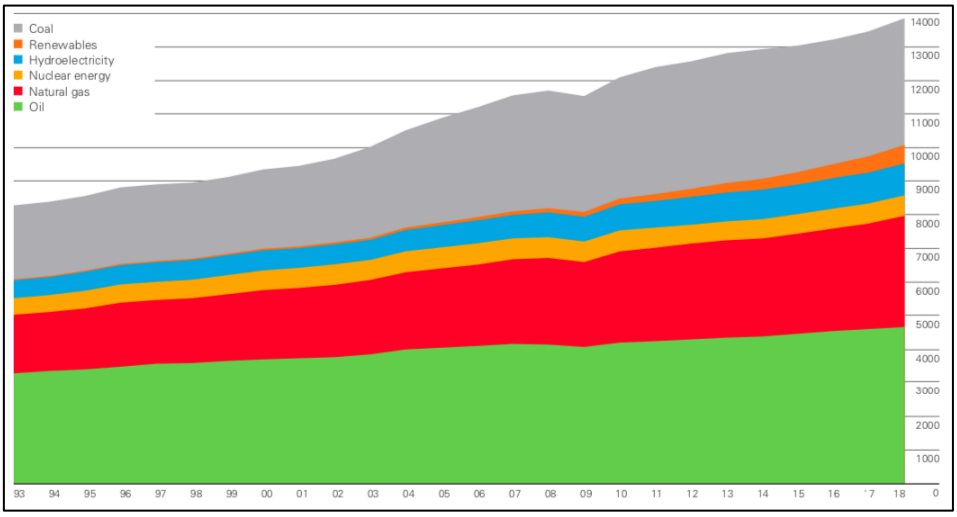

Figure 18: World energy Consumption (Milion Tonnes oil equivalent). Source: BP, 2019c, p. 1.

Having these various trends in mind, in particular global trade (see figure 14), global CO2 emissions (see figure 17) and world energy consumption (see figure 18), it seems irrational and very dangerous to make humanity's own survival dependent on the sole development of currently non-existent technologies, such as CCS. While one could think that democratic political institutions could help trigger the societal changes necessary to address climate change, Pierre Rosanvallon, professor at the Collège de France, suggests otherwise after having extensively examined what he calls the myopia of our western democracies (Rosanvallon, 2010). Indeed, Rosanvallon mentions that democracies tend to have a *"preference for the present"* and a short-term approach due to short political cycles (Rosanvallon, 2010, p. 151), hence creating an inertia on necessary long-term political decisions on environment protection.[21]

Taking the previous comments into consideration and when looking at the timeframe proposed by the IPCC, it seems more than idealistic to believe that a deep societal and technological transition could take place within the next ten or twenty years. Indeed, the IPCC emphasizes the necessity to reach a decline of CO2 emissions of about 25 per cent by 2030 and reach net zero around 2070 so as to achieve pathways close to RCP 2.6 (and respect the Paris Agreement), hence confirming the short timeframe for taking the necessary measures. It is interesting to note that for once, environmental "long-term" deadlines are almost identical to what the financial sector considers as long-term investments. Indeed, it is

[21] At this point, it seems more than necessary to mention that authoritarian regimes do not have a specifically enviable environmental footprint and it is definitely not this thesis's objective to preach for an environmental authoritarianism. In fact, an outstanding amount of literature exists on the subject of bringing ecology and democracy together and in the case of any interest on the subject, the reader may turn to authors such as Dominique Bourg, Robyn Eckersley, Bruno Latour or Kerry H. Whiteside.

commonly considered that the time horizon for financial long-term investments is of ten or more years (Chen, 2018b), hence proving a certain correlation between environmental and financial goals which could be used as a leverage for increasing ESG, impact and green investments. Unfortunately, the 2018 volume of impact investment, of about USD 502 billion worldwide (Global Impact Investing Network, 2019, p. 6), remains too low when compared to continuous unsustainable investments such as USD 790 billion in fossil fuel supplies (IEA, 2018, p. 4). Furthermore, a 2016 report from the MIT Sloan School of Management and the Boston Consulting Group (BCG) provides additional reasons to such discrepancies as it states that *"75 percent of top executives in investment firms agree that a company's good sustainability performance is materially important to their firm when making investment decisions"*, yet *"only 60 per cent of managers in publicly traded companies believe good sustainability performance matters to investors"*, thus proving a critical management misperception in times of climate urgency (Unruh, Kiron, Kruschwitz, Reeves, & Rubel, 2016).

To conclude, it is assumed that in order to comply with the Paris target of keeping temperatures at 1.5-2°C above pre-industrial levels, substantial modifications are necessary to the way our society functions and this in a very short time frame, making this scenario a best-case and not so probable one. Moreover, the political and economical inertia witnessed during the past ten to fifteen years (maybe even more) does not inspire faith in an RCP 2.6 scenario. Pessimistic (but realistic) approach confirmed by the CRO Forum as it indicates that *"the Paris target to limit dangerous physical effects of climate change is vital but tough to meet. Research indicates that 3-4 °C warming is most likely. There is a risk of >5°C which would be catastrophic"* (2019, p. 5) (see figure 19). What are then the alternative pathways, and what different impacts could they have on our society and economy? The next sub-section will have a closer look at these crucial questions.

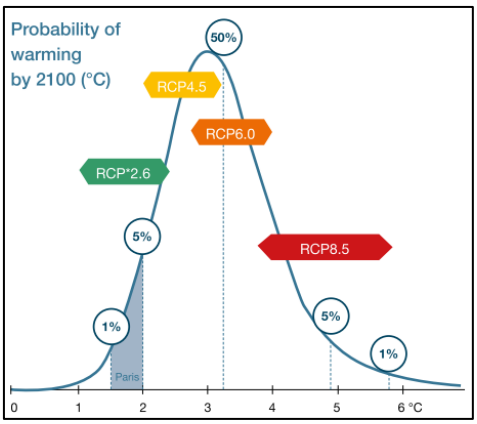

Figure 19: Probability of warming by 2100 in °C.
Source: CRO Forum, 2019, p. 5.

2.1.2.3. The terrifying RCP 8.5 scenario

Before diving into detail, it is noteworthy to mention a 2019 report from the National Center for Climate Restoration[22] which discusses the notion of "scientific reticence". Indeed, the provocative think-tank mentions that "*climate scientists may err on the side of "least drama", whose causes may include adherence to the scientific norms of restraint, objectivity and skepticism, and may under predict or down-play future climate changes"* (Spratt & Dunlop, 2019, p. 5). The institution further mentions that "*security analysts warned that, in the two previous decades, scientific predictions in the climate-change arena had consistently under-estimated the severity of what actually transpired"* (p. 5). The above statement is worrisome as the reality might be well underestimated by the scientific community and the future might be in fact even worse than predicted.

Given that the probabilities of achieving the Paris goal of keeping temperatures within 1.5°C and even 2°C are very thin unless drastic societal changes take place in a very near future, the slow pace of political, economical and social changes as well as human's difficulty to apprehend exponential growth leads us to consider a darker environmental future. In this respect, having a detailed idea of what the most credible worst-case scenario may look like and studying its consequent societal impacts provides us with valuable knowledge regarding the insurance industry's resilience. As a perfect environmental stress test for the (re)insurances current business model, we will examine the most extreme RCP scenario, the feared and catastrophic RCP 8.5 and its minimum of 5°C temperature increase. While it is true that the most likely future is somewhere between RCP 4.5 and 6.0, equivalent to temperature increase of about 3-4°C (see figure 19), we believe that a realistic stress test for the (re)insurance industry should not only consider the most "probable" future, but should also face the worst planned situation, being RCP 8.5. Moreover, this scenario is not entirely improbable and should be seen as "*uncomfortably plausible"* since it is perfectly in line with current "business as usual" GHG emissions and climate policy trends (CRO Forum, 2019, p. 23).

a) Story line and main drivers

As a first step towards understanding what an RCP 8.5 future may look like and how it could impact the insurance industry, it is necessary to analyze what the scientific literature

[22] The National Centre for Climate Restoration, also known as Breakthrough, is an independent think tank which at conveys a critical approach to influence climate debate and policy making.

considers to be the most probable story line, as well as comprehend what the main drivers are of such scenario. For this purpose, we will use Riahi et al.'s (2011) RCP 8.5 analysis as it presents a very comprehensive approach.[23]

The detailed analysis offered by Riahi et al. considers three principal drivers to an RCP 8.5 scenario. A growing economy, an expanding world population and a slow energy efficiency improvement are proposed as a probable explanation for *"a large scale increase of primary energy demand by almost a factor of three over the course of the century"* (Riahi et al., 2011, p. 43), which is mostly met by fossil fuels. The developed storyline mentions a *"heterogeneous world with continuously increasing global population, resulting in a global population of 12 billion by 2100"* (p. 43). In addition to the demographic growth, *"per capita income growth is slow and both internationally as well as regionally there is only little convergence between high and low income countries"* (p. 42). The described slow economic development causes little progress in terms of efficiency and when combined with a high population growth, leads to higher energy demand (p. 43). Besides, this scenario assumes a *"slow pace for innovation in advanced non-fossil technology, leading for these technologies to modest cost and performance improvements"* (p. 43), and making fossil fuel technologies economically attractive when compared to more sustainable options. This situation also implies the *"availability of large amount of unconventional fossil resources"* (p. 43), allowing an increase in extractable reserves and prolonging the use of fossil fuels. In other words, *"resource availability is not necessarily a constraint but easily accessible conventional oil and gas become relatively scarce in comparison to more difficult to harvest unconventional fuels like tar sands or oil shale"*. In this regard, the 2018 World Energy Investment Outlook report from the International Energy Agency (IEA) provides an interesting input as it mention a rise in the overall energy share of fossil fuel to 59 per cent due to increased spending in upstream oil and gas (IEA, 2018, p. 2), thus demonstrating a non-sustainable trend towards a continued use of fossil fuel. Finally, the low economic interest towards sustainable technologies leads to their slow development pace and forces the future energy system to move towards *"coal intensive technology choices with high GHG emissions"* (p. 43).

[23] Although a certain amount of other scientific research does exist on the subject, a choice had to be made due to time and space constraints, which do not allow to examine all available research in this regard.

To summarize, the RCP 8.5 scenario presents a future world with expanding global population, a *"relatively conservative business as usual"* (p. 43) economic environment with intermediate development in terms of total GDP growth, and high energy demands due to slow improvement in primary energy intensity (0.5 per cent per year over the century) linked to slow technological advancements (Riahi et al., 2011, p. 43) (see figure 20).

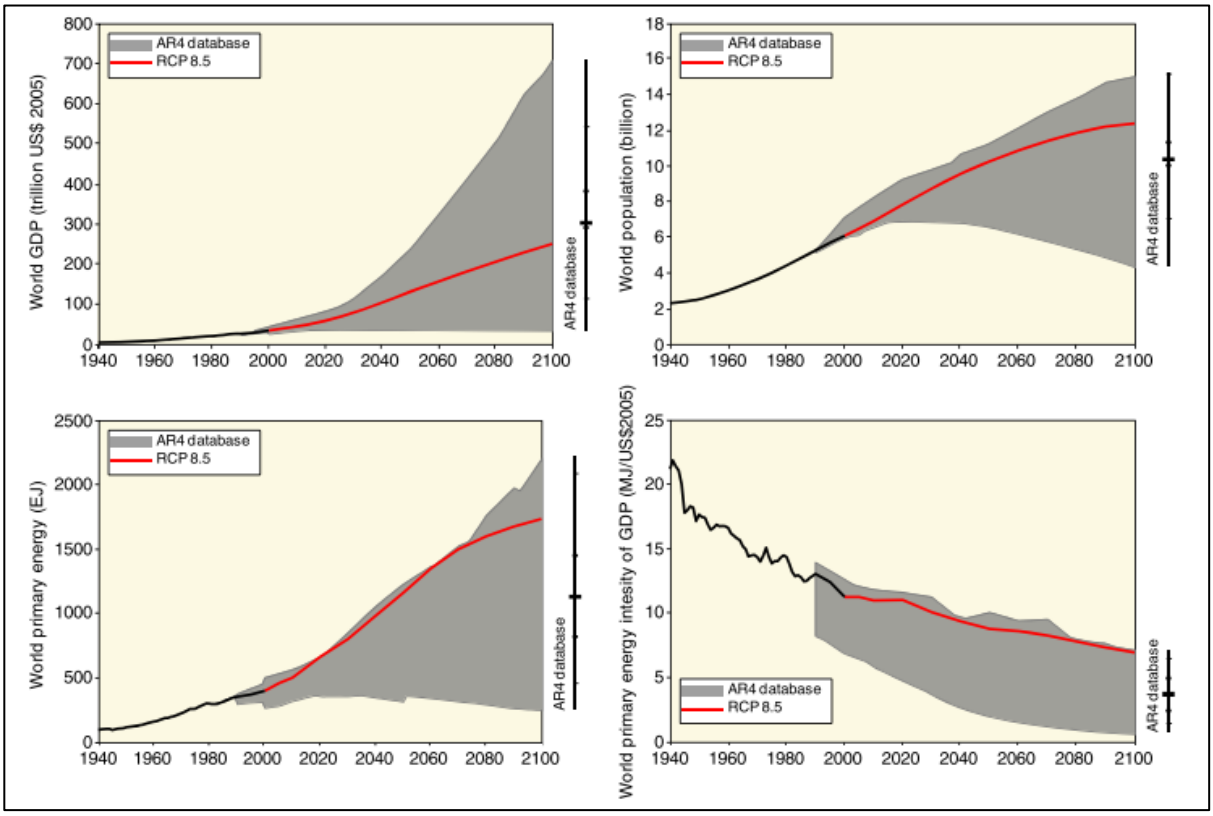

Figure 20: Global development of main scenario drivers in RCP 8.5. (red lines) compared to the range of scenarios from the literature (grey areas) (IPCC AR4, Nakicenovic et al., 2000; Fischer, Tubiello, Van Velthuizen, & Wiberg, 2007). Right hand vertical lines give the AR4 database range in 2100, including the 5th, 25th, 50th, 75th, and 95th percentile of the AR4 scenario distribution.
Source: Riahi et al., 2011, p. 44. With data from IPCC AR4 scenario database, Fisher et al. 2007, Nakicenovic et al. 2000.

Arguably, these trends, in particular high fossil-intensive energy combined with an increasing population and associated demand for food, would be the main cause of future increase in GHG emissions (see figure 21). Accordingly, Riahi et al. (2011, p. 48) models a Co2-eq. emission increase of more than 50 per cent by 2050 and to about *"120 GtCO2-eq. by 2100 (compared to 2000)"*. This research refers to two main motives for GHG increase: the energy sector on the one hand and the increased use of fertilizers and intensification in agricultural production on the other hand, resulting in a *"rise to the main source of N2O emissions"*.

Lastly, an *"increases in life-stock population, rice production, and enteric fermentation processes drive emissions of methane (CH4)"* (p. 48), further increasing the destructive effects of GHG emissions.

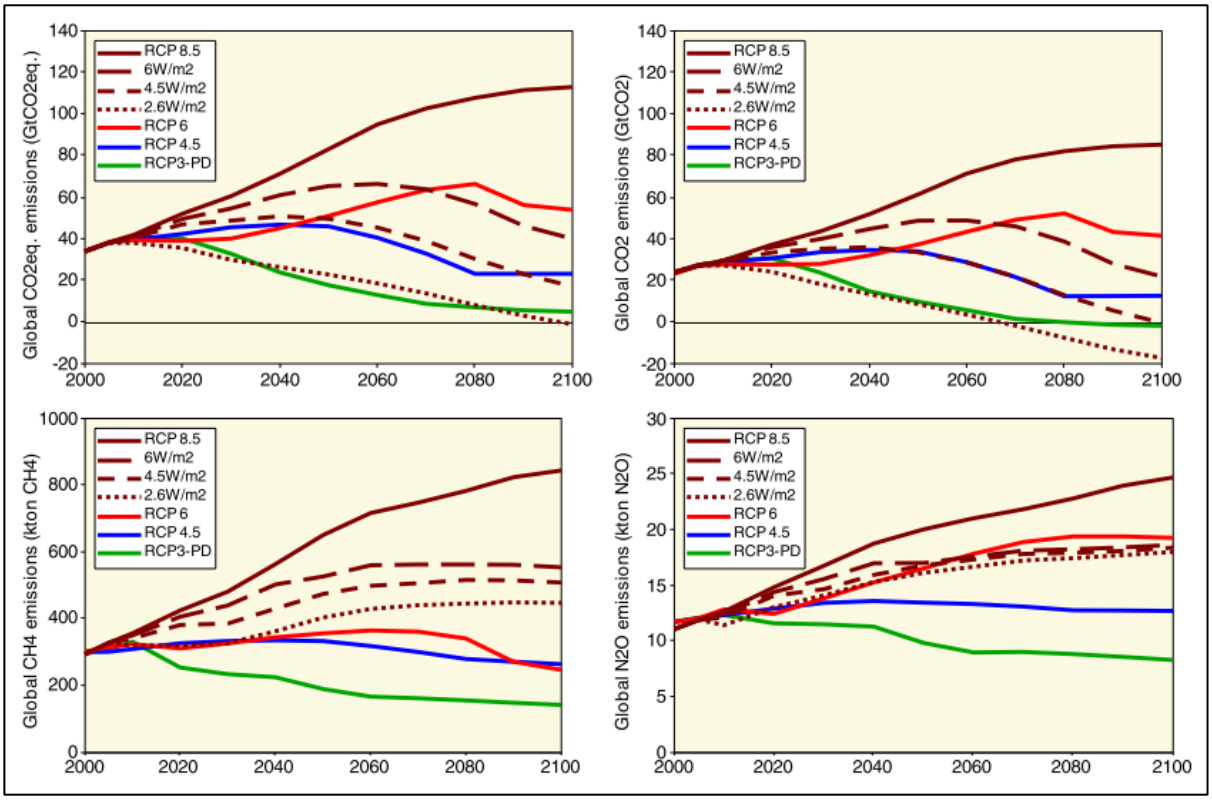

Figure 21: Development of global GHG emissions in RCP8.5. (CO2-eq., CO2, CH4, and N2O) and MESSAGE mitigation scenarios used in Riahi et al. 2011 (brown lines). For a comparison the trends of the official RCPs are shown as well (red = RCP6, blue = RCP4.5, green = RCP3-PD)
Source: Riahi et al., 2011, p. 49.

b) Earth system: Beware of the Tipping points!

As previously mentioned in section 2.1.1, the Earth constitutes a dynamic system and system science is therefore extremely useful in helping to fully understand the global catastrophic impacts of RCP 8.5. As a matter of fact, Meadows et al. (2004) mentions in the 30-year update of the world renown *Limits to Growth* that *"a system perspective lets people see some things they would never have noticed from any other vantage point"* (p. 4). For the sake of clarification, it is useful to briefly introduce the dynamic system perspective as conveyed by, not only the *Limits to growth* (1972, 2004) report, but also an entire scientific community (Klir, 2001). As defined by the *Dictionaire de la pensée écologique, "a system is a set of elements or components interacting according to certain rules (fixed or not, simple or complex), forming a more or less organized dynamic structure, integrated and isolated from*

the external environment. The concept of a system is used in many scientific fields from physics and chemistry, sciences of the universe, engineering and technology, to the humanities and social sciences, through biology, ecology and environmental sciences." (Couvet & Teyssèdre, 2015, p. 962, our translation). Furthermore, the system scientific field uses a specific terminology to detail the specifications of a system. Therefore, words such as *"feedback loop"*, *"tipping point"* and *"resilience"* have a particular importance when observing the Earth's dynamic systems. To clarify, a feedback loop implies a *"causal chain of factors or actions in which a factor has a return effect, called feedback, on one of its upstream cause"* (Teyssèdre, 2015, p. 103, our translation). Moreover, *"every ecological system, as a complex dynamic system exchanges matter and energy with its environment and has negative (-) and/or positive (+) feedback loops set in motion by modifications of internal or external origin"* (p. 103, our translation). In short, negative (-) feedback loops allow organisms to stabilize their environment, thus maintaining favorable living conditions. Unfortunately, "*the ability of ecosystems to regulate through negative feedback loops is necessarily limited"* and *"beyond a certain disturbance threshold, they can give way to positive feedback loops or amplifiers, which accelerate the transformation of the system"* (p. 104, our translation). In ecology, such critical transition between two stable states can be seen when, for example a forest ecosystem transitions into a savannah type state (Couvet & Teyssèdre, 2015, p. 964). On a finale note, the overly used term of "resilience" is defined by the perturbation intensity that a system can endure before changing state (p. 964).

Having the above systemic approach in mind, it becomes easier to apprehend Earth's climate system and the associated risk of an RCP 8.5 type temperature increase. Undeniably, climate change will affect several crucial tipping points, pushing the current system into a new state potentially unfit for humankind. In fact, a tipping point arises when "*a critical observable threshold is crossed",* thus indicating a system state modification (CRO Forum, 2019, p. 11). Figure 22 provides an extensive overview of the potential tipping points and their related triggering temperature, as well as the cascading effect they could have (Will Steffen et al., 2018). The catastrophic scenario conveyed by RCP 8.5 could potentially mean a drastic modification of the state of current climate patterns, creating uncertainty towards the Earth's future habitability. While the main goal of this paper is not to cover the whole of system science and the different tipping points, the central message to remember should be the potential drastic global and cascading effects when overshooting a tipping point within the Earth's climate system.

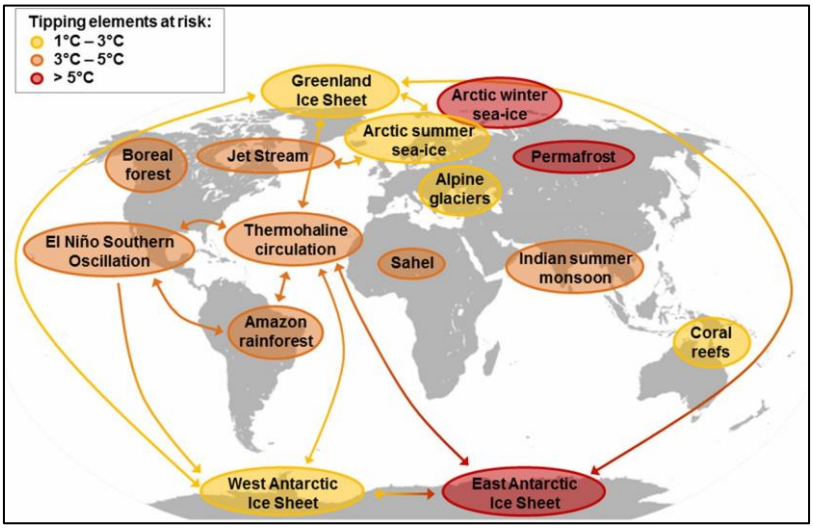

Figure 22: Global Map of potential tipping cascades.

The individual tipping elements are color-coded according to estimated thresholds in global average surface temperature. Arrows show the potential interactions among the tipping elements based on expert elicitation that could generate cascades. Note that, although the risk for tipping (loss of) the East Antarctic Ice Sheet is proposed at >5 °C, some marine-based sectors in East Antarctica may be vulnerable at lower temperatures. Source: Will Steffen et al., 2018.

c) Physical and economic impacts

Having established the potential main drivers of a nightmarish RCP 8.5 scenario, as well as the different tipping points that could potentially push Earth's system into a different and less welcoming state for humankind, the following paragraphs will provide an overview of the various environmental and societal effects of this scenario in order to address its impact on the insurance industry. Indeed, the Earth system's modification could carry drastic physical and economic impacts, thus potentially affecting the various insurance industries' lines of business.

Extreme heat waves

When writing these lines in early June 2019, the Republic of India is experiencing one of the most serious heat waves of its history with temperatures exceeding a flabbergasting 50°C, causing water shortage and heavy casualties including dozens of deaths by sunstroke (Dalton, 2019). The impact of such extreme temperatures on the human body is known to be critical as it defies its adaptation capacities (Bourg, 2018, p. 61) leading to the shut down of sweating aptitudes and cascading into severe heat stroke and potential death (Harmin, 2010). As and outlook for the future, Dominique Bourg mentions that South Asia could quickly become inhabitable due to constant high temperatures and western European countries such as France could be subject to heat waves of 50°C by the end of this century (2018, p. 61). In fact, IPCC models display a median temperature increase of 4.5°C, with a range of 2.8°C to 7.8°C (CRO Forum, 2019, p. 23) by 2100, thus multiplying by 300 the amount of people endangered by extreme heat waves (p. 6) (see figure 23). In addition, a recent ILO report studying the impact

of heat stress[24] on labor productivity and decent work within the frame of global warming (2019) provides an interesting input. Indeed, the international organization mentions that *"excessive heat during work creates occupational health risks; it restricts a worker's physical functions and capabilities, work capacity and productivity. "Heat exhaustion" occurs when body temperature exceeds 39°C: it is associated with reduced labour productivity, a greater prevalence of job-related errors and an increased risk of accidental workplace injuries"* (2019, p. 13). As a result, extreme temperature modifications could represent a serious threat to health/injury insurance coverage in regions close to the equator, such as South Asia or Sub-Saharan Africa, as life underwriting may become too risky and to costly for the (re)insurance sector, thus having a heavy impact on its insurability.

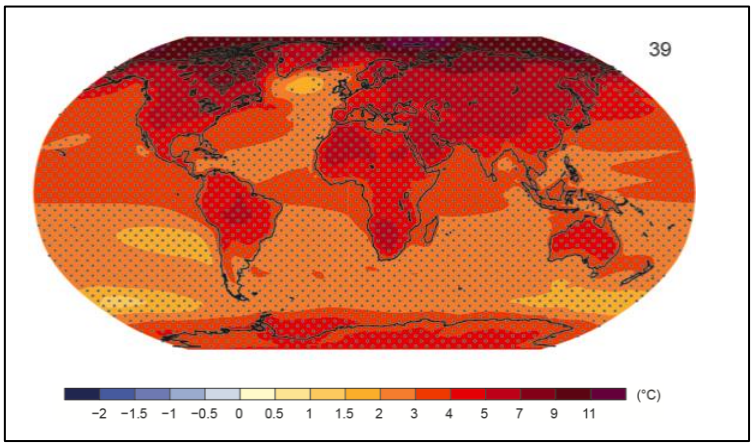

Figure 23: Change in average temperature (1986-2005) to (2081-2100) of the business as usual RCP 8.5 scenario.
Source: IPCC, 2013.

It is worrisome to note that the ILO report suggests that even in a very improbable RCP 2.6 scenario with temperature increase of only 1.3 degrees by 2030, the share of total working hours lost will be of 2.2 per cent, equivalent to 80 million full-time jobs or USD 2,400 billion in monetary terms (2019, p. 26) (see figure 24). With such high data for a very soft RCP 2.6 scenario, one could imagine how important the impact of RCP 8.5 would be on the global workforce. This reduction of work productivity would surely have a drastic impact on the insurance industry as the level of incomes may be correlated to this reduction, hence increasing the insurance gap in vulnerable countries and reducing overall societal resilience.

[24] The ILO defines heat stress as the *"heat received in excess of that which the body can tolerate without physiological impairment"* (ILO, 2019, p. 13).

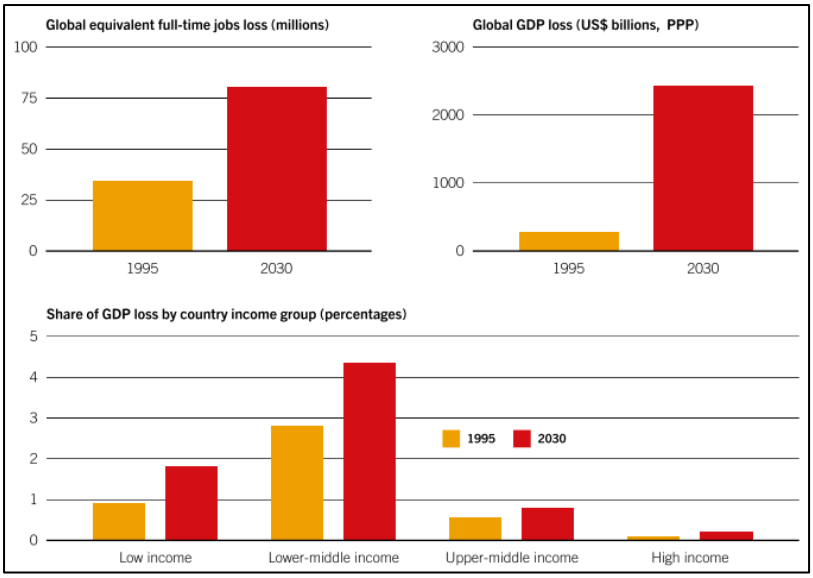

Figure 24: Equivalent full-time jobs and GDP loss to heat stress, global and by country income group, 1995 and projections for 2030 using as input the RCP2.6 climate change pathway, which envisages a global average temperature rise of 1.5°C by the end of the century. Source: ILO, 2019, p. 26.

Sea-level rise

IPCC's RCP 8.5 scenario is modeled to bring a consequent increase in temperature, thus triggering crucial tipping points of the Earth's climate system. The potential physical impacts of such trend is tragic as it may lead to a sea-level rise ranging from 0.5 to 1.7 m by 2100, or even more if destabilized areas from the Arctic and Antarctic ice caps begin to melt. This consequent rise in sea level is forecast to greatly increase the scope of coastal assets to defend, as demonstrated within figure 25 with the example of New York City (Climate Central, 2019). Indeed, it is estimated that the RCP 8.5 scenario would place USD 27.5 trillion coastal assets in jeopardy, which is massive when compared to the USD 10.2 trillion linked to a Paris Agreement type scenario (1.5°C increase in temperature) (CRO Forum, 2019, p. 5). The enormous impact of sea level rise on P&C underwriting will be further discussed within the next section, but figure 25 already demonstrates the difficulties this line of business is about to face.

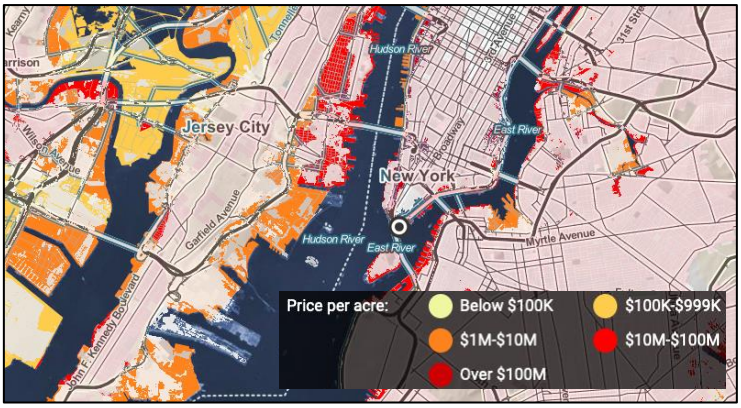

Figure 25: Property exposure in New York City with a 2 m sea level rise (price/acre).
Source: Climate Central, 2019.

Ice-free Arctic summers

The scientific community considers that an increase in temperature of over 5°C would cause ice-free Artic summers every year (CRO Forum, 2019, p. 5). This would open new trade routes[25] as well as ice-free new opportunities for the insurance industry, such as Marine Cargo insurance and coverage for new oil & gas extraction facilities, as 22 per cent of global undiscovered petroleum resources are supposedly located in the region (U.S. Energy Information Administration, 2009). This trend was confirmed in a Lloyd's of London 2012 report which mentions that "*oil and gas investment in the Arctic will account for a relatively small but strategically significant portion of the energy industry's global investment over the next two decades"* and the UK based insurer adds that *"sustaining current and projected rates of arctic oil and gas could transform local economies and global energy dynamics"* (Emmerson & Lahn, 2011). Nevertheless, this new access to resources may bring political tensions between neighboring nations such as the Russian Federation, Sweden (the EU) and the U.S., and armed conflicts may develop, thus increasing risks for insurers. In addition, the discovery and use of additional oil and gas could have a dramatic impact on the much needed energy transition as these resources would create a new fossil fuel-induced dynamic for the economy. As very often, this new scenario creates a dilemma for the insurers between short-term gain by developing "arctic" insurance products and a long-term vision of environmental protection by limiting their coverage of non-sustainable energetic resources and arctic trade routes.

Tropical cyclones, extreme rainfalls and wildfires

Since the insurance industry is significantly exposed to and dependent on sever weather events such as tropical cyclones and extreme rainfalls (see section 1.2.1), a warming of more than 5°C would not bring any good news to the industry, as it would bring with it a consequent increase in the strength of tropical cyclones, as well as amplified rainfalls (CRO Forum, 2019, p. 6). In fact, stronger cyclones of category 4 and 5, similar to Andrew and the HIM cluster, are destined to increase by almost 55 per cent and convey 35 per cent additional rainfall (Knutson et al., 2015). These drastic variations may lead to the un-insurability of seashore assets, hence heavily impacting P&C underwriting in those regions. Indeed, well-populated and economically dynamic locations such as the United States' Southern and

[25] Vladimir Putin has underlined *"the importance of the Northern Sea Route as an international transport artery that will rival traditional trade lanes"* (Council on Foreign Relations, n.d.).

Eastern coasts and its biggest cities (e.g., New York City, Washington D.C., Boston, etc.) may become increasingly difficult to insure as extreme events may cause solvency issues to insurers who could become more and more reticent to provide insurance coverage to the concerned geographical areas. Furthermore, life underwriting could be exposed to similar threats as the death toll caused by these direct physical impacts of climate change could significantly increase.

In addition to this trend concerning tropical cyclones, the frequency of extreme rainfalls and the extent of wildfires are also likely to considerably escalate. In fact, it is estimated that the frequency of extreme rainfall such as the June 2018 record-setting precipitation on Lausanne (Switzerland) with 41 mm of water falling from the sky within 10 minutes (MétéoSuisse, n.d.), could increase by 150 per cent (CRO Forum, 2019, p. 5). Knowing that the Lausanne event has caused P&C damages estimated at about CHF 27 million (RTS, 2018), it is frightening to imagine what such storm recurrence could cause to bigger and more important cities and their insurance markets. Finally, in a similar trend, the extent of wildfires is at risk of multiplying by 2.6 (CRO Forum, 2019, p. 5), thus meaningfully increasing risks for P&C insurers in wildfire prone regions, such as California or the Mediterranean coast.

Pandemics, epidemics and mental health

Recent studies completed on the effect of an RCP 8.5 scenario on pandemics and epidemics, such as the dengue fever (Fan & Liu, 2019), malaria (Hundessa et al., 2018) and Chikungunya (Tjaden et al., 2017), demonstrate that such diseases would gain on importance. In fact, when taking malaria as an example, *"global climate change is likely to increase the geographic range and seasonality of malaria transmission"* and *"areas suitable for distribution of malaria vectors are predicted to increase"* (Hundessa et al., 2018, p. 1).

Furthermore, a Stanford University study, led by economist Marshall Burke and focused on the effect of climate change on mental health, demonstrated a correlation between higher suicide rates and increased temperatures (Burke et al., 2018). Indeed, based on data collected during multiple decades in Mexico and the USA, the research study provides noteworthy (and frightening) figures as it concludes that the rate of suicides has increased by 0.7 per cent (Mexico) and 2.1 per cent (USA) for a 1°C rise in monthly average temperature (p. 723). The study further states that "*we project that unmitigated climate change (RCP8.5) could result in a combined 9–40 thousand additional suicides (95 per cent confidence interval) across the United States and Mexico by 2050, representing a change in suicide rates comparable*

to the estimated impact of economic recessions, suicide prevention programmes or gun restriction laws" (p. 723). These alarming research documents provide us with a clear overview of the tough environment that the L&H insurance sector is about to evolve in.

Direct economic effects

As previously mentioned, *the Stern review on climate change* (2007) focuses on the potential radical economic effects of climate change on our global economy. To recall, the report mentions a potential overall loss of at least 5 per cent of global GDP every year (p. 15). This frightening data corresponds to the CRO Forum's prediction of a 45 per cent loss of Global GDP by 2100 if humanity follows an RCP 8.5 scenario.[26] In addition, as a result of the previously listed physical impacts of a 5°C warming path, such as heat waves, extreme weather patterns and epidemics, many assets would become stranded for obvious physical reasons. Indeed, such a hostile environment could cause steep increase in uninhabitable zones, including most of South Asia (Bourg, 2018, p. 61), and could result in a decrease in agricultural activities due to diminishing practicable lands. It is certain that the agriculture sector will be profoundly affected with almost 60 per cent yield loss by 2100 (CRO Forum, 2019, p. 6) due to the extreme conditions (heavy rains and droughts), thus leading the world into a potential widespread famine and mass migration to human survival-friendly higher latitude countries (p. 30). Besides agriculture, other water intense industries will strongly diminish as per the fading resources (p. 5). Finally, the tourism industry will also be seeing a strong impact in an RCP 8.5 future as temperature increases and climate patterns change. As an example, the European Tool-supported policy development for regional adaptation (ToPDAd) mentions that skiing tourism will have difficulties to adapt to climate change as the snow cover will deteriorate in most regions of Europe, causing consequent income losses for tourist-dependent areas such as the Swiss, German and Austrian Alps (ToPDAd, 2015, p. 3).

d) RCP 8.5 and the insurance industry

To conclude, we have observed that following a "business as usual" path would not only lead to a catastrophic impact of on the environment, our society and the economy, but such an unfriendly environment could also represent a serious issue for the (re)insurance industry as *"the social and political consequences could significantly deplete the economic strength of societies globally so, for many, insurance may become a thing of the past"* and *"government*

[26] A 2018 global GDP of USD 80 trillion is used as a basis (CRO Forum, 2019).

may struggle financially, impacting their ability to support catastrophe pools or other insurance type activities, or to fund catastrophe responses" (CRO Forum, 2019, p. 30), hence putting additional pressure on the insurance industry. Significantly, both P&C and L&F branches of the insurance industry would suffer from such an extreme environment.

On the one hand, P&C underwriting will see the strongest impact on its Property, Specialty Lines[27] and Motor due to direct exposure to weather events including stronger tropical cyclones and larger wildfires. As seen in chapter 1, physical damages to property have historically dominated claim costs within the P&C segment, hence increasing *"the significant capital requirement under the Solvency II regime"* (p. 27). However, it remains a central question to know whether the capital required under Solvency II would suffice in an environment as inhospitable as the one described in the lines above. In addition, the Liability branch of the insurance industry could also feel the indirect effect due to potential changes in legislations and legal norms. In fact, *"a shift in the public mood around climate might encourage climate-related liability actions"* (p. 27) leading to uncertainties on potential future claims and related costs of such insurance. Nevertheless, we have also observed that modifications in climate patterns may open new opportunities for P&C insurers. Indeed, ice-free arctic summers will open additional trade routes and create new business opportunities for marine insurance. The exploitation of newly discovered arctic resources, oil and gas amongst many others, will provide P&C insurers with additional infrastructure coverage opportunities, leaving space for private insurance solutions in a +5°C world. However, this hostile environment may result in complex geopolitical and environmental risks, causing price escalation for insurance premiums, thus making *"insurance an expensive commodity available only to wealthier in society"* (p. 30) and significantly increasing the protection gap mentioned in chapter 1.

On the other hand, the L&H branch is also directly exposed to the effects of climate change in a +5°C temperature rise scenario, which could include extreme temperature, lack of access to water and famine, mass migration and elevated morbidity rates, thus heavily impacting new business for L&H insurers (p. 32). Indeed, as previously mentioned, the WHO expects 250,000 additional deaths per year between 2030 and 2050 due to epidemics, heat strokes and other heat related consequences (WHO, 2018), demonstrating a strong correlation between

[27] The specialty lines insurance market consists of the segment where the more difficult or unusual risks are written such as Marine and Aviation (tennant.com, n.d.).

morbidity, mortality and global warming and creating a risk of adverse claims experience[28] for the insurance industry (CRO Forum, 2019, p. 31). In addition to the direct physical impacts caused by the heat, it has been established that climate change could cause a steep increase in the amount of mental health claims, leading to higher premium prices and making coverage unaffordable for a part of the society. It is also interesting to mention that *"the extent to which the life insurance sector could be affected by climate change-related risk depends on the type of insurance products across different regions. Insurance portfolios that pay out if the insured person is alive (such as annuities and pension) and in the event of death (for example, term and whole life) are exposed to longevity and mortality risks respectively"* (2019, p. 31). Furthermore, "*income and health insurance portfolios are generally short-term products which are exposed to morbidity risks"* (p. 31) whereas *"most health and disability covers are annually renewed, so are closer to P&C lines from a pricing perspective, and therefore less susceptible to mortality and morbidity changes"* (p. 32). In other words, losses caused by mortality and morbidity rates depend widely on the diversification of the insurances' portfolio.

As a conclusion, a future similar to the one portrayed by the RCP 8.5 scenario could cause far-reaching insurability issues and trigger a serious blow to the industry's resilience. Indeed, as exhibited, some geographical zones may become uninsurable as premiums would become unaffordable to the local population, hence increasing the protection gap that the (re)insurance industry has worked on narrowing during the past decades. In these decimated and high-risk regions, State-led insurance systems such as the ones described in section 1.1.3 could be the only viable options, and this, of course, further depends on whether a stable governmental structure could sustain in such an environment.[29] Private insurers and reinsurers will also have to carefully analyze what is considered to be *"truly uninsurable"* as taking wrong decisions could damage their resilience and limit their ability to cover the insurable (CRO Forum, 2019, p. 24). It is also worth recalling that a +5°C scenario would strongly impact Earth's system tipping points, leading to a state of uncertainty that is highly incompatible with the insurance industry's climate modeling, amplifying the difficulties to evaluate risks and possibly affecting the industry's resilience to severe weather events (Lloyd's, 2014. p. 4). The potential temporal correlation of the different physical risks (ie.,

[28] Averse claim is a claim to property by one in possession thereof asserted against a trustee or receiver in bankruptcy (USLegal.com, n.d.).

[29] Please refer to sub-chapter 2.3 on society collapse for an overview of the sustainability of democratic governments during a state of collapse.

tropical cyclones, wildfires, heavy rainfalls, et…) in an RCP 8.5 scenario are non-negligible and could result in an accumulation of losses across several lines of business, thus causing a severe threat to the much needed global risk diversification of the insurance industry's business model as per chapter 1 (CRO Forum, 2019, p. 25). This accumulation of risk may result in considerable solvency issues and great difficulties for the industry to operate. Therefore, it can be concluded that an RCP 8.5 scenario hostile environment would significantly weaken the insurance industry and cause serious harm to its long-term resilience.

But what if this nightmarish scenario, as described in the lines above, would also be accompanied by a financial and economic meltdown such as the 2007-08 systemic crisis?

2.1.3. The next financial and economic meltdown: the final blow?

After having extensively reviewed the environmental front of what could be foreseen as a worst-case scenario for humankind and the insurance industry, the following section will aim at providing a comprehensive overview of how a financial structural and systemic crisis could come as a supplementary layer to this already catastrophic picture. In this regard, we will begin by discussing the multiple effects of the 2007-08 structural crisis[30] on the global economy and the insurance industry, as this case study provides a good overview of the resilience of the current financial ecosystem, of which (re)insurances are prominent actors. We will then further examine the insurance industry's potential exposure to systemic risk and will conclude by discussing the industry's current and future economic resilience to shock events.

2.1.3.1. The 2008 financial crisis: a global, systemic and structural event

To begin, it must be clarified that the goal is not to review the various causes of the 2008 crisis as the subject has already been extensively covered and is not of a major interest to this paper. Recent literature from authors such as Andrew Ross Sorkin (Sorkin, 2009) and Timothy F. Geithner (Geithner, 2014) lengthily covers the numerous causes of the 2008 event, but it is mostly the devastating consequences of the financial crisis that are of interest to us. Indeed, it will be demonstrated that this financial crisis is a perfect example of the global financial system's brittleness and could, if taking place in a +5°C environment, lead to an impossible survival of the contemporary insurance industry's business model. Certainly,

[30] This paper will be using the terms "2008 crisis", "2008 event" and "2007-08 crisis" interchangeably to refer to one and unique event: the financial crisis that began in 2007-08.

the recent increased interconnectivity of the financial network consisting of a complex web *"of receivables and obligations linking balance sheets of countless intermediaries such as banks, hedge funds or insurances"* has created an ideal environment for future contagions (Servigne, 2015, p. 61, our translation). A most insightful illustration of the increased interconnectivity and complexity of the financial ecosystem is conveyed by the example of the growth in page number of the Basel regulatory framework. Surely, the size of the Basel framework, aimed at promoting stability in the international financial system (Perry, 2019) went from 30 pages in 1988 (Basel I) to 616 pages in 2010 (Basel III) and clearly demonstrates the increased complexity of the economic sector (Servigne, 2015, p. 109). An additional example comes through the recent creation of new financial products contributing to enhancing the complexity of financial markets, such as Collateral Debt Obligations (CDO) and Credit Default Swaps (CDS) which are often said to generate an increased obscurity and lack of transparence within financial markets (pp. 109-110). As a clarification, a CDO is a *"structured financial product that pools together cash flow-generating assets and repackages this asset pool into discrete tranches that can be sold to investors"* (Chen, 2019), whereas a CDS is a *"financial derivative or contract that allows an investor to swap or offset his or her credit risk with that of another investor"* (Kuepper, 2019).

Moreover, recent literature focused on the short and long term effects of the 2008 crisis (essentially emerging from the U.S.), considers the 2008 financial crisis to be the worst economic disaster since the Great Depression of 1929 (Merle, 2018) and carries a strong emphasis on the global, systemic and structural facets of the event. Indeed, the "structural" aspect of this crisis, as opposed to "cyclical crisis" should be highlighted, as it is a type of event with the deepest and strongest societal effects. Undeniably, cyclical crisis convey a much lesser impact than structural crisis, which are characterized by devastating impacts to the real economy and followed by long period of slow economic progress, as proven by the post-2008 era and its profound modifications (Baira Dering, 2017). The 2008 crisis carried drastic short-term effects on financial markets with U.S. stocks losing nearly USD 8 trillion between late 2007 and 2009 (Merle, 2018). Moreover, the resilience of well-known financial institutions was deeply challenged with a long list of bankruptcies and state bailouts. Indeed, pictures of Lehmann Brothers Holding Inc. employees leaving their New York head office with a paper box in their hands on September 15, 2008 was widely covered by international media and came as a strong challenge to the "too big to fail" idea of the time (Lioudis, 2019). On the state bailout front, the Fanny Mae and Freddie Mac case study comes as one of the

most prominent examples, with the U.S. Treasury Department purchasing USD 100 billion in their preferred stock and mortgage-backed securities in order to save both institutions (Amadei, 2018). On a wider scale, the global *"big bank bailout"* is most commonly known to be of USD 700 billion within the U.S., but the Special Inspector General for the U.S. Troubles Asset Relief Program (TARP) mentions a total government commitment of about USD 16.8 trillion for the 2008-2015 period (Collins, 2015).

In addition to these financial sector giants going bankrupt or being saved by governments, it is also primordial to mention the deep cascading impact of the financial crisis on the real economy. In fact, the 2008 event's repercussion on actual people can be seen through the extreme U.S. unemployment rate that skyrocketed to as high as 10 percent in 2009 and took over a decade to come back to pre-crisis levels (see figure 26).

Figure 26: U.S. Post-crisis unemployment rates (in %) from 2007 to 2019.
Source: Tradingeconomics.com, statistics from U.S. Bureau of Labor.

In all, it is estimated that the event led to Americans loosing almost USD 9.8 trillion in wealth *"as their home values plummeted and their retirement vaporized"* (Merle, 2018). Furthermore, the long-term effects of the 2008 meltdown are still felt in 2019 with worldwide profound structural changes on the economic front, especially through new regulations such as the previously mentioned Basel II and III (banking sector) and the Solvency II (insurance sector) frameworks (Gatzert & Wesker, 2012, p. 539). The 2008 event has also led to deep global geopolitical transformations with the rise to power of populist candidates such as Donald Trump in the U.S. and Jair Bolsonaro in Brazil (Green, 2018), leading, among other things, to the current trade war between the U.S. and China (Dollar, 2018).

The multiple effects of the 2008 crisis revealed within the lines above should come as a clear demonstration of the interconnectivity and weaknesses of our global economy, potentially leading to drastic cascading geopolitical effects. In fact, financial downturns, such as the 1929-39 Great Depression and 2007-08 financial crisis lead to deep impacts on the real

economy causing actual people to suffer from the collapse of such a fragile house of cards. The 2008 event led to seriously questioning the financial system's resilience, but a query remains on the insurance sector's resistance to such a global crisis. How did the insurance industry do during that 2007-2008 timeframe?

2.1.3.2. The insurance industry and the 2008 crisis

As described in previous sections, the insurance industry would feel strong and direct impacts from an RCP 8.5 type environmental scenario. To further develop our argument, it is interesting to ask the question of whether and to what extent the insurance industry is resilient to a financial crisis. Could such an event weaken the sector and serve as a trigger to its collapse? The following lines will aim at answering these various questions by analyzing the different roles and (re)actions of the insurance industry during the 2007-08 financial crisis. This breakdown will help us get a better grasp of the industry's resilience to such an event and extrapolate the industry's potential reactions to such a crisis but on a much more hostile and damaged planet.

To begin, the non-negligible responsibility of the insurance industry towards the 2008 financial crisis has been emphasized in a 2009 OECD report. In fact, "*financial instruments used in the massive credit risk transfer prior to the financial crisis have had at their core, in many cases, insurance-like innovative financial instruments"* such as CDS (Schich, 2009, pp. 2-3). Indeed, the role of financial guarantee insurance in *"wrapping, and elevating the credit standing of complex structured products"* to make them more attractive to investors (OECD, 2011, p. 11) has strongly contributed to the global distribution of *"toxic assets"*. For the sake of clarification, "toxic assets" are assets that become illiquid due to the disappearance of the secondary market for buying and selling them. This term was used, in the context of the 2008 financial crisis, to describe *"the drying up of the market for mortgage-backed securities, CDO and CDS"* (Chen, 2017). During the 2008 event, these assets became increasingly difficult to move, *"resulting in large collections of these deeply troubled assets sitting on the books of various financial institutions. As the decline in value continued, these assets threatened the solvency of the banks and institutions that were unable to unload them"* (Chen, 2017). It is interesting to note that some insurance companies "*actually accumulated significant exposure to credit default derivatives on one or the other side of their balance sheets"* (Schich, 2009, p. 3) making them more unstable during the crisis.

A good example of such behavior is the case of AIG Incorporated (AIG). Studying the financial difficulties of such a major player provides a good indication of the sector's capabilities to survive a catastrophic financial event. Certainly, the *"narrowly avoided collapse of AIG Inc."* is of particular interest as it demonstrates the fragility of an institution considered to be one of the world's largest insurance groups and widely seen as part of the *"too big to fail"* family (Merle, 2017). Interestingly, AIG, a global financial service holding company with "*71 U.S. based insurance companies and 176 other financial service companies"* (OECD, 2011, p. 11) and about USD 1 trillion in assets in 2007 lost a massive USD 99.2 billion during the 2008 financial turmoil (McDonald & Paulson, 2015). A 2015 research paper from the Kellogg school of management at Northwestern University offers additional knowledge on the reasons for such troubles. This research concludes that *"the company's credit default swaps are generally cited as playing a major role in the collapse, losing AIG $30 billion. But they were not the only culprit. Securities lending, a less-discussed facet of the business, lost AIG $21 billion and bears a large part of the blame"* (McDonald & Paulson, 2015). This example of a failing institution clearly demonstrates the narrow link between an insurance company's investments and its long-term resilience. In fact, on September 16, 2008 the Federal Reserve Bank of New York stepped in with a USD 85 billion loan in order to save AIG (McDonald & Paulson, 2015), amount that swelled to USD 182 billion within the following 10 years (Merle, 2017). In addition, the AIG case study perfectly illustrates the fact that *"specific incentive problems could arise in complex financial groups when different parts of the group pursuing different activities (and generating different risk profiles) either use the same capital base or when some parts of the groups either explicitly or implicitly benefit from capital raised via less risky members of the group"* (Schich, 2009, p. 3), or in other words, there seem to be a strong correlation between the complexity of the financial group and potential difficulties. This is definitely something to keep in mind when studying global and highly complex (re)insurance groups such as Allianz, AXA or Swiss Re. On a global level, and as described in figure 27, it is also interesting to mention that four major insurance groups *"accounted for 54 per cent of all write-downs worldwide, namely AIG, ING Groep N.V., Am Ambac Financial Group Inc and Aegon NV"* with amounts valued at *"USD 98.2 billion, USD 18.6 billion, USD 12.0 billion and USD 10.7 billion respectively"* (OECD, 2011, P. 12). As per complete transparency, it is primordial to further indicate that most insurers who encountered serious difficulties during the crisis, such as AIG, where brought down by their *"quasi-banking"* activities, similarly to "*monoliners concentrated*

exclusively on financial guarantees and CDS writing and trading" (The Geneva Association, 2010, p. 3). Finally, the Geneva Association notices that "*more than 90 per cent of State support to insurers went to those with significant, failing non-insurance businesses"* (p. 3).

	Writedown & Loss	Capital Raised	Shortfall
Insurance companies			
American International Group (AIG)	98.2	98.1	-0.1
ING Groep N.V.	18.6	24.1	5.5
Ambac Financial Group Inc	12.0	1.4	-10.6
Aegon NV	10.7	4.0	-6.7
Hartford Financial SVCS GRP	9.7	6.4	-3.3
Fortis	9.3	22.7	13.4
Swiss Re	8.5	2.9	-5.6
Metlife Inc	7.2	4.0	-3.2
Allianz SE	7.0	2.0	-5.0
Allstate Corp	6.6	0.0	-6.6
Prudential Financial Inc	6.6	5.9	-0.7
MBIA Inc	5.7	1.0	-4.7
Aflac Inc	5.2	0.0	-5.2
Genworth Financial Inc-CL A	4.8	0.6	-4.2
XL Capital	4.0	2.6	-1.4
CNA Financial Corp	3.1	1.2	-1.9
Zurich Financial	3.1	0.0	-3.1
Other	40.7	14.8	-25.9
Total	261.0	191.7	-69.3
memo item: total US	188.9	127.4	-61.5
memo item: total European	69.0	59.9	-9.1

Figure 27: Write-downs, credit losses and capital raised by major insurance companies as of January 2010 (in billions, USD).
Source: OECD, 2011, p. 12.

The 2008 crisis has revealed the concentrated exposures to credit and market risks of certain insurance industry companies, such as U.S. mortgage and financial guarantee insurance groups and some insurance-dominated financial entities (Schich, 2009, p. 2), thus leading to the vital question of the solvency of some "to big to fail" establishments. In this regard, figure 28 describing the solvency margin of OECD and non-OECD countries offers a good overview of the insurance industry's solvency during the 2007-08 timeframe. For the sake of clarification, the OECD describes its solvency margin (or solvency ratio) as the ratio between the available solvency capital and the required solvency capital expressed in percentage (OECD, 2011, p. 33). In other words, the solvency margin indicates how ready a company is to meet unforeseen exigencies. The OECD further adds that *"the purpose of the table is to highlight trends within a country, not across countries, given differences in solvency regulation"* (p. 33). With a global overview, figure 28 demonstrates that most insurance companies *"still display solvency buffers over minimum statutory solvency requirements"* (p. 29), thus leading to additional confidence for the future. Nevertheless, available solvency levels in 2008 reached a minimal state in certain countries such as Spain and its Life segment

or *"to a lesser extent, France, Italy, and Portugal"* (p. 29) leading to the important raise of capital as demonstrated in figure 28.

Country	Life insurance		Non-life insurance		Composite undertakings	
	2007	2008	2007	2008	2007	2008
AUS	..	..	201.9	185.9	..	..
AUT	163.9	202.3	434.2	539.6	..	..
BEL	160.4	186.5	394.5	451.1	214.0	207.9
CAN	222.4	225.6	240.1	236.4	..	..
CHE	..	201.8	..	325.3	..	..
CZE	284.5	..	393.8	..	..	..
DEU	207.2	..	308.4	..	..	..
ESP	198.1	112.6	342.6	321.2	..	..
FIN	359.0	242.8	372.6	287.3	..	..
FRA	259.5	168.9	705.2	450.1	262.6	139.4
HUN	..	202.2	..	..	..	..
IRE	296.0	217.4	359.4	368.7	..	..
ITA	191.0	170.5	274.2	263.1	..	..
LUX	158.6	164.5	295.4	289.2	..	..
MEX	222.5	290.4	161.4	170.4	178.1	172.4
NLD	262.6	..	275.0	..	..	..
POL	347.3	285.8	667.0	642.7	..	..
PRT	148.4	139.6	221.0	200.0	165.4	154.3
SVK	247.2	363.8	672.6	608.0	270.3	311.6
TUR	295.6	309.4	140.0	148.0	366.4	351.0

Figure 28: Solvency margin by type of segment in selected OECD and non-OECD countries as of January 2010 (in %).
Source: OECD, 2011, p. 29.

However, it is also significant to mention that all has not been negative during the 2008 turmoil and that the insurance business essentially stood out as a good player within the financial sector. Indeed, the insurance business model as described in chapter 1 with its well-built interrelations between insurers and reinsurers proposes some stabilizing features for the overall financial system (The Geneva Association, 2010, p. 3). As detailed by the Geneva Association *"insurance is funded by up-front premiums, giving insurers strong operating cash-flow without requiring wholesale funding. Insurance policies are generally long-term, with controlled outflows, enabling insurers to act as stabilizers to the financial system. During the crisis, insurers maintained relatively steady capacity, business volumes and prices"* (p. 3). Actually, by virtue of a longer-term investment horizon (especially Life insurers) and a conservative investment approach, the insurance industry widely contributed to stabilizing the economic environment and suffered a much lesser loss than its banking counterparts (OECD, 2011). As a confirmation, figure 29 demonstrates that the insurance industry reported write-downs and credit losses of "only" USD 261 billion in 2010, thus

being very far from the overall banking sector's USD 1,230 billion losses (OECD, 2011, p. 12).

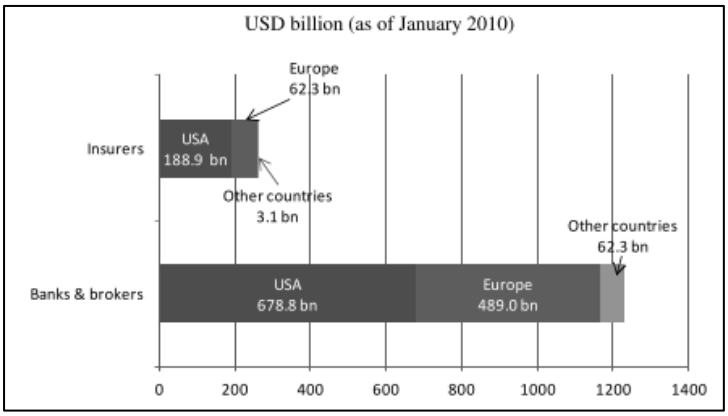

Figure 29: Write-downs, credit losses in the banking and insurance sectors worldwide as of January 2010.
Source: OECD, 2011, p. 12.

To conclude, it can be stated that the 2008 crisis came as a transformational and challenging event for the entire (re)insurance industry as its core business model and solvency were deeply tested, thus requiring further regulations such as the previously mentioned European Solvency II framework (Affolter, 2009). The idea that the insurance industry served as a stabilizer should also be pointed out, as this will influence its long-term resilience when compared to banking institutions, for example. Nevertheless, in the wake of the 2007-08 crisis, the subject of the insurance industry's protection to systemic risks came as one to be addressed promptly since it could challenge an entire industry. The next sub-section will discuss systemic risk within the insurance industry and the current state of its regulations so as to further assess its economic resilience.

2.1.3.3. The insurance industry, systemic risk and macroprudential policy

The exposure to systemic risk of various financial and economic sectors has been widely discussed within international institutions as it was considered to be a major contributor to the 2008 financial crisis (Chen, 2018a). The insurance industry is no exception to this trend with inquiring documents from the EIOPA (2019), the International Association of Insurance Supervisors (IAIS) and the Geneva Association (2010) amongst many others.

Indeed, in March 2019, the EIOPA released a noteworthy discussion paper on the theme of systemic risk and macroprudential policy within the insurance industry declaring that *"the financial crisis has shown the need to further consider the way in which systemic risk is created and/or amplified, as well as the need to have proper policies in place to address*

those risks. So far, most of the discussions on macroprudential policy have focused on the banking sector due to its prominent role in the recent financial crisis" (EIOPA, 2019, p. 7). For the sake of clarification, this paper will use the FSB's definition of systemic risk, as it is known to be the most commonly referenced one (The Geneva Association, 2010, p. 23) and is extremely similar to EIOPA's own definition in article 22 of its Regulation (EIOPA, 2019, p. 9).[31] Systemic risk is thus defined as *"the risk of disruption to the flow of financial services that is (i) caused by an impairment of all or parts of the financial system; and (ii) has the potential to have serious negative consequences for the real economy"* (p. 23). So as to further refine this definition, figure 30 provides a comprehensive and detailed overview of EIOPA's approach to systemic risk within the insurance sector.

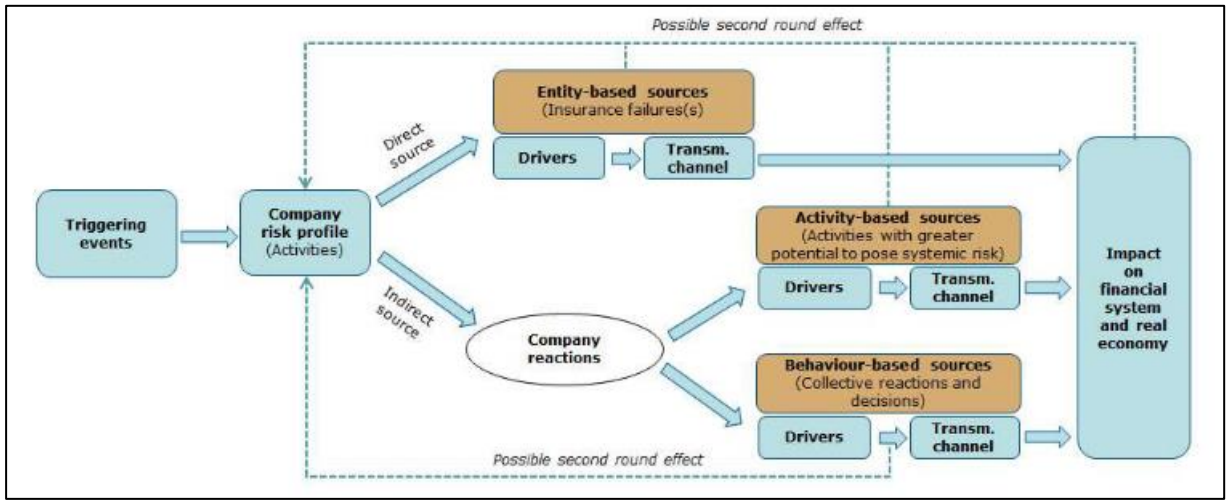

Figure 30: EIOPA approach to systemic risk.
Source: EIOPA, 2019, p. 13.

According to this approach to systemic risk, a triggering event, defined as an *"exogenous event that has an impact on one or several insurance companies"* (EIOPA, 2019, p. 12), seriously challenges the entire financial system and the real economy through the destabilization of key players within the insurance industry. In fact, the document mentions a wide array of triggering events from macroeconomic factors (e.g., unemployment, inflation, etc…) and financial factors (e.g., financial innovation, state of the banking system, etc…) to non-financial factors (e.g., demographic changes, legislative changes, natural catastrophe).[32] It should be emphasized that severe weather events, as described in the previous lines, are

[31] Article 22 of EIOPA Regulation defines 'systemic risk' by reference to Article 2(c) Regulation (EU) No. 1092/2010 (EIOPA, 2019, p. 9).

[32] Please be advised that an extensive list of triggering events, systemic risk drivers and main transmission channels can be found in appendix 5.2 of this document.

truly considered as a potential trigger to a systemic crisis, thus confirming the narrow link between the environmental RCP 8.5 scenario, as presented in this chapter, and a global financial crisis.

Considering the above, current macroprudential policies, most commonly defined *"as a framework that aims at mitigating systemic risk (or the build-up thereof), thereby contributing to the ultimate objective of the stability of the financial system and, as a result, the broader implications for economic growth"* (EIOPA, 2019, p. 9) should be regarded as a significant subject when discussing the sector's resilience to triggering events. In fact, EIOPA considers that traditional insurance activities are *"generally less systematically important than banking"* but could also *"potentially create or amplify systemic risk"* (p. 11). In this regard, the institution considers that the insurance industry should adopt a macroprudential approach as such policies focused on insurance could serve as a suitable crisis prevention tool (pp. 11-12). Since this paper is not meant at extensively covering all available macroprudencial policies, we will be mentioning but a few of them without going into further details. The key message should be that the insurance industry is subject to systemic risk and that regulators are working on developing tools aimed at enhancing financial stability.[33] As a matter of fact, EIOPA's research document points out that several tools proposed by the Solvency II framework could potentially have microprudential impact, even though it is *"not a macroprudential framework*" (EIOPA, 2019, p. 17). In addition, it is said that the current framework could be enhanced by various tools such as Recovery plans and Systemic Risk Management Plans (EIOPA, 2019, p. 19) (see appendix 5.3).

To conclude, systemic risk seems to be an item to be taken seriously when studying the insurance industry's resilience to a future nightmarish environmental scenario. Indeed, as previously demonstrated, a +5°C climate warming could enhance the strength of severe weather events (i.e., tropical cyclones), thus serving as a potential trigger to a systemic financial crisis. It also seems important to recall the increasing dependency of the reinsurance sector on capital markets through Insurance Linked Securities (see sub-section 1.1.4.2), thus amplifying the risk of a potential collapse within the insurance industry in the case of a global economic downturn. Indeed, a 2008 type of financial crisis could severely reduce reinsurance capacity and cause the breakdown of the (re)insurance house of cards even if the various

[33] Financial stability and systemic risk are two strongly related concepts. Financial stability can be defined as a state whereby the build-up of systemic risk is prevented (EIOPA, 2019, p. 9).

macroprudential tools, if added to this equation, could serve as financial stabilizers limiting the damages and boosting its resilience to future shocks.

But how does the future look like from a financial point of view? Has the financial sector really learned from the 2007-08 experience and become more resilient?

2.1.3.4. What about the future? An economic outlook

As seen in the lines above, the 2008 financial crisis has had a deep impact on the entire financial system and the insurance industry with the creation of additional regulations meant at stabilizing the whole structure. However, a central question remains: did this event that took place more than a decade ago help the financial sector to learn from its mistakes and become more resilient?

As a matter of fact, it is natural (and maybe a little naive) to believe that the society has worked on building a more resilient system after such a dramatic financial event and all of its collaterals, but a 2018 Sigma report from the Swiss Re Institute begs to differ. Indeed, this document which aims at providing a *"global economic and insurance outlook"* for the 2020s timeframe conveys a dark and unfriendly picture, as it states: *"overall, we do not think the global economy has become more resilient. On the contrary: ten years after the 2008-09 global financial crisis, the world economy remains ill-prepared for the possibility of a repeat event"* (Swiss Re, 2018a, p. 22). The Swiss company adds that *"major economies are now less well equipped to rebound from unexpected shocks than they were before the crisis"* (p. 22). What are the reasons causing Swiss Re to convey such a pessimistic view of our future?

As a first factor, the Swiss reinsurance company mentions the global economic growth trend which has significantly declined from about 5 per cent in 2006 to *"just about 3 per cent in 2018"* (p. 22). Secondly, the total debt ratio trend does not contribute to strengthening societal resilience (see figure 31). Indeed, the numbers are fairly higher in 2018, with a ratio equivalent to 318 per cent (or USD 247 trillion in absolute terms), compared to the 2008's 282 per cent (Swiss Re, 2018a, p. 22). Swiss Re further mentions that data from the *Global Debt Monitor* database of the Institute of International Finance (IIF) confirms the fact that risks *"have migrated from banks to non-financial corporate and government balance sheets"* (p. 22). This risk-bearing shift to governmental entities does not carry any positive news, as

we will see in the next sections that political stability is key to socio-economic resilience against the scenario of a total societal collapse.[34]

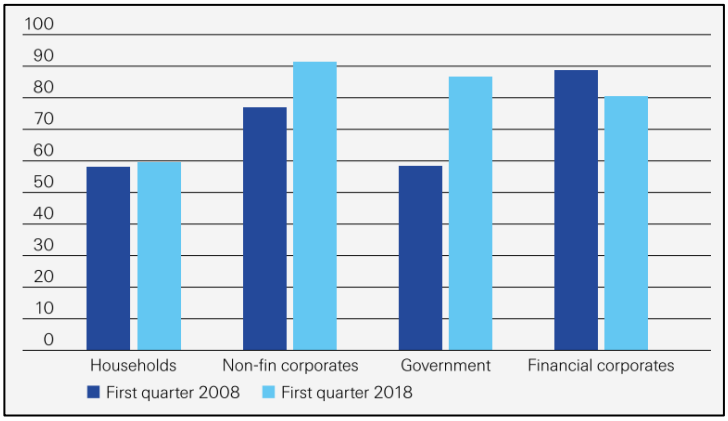

Figure 31: Global debt to GDP ratios (%).
Source: Swiss Re 2018a, p. 23. Data from Global Debt Monitor Database, Institute of International Finance.

A third, and most important factor stems from the financial market structure itself. Indeed, Swiss Re estimates that "*the Fed, ECB, Bank of England and Bank of Japan all own between 20 – 45 per cent of their domestic government bond markets"*, thus diminishing the risk-signaling function of Bond prices (Swiss Re, 2018a, p. 23). In addition to the above, the post-crisis low yield environment has forced Life insurers to modify their business models. The International Monetary Fund (IMF) also mentions that Life insurers have reduced the guaranteed returns on new policies (see figure 32) and have modified their product mix (IMF, 2017, p. 14) so as to increase their flexibility. In fact, *"the low yield environment has contributed to a large mismatch between guaranteed returns to policy holders (liabilities) and available investment yields (assets) for life insurers"*, thus leading to these modifications (Swiss Re, 2018a, p. 23).

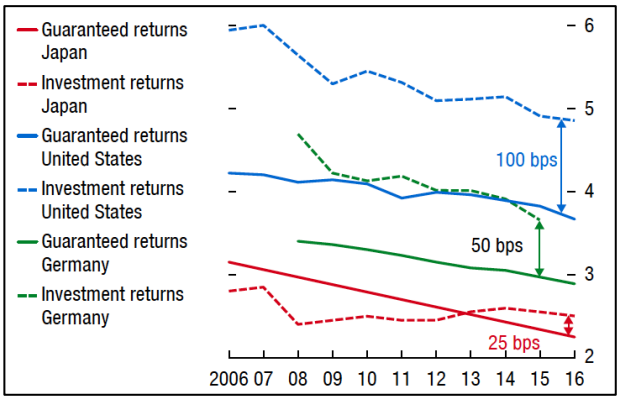

Figure 32: Average Investment Returns and Guaranteed returns of Life insurance companies (%, on existing mix).
Source: IMF, 2017, p. 14.

[34] Please refer to section 2.3.2. detailing the various elements of a collapse. Indeed, Orlov's third stage of collapse is on the political level (2013, pp. 123-194).

Finally, a fourth and last factor of anxiousness invoked by the Swiss Re institute is the ongoing tendency of several advanced economies to move towards less open systems. In fact, major economies in North/South America, Europe and Asia have shown some attraction towards President Trump's "America First" protectionist vision with its restrictions on trade and migration (Swiss Re, 2018a pp. 7-10). It is interesting to notice that trade tariffs are of importance to insurers as Swiss Re expects *"that global premium growth will be hit, particularly in marine and trade credit lines"* and further adds that *"a 1 per cent decrease in world trade reduces marine cargo premium growth by 0.89 per cent"* (p. 9). To conclude, the Swiss company observes that *"openness increases the exposure to crisis via contagion but arguably, openness also allows stricken nations to bounce back more quickly"* (p. 23).

Adding to the above, and as previously exposed in chapter 1, narrowing the various protection gaps would allow for additional societal resilience. However, when looking at the data proposed in figure 33, one can see that we are still very far from reaching an acceptable and economically plausible set of protection gaps worldwide.

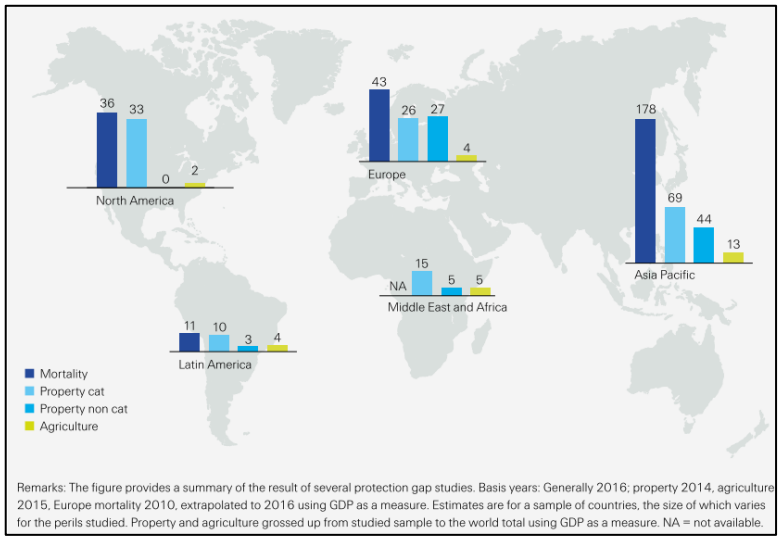

Figure 33: Protection gaps by line of business measured in terms of (risk) premium equivalents (USD billions).
Source: Swiss Re, 2018a, p. 26.

In fact, both mortality and natural catastrophe protection gaps have widened in a number of geographical areas during the past decades. As an indication, Swiss Re estimates the global mortality and property (cat and non-cat) gap to be of approximately USD 500 billion, representing 70 per cent of the current respective insurance market sizes or 0.6 per cent of the global GDP (Swiss Re, 2018a, p. 25). Mortality represents a consequent share of the total number as it is estimated to reach USD 270 billion, accounting for *"almost 90 per cent of the*

current size of the respective market premium" (p. 25). These various protection gaps confirm the existence of a humongous potential market growth for the insurance industry, but also clearly demonstrate the lack of societal resilience of some regions to extreme scenarios, such as the one presented in this chapter.

To conclude this section, it is evident that the fossil fuel driven society we live in is by far not ready for, or resilient against, a catastrophic scenario entangling an extreme global warming and a global financial crisis. Indeed, alarmist reporting from both environmental and financial entities does not demonstrate a "bright and shiny" future. On the contrary, it seems that we have entered an unstable and dangerous path by acting fast enough neither on the environmental nor on the financial fronts. Undoubtedly, the lines above have exposed the fact that the RCP 8.5 scenario is not as improbable as one might think since our society seems to pursue its "business as usual" path. On the economic and financial fronts, it appears that we have not entirely learned from the past when observing Trump administration's current deregulation trend in the U.S. (Brookings, 2019). Furthermore, the economic outlook brought by Swiss Re reports a future full of danger and instability, demonstrating that the resilience of our economic system does not appear stronger than it was before the 2008 crisis. The shadow of a repeating financial downturn should be very worrisome as it could deeply impact financial markets and the real economy, thus lowering our response capabilities to extreme weather events and other global warming impacts. The above observations could make anyone nervous, as they show the urgent need to be working on a more resilient system, work that is currently not moving forward due to the global political inertia on the subject. However, the insurance industry's potential role as a financial stabilizer and its longer-term vision should not be ignored, as it could become useful in the near future.

As we turn to such a potential catastrophic future, a logical answer would be to inquire about the various thoughts and actions that have brought us here and whether some alternative thinking could lead to a different and less painful outlook. Could the perception of risk and catastrophes conveyed by the insurance industry be influencing the way we structure our society and react to frightful events? Is this very specific societal vision affecting our resilience to shocks? As previously established, global warming and the financial sector's increasing complexity have brought us into a VUCA world in which we develop a tendency to excessively gather and analyze data (Vallat, 2014, p. 49), but a further question remains on the actual possibility (and usefulness) of modeling and evaluating every possible risk in such

an unstable environment. Are there events that are just impossible to model? Events that could turn the situation into a much worse (or better) scenario? Subsequently, is humankind's dominance over nature so powerful that it could forecast the Earth's future reactions and avoid total collapse? Or is this vision a part of a specific historic paradigm that was built around our society? The next sub-chapter will deep-dive into the origins of the notions of risk and catastrophes so as to further evaluate our preparedness to an extreme future.

2.2. Can we foresee catastrophes and risks? A philosophical approach

Chapter 1 and the first section of this chapter have demonstrated how dependent the insurance industry is on the notion of "risk" and how necessary it is for it to plan and model the future. Indeed, in order to fix premium prices, (re)insurances have to possess an excellent overview of the different risks, including climate risks. Unfortunately, it has also been observed that climate change will bring its part of deep uncertainty in regards to the Earth system's reaction to human interferences, uncertainty further enhanced by the growing complexity of financial systems.

Taking these various observations into consideration, the following section will investigate whether the deeply rooted notion of "risk" is the most adequate one when entering into an environment such as the one described in this paper. In addition, and to deep dive into the concept of modeling, this paper will challenge humankind's belief that it can actually predict and model the future. Finally, it will turn to the way the current society perceives catastrophes and consider the existence of alternate approaches, different from the one that has brought humanity on the brink of a catastrophe.

2.2.1. Can we still talk about risk?

As the reader may have noticed, the notion of risk has covered many pages of this paper. However, we have also observed that the insurance industry has been facing growing difficulties in analyzing and calculating risk within the uncertainty of a global warming environment. As a consequence, this section will question the adequacy of using the notion of risk in such a surrounding by examining the origins and the prerequisites of what Ulrich Beck calls *"the risk society"* (Beck & Ritter, 1992). We will then turn to the thought-provoking notion of "transcendental damages" brought forward by Dominique Bourg in his books *Du risque à la menace* (Bourg, Joly, & Kaufmann, 2013) and *Une Nouvelle Terre* (2018). As we

are about to discover, the notion of risk carries a very specific history and scientific background requiring certain prerequisites to assure its existence. In this regard, Dominique Bourg's observations (2013, 2018) on the subject are of utmost interest as they offer a holistic approach from an environmental and philosophical expert.

2.2.1.1. Risk: historical background and prerequisites

To begin, it is necessary to provide a brief historical background on the birth and development of the notion of risk in order to fully comprehend the setting in which it was established and the reasons why it may not be the most accurate tool to use in the current context of global warming.

a) A paradigm of scientific certainty

The way we commonly use the term "risk" was born during the notorious argument between Rousseau and Voltaire following the November 1755 Lisbon earthquake. As detailed by Bourg (2018), Rousseau's approach in terms of human responsibility widely differed to Voltaire's vision of the event as a lack of divine providence (pp. 55-56). Consequently, as historian Grégory Quenet confirms, *"the most frequently mobilized historian reference by non-historians remains Jean Delumeau, whose work on fear reinforces the partitioning between times of catastrophes and times of risk, describing a medieval society under the constant threat of epidemics, God, witches, etc. (Delumeau, 1978). The earthquake of Lisbon, in 1755, appears as the event that puts an end to this paradigm"* (2010, our translation). In other words, the 1755 event supposedly made the western society transfer from a paradigm where catastrophes were conceived as supernatural events (the times of catastrophes) to a science base paradigm where natural phenomenons are subject to scientific knowledge (the times of risk). However, Gregory Quenet and Dominique Bourg, both warn not to overly infantilize past generations and overuse simplified dualistic models as *"humans have probably never surrendered blindly to the gods"* (Bourg, 2018, p. 56, our translation). Nevertheless, it remains interesting to observe that the notion of risk has developed in a timeframe of evolving scientific knowledge and a very specific vision of science. As a matter of fact, Alain Papaux, Law professor at the University of Lausanne, describes "modern" science,[35] background in which the notion of risk was born, as part of a

[35] Alain Papaux's *Droit, Société et Environnement* master class details the evolution of the conception of science from a "modern science" full of certainty to a "contemporary science" leaving space to uncertainty and subjectivity.

paradigm where the *"real"* is deterministic and mathematizable. In this paradigm, "truth" is considered as "objective" and "absolute" and detached from any cultural influence (personal communication, 2017). In other words, the "modern" paradigm, originating from authors such as Descartes, Lavoisier and Kant, conveys a sense of certainty and carries the idea that humans can dominate nature with their increasing knowledge. In this regard, the parallel between the above paradigm and the growingly complex modeling and risk calculations developed by insurers should be emphasized as it points to this sense of certainty and confidence that we, humans, can control nature as a whole by planning how it will act in the future.

b) Prerequisites: Individualism and money

In addition to the specific scientific surrounding in which the notion of risk was born, Bourg explains that the said notion requires certain prerequisites to exist. Indeed, as per this author (2018, p. 56), Rousseau's allocation of risks to individual responsibility marks the rise of the *"society of individuals"*. Bourg further clarifies that *"it is of course necessary to understand "individual" in the moral sense, and not only in the physical sense, that is to say by virtue of a society in which the individual detaches itself from the group"* (p. 56, our translation). As a matter of fact, this very specific vision of society emerged during the contract philosophy era (17th and 18th century) with authors such as Jean Jacque Rousseau and his famously known *Social Contract* (1762), affirming, amongst many other things, that the individual comes ahead of the group. It is within this particular vision of society that the insurance system and risk have developed into what they are today and have caused *"individuals to detach themselves from each other and individually take risks, as they know that they are partially protected by an insurance safety net"* (Bourg 2018, p. 57).

In addition to this *"society of individuals"*, the elaboration of money can be considered as a second prerequisite to the expending use of the notion of risk (p. 57). Indeed, when looking at the insurance business model detailed in this paper, one can observe that it could not exist without exchange of money in the form of country currencies. Certainly, insurance premiums and claim compensation mechanisms are two examples of the insurance industry's close relationship to money. Furthermore, when going back to the insurability criteria presented in chapter 1, one can see that the absence of money would not allow the much-needed risk quantifiability, as risks are commonly evaluated in monetary values. Consequently, it is impossible to deny that *"risk goes hand in hand with monetary compensation mechanisms"*

(p. 57) and more importantly *"these mechanisms make sense only if the risk, or more precisely its potential realization, impacts only a small number of individuals, but never the group or the whole of society"* (Bourg, 2018, pp. 57-58). Indeed, let us not forget that the diversification of risk represents a very important strategy to insurers, strategy that would not exist without the idea of money as a *"universal equivalent"* (p. 58).

2.2.1.2. Times have changed: risk vs. transcendental damages

Unfortunately, as witnessed in the first section of this chapter, humankind's impact on the environment has deeply evolved since the times of Voltaire and Rousseau. Humankind has increasingly become a global force through globalization and the "Great acceleration"[36] presented earlier provides a perfect overview of the fact that we have entered into a new era most commonly known as the Anthropocene. Our destructive and systemic impact on planet Earth remains unchallenged, hence creating an environment in which the notion of risk becomes less and less appropriate. Indeed, as clarified by Bourg the use of "risk" may lead to a *"biased"* and *"attenuated perception"* of this era in which *"we have been progressively evolving since the 1950s"* (2018, p. 55). In parallel to these planet-wide structural modifications, Professor Papaux considers that scientific perception has deeply evolved since the "Modern" science era leading us into a new "contemporary" paradigm. In fact, prominent literature from authors such as Ilya Prigogine (1997)[37] and Michel Serres (1990)[38] offers a very different approach to our relationship with science and nature when compared to the "modern" vision. Certainly, in this contemporary paradigm, the modern scientific "certainty" gives way to contemporary "emerging properties" or "uncertainty" and "absolute truth" becomes "likelihood", "relevancy" and "point of view" (personal communication, 2017). This deep structural change in the way science perceives certainty leads to potential queries on the relevance of the notion of risk as it seems to be based on an outdated and unfit paradigm.

In addition to this "revolution" in paradigms, the deep and drastic damages caused by humans to the environment represent yet another important challenge to the notion of risk and its prerequisites. Indeed, as previously explained, the impact of our actions has cascaded into

[36] See figure 13, for a detailed overview of the "great acceleration".

[37] Iliya Prigogine's *The end of certainty* provides a challenging overview of the concept of certainty carried by modern science (Prigogine & Stengers, 1997).

[38] His book, *Le contrat naturel* proposes an interesting overview of our relationship to nature (Serres, 1990).

drastic damages deeply hurting our biosphere[39] on a global scale. It is important to mention that these damages are not limited to climate change as they include biodiversity loss, nitrogen cycle, depletion of stratospheric ozone, ocean acidification, fresh water and soil use, chemical pollution and atmospheric aerosols as demonstrated within Rocktröm's nine planetary boundaries (Bourg, 2013, p. 112). In fact, the interrelation between these multiple factors (for instance, the state of biodiversity influences resilience towards climate change and the latter will deeply impact the species erosion rate) confirms the fact that we are no longer dealing with hazards[40] that can be considered individually but with a global and interrelated threat (Bourg, 2013, pp. 112-113). Undeniably, as Bourg suggests, increasingly violent tropical cyclones, deadlier droughts and floods cannot be taken as independent and unique events as they all depend on global *"continuous degradation mechanisms, such as the modification of the atmosphere's chemical composition"* (Bourg, 2018, p. 59, our translation). Having these dramatic societal and natural impacts in mind, the notion of "risk" (even of global risk) seems clearly inappropriate when discussing humanity's own survival on planet Earth. Indeed, it would appear that the necessary individualism required for the existence of "risk" undoubtedly collapses when the whole of society faces a similar and potentially vital menace. Consequently, *"if the realization of these risks were to affect the whole of society, the insurance system would collapse. The suspension of insurance systems in the event of war provides a good example as in this case, damages become systematic and affect the entire society and not only individuals"* (Bourg, 2018, p. 58, our translation). Likewise, the monetary approach detailed earlier seems to fall apart in the case of such a dramatic turn of events. Indeed, a monetary compensation scheme is unrealistic and even absurd when looking at the scale of degradations in the agricultural sector, raise of pathogens, inhabitability of entire regions and to a certain extent a tilting of Earth systems causing the loss of natural conditions essential to human existence (Bourg, 2013, p. 116).

Bourg further mentions that *"the notion of risk is not only inadequate, but it is also dangerous"* (2013, p. 116, our translation) as it *"suggests that humanity could break the deadlock in which it is sinking by small economic calculations and / or the development of a few new technologies"* (p. 116, our translation). In fact, the notion of risk creates a deep

[39] This paper will use Mc Neill's's definition of biosphere as *"the viability envelope that conditions the existence of humanity, and which includes the biosphere in the narrow sense of all living species, the hydrosphere, the pedosphere as well as the superficial layers of the atmosphere and the lithosphere"* (Mc Neill, 2010 in Bourg, 2013).

[40] The exact word used by Dominique Bourg is « aléas » defined by the Larousse dictionary as *"unpredictable and mostly unfavorable turn of events and linked to an activity or action".*

confusion between micro and macro levels as "risk" increases human's tendency to focus on specific regions and habitats whereas it is the human society's survival as a whole that should be in focus. As an illustration to the above, Bourg mentions that *"it is not this type or this type of economic activities that is threatened, but the possibility itself of exercising such activities"* (2018, p. 62, our translation). As a final observation, the meaninglessness of using the notion of risk in such dramatic circumstances is enhanced by its close relationship to the betting environment as "risk" induces "taking risk" and it sounds particularly irrational to take a bet on humanity's own existence (p. 63).

As an answer to the above assessment of the notion of risk, one could suggest that the notion of "transcendental damages" brought forward by Dominique Bourg (2013, 2018) which proposes a global and holistic overview of our Earth system's degradation, is more relevant to the situation. Indeed, the author mentions that we are currently facing a *"concrete transcendental, impacting the natural conditions necessary to our existence, that sends us back to the existing state of the Earth system capable of human habitability"* (p. 62). It is important to mention that the concept of transcendental damages proposes a new vision, free from "risk" prerequisites, as it suggests a distinctive paradigm closer to a traditional society and its social connections, as opposed to the individualism of the "society of individuals" (pp. 58-59).

As a conclusion, the notion of risk clearly does not fit the actual turn of events with deep damages to our Earth and provides a wrongful idea of our potential reaction and resilience capacities to such global happenings. Therefore, it may be advisable for the insurance industry to develop alternative approaches such as "transcendental damages" and depart from the siloed[41] approach carried by risk and individual hazards as it could lead to missing the bigger picture and impacting the industry's resilience to upcoming events.

2.2.2. Dive into the highly improbable: Black Swan events

In addition to using the notion of risk, the insurance industry has a very narrow relationship with, and dependency on, the capacity of modeling and planning the future.

[41] For the sake of clarification, a "silo approach" or "silo mentality" originally referred to storage containers for grain or missiles and has most commonly become a *"metaphore for separate entities that stockpile information and effectively seal it in. In business, it refers to an organization that is made up of divisions that operate independently and avoid sharing information"* (Kenton, 2019) . In this paper, we refer to a silo approach to explain the division established between the different environmental issues but this paper strongly advocates for a more holistic approach.

Indeed, as previously mentioned in chapter 1,*"catastrophe modeling technology is now used extensively by insurers, reinsurers, governments, capital markets and other financial entities. They are an integral part of any organization that deals with natural catastrophe"* and even more interestingly *"the models help to quantify our understanding of the natural world"* (Lloyd's, 2014, p. 4). However, the confidence carried by modelers as to the possibility of developing models capable of understanding the future is increasingly challenged by the uncertainty and complexity inherent to climate change as it becomes impossible to model future events based on the past. In fact, *"uncertainties associated with the estimation of the extent and frequency of the most extreme events means that the climate change impact can be difficult to account for in risk models"* (p. 4). As an answer to this major issue, insurers have worked on developing increasingly complex models as to build what the industry calls *"forward projections"*. Interestingly, and when delving deeper into the above, it becomes apparent that the insurance industry's business model resides solely on its availability to "understand" and "plan or model" the future. Indeed, a sizeable mismatch between forecasted risks and actual events (weather events for example) could cause extremely high and unplanned financial losses leading to potential solvency issues on several lines of business. Consequently, this leads us to a more profound and philosophical question: are humans, through their complex probabilistic calculations, really capable of modeling the future with sufficient confidence? Or are there some events that our sophisticated models cannot foresee, thus causing unexpected and catastrophic impacts on our resilience? As we look deeper into the impacts of what Nassim Nicholas Taleb describes as Black Swan events (2010), we will understand humans' difficulties to grasp what we consider as the "highly improbable". Taleb's best selling book offers an interesting philosophical and statistical insight into the *"impact of the highly improbable"* making it one of the most complete documents on the subject.

To begin, the author describes a Black Swan as an event with three main attributes: *"first, it is an outlier, as it lies outside of the realm of regular expectations, because nothing in the past can convincingly point to its possibility. Second, it carries an extreme impact. Third, in spite of its outlier status, human nature makes us concoct explanations for its occurrence, making it explainable and predictable"*(Taleb, 2010, p. XXII). It is interesting to note that this short definition already provides us with an insight on how the highly improbable can deeply impact the insurance industry. Indeed, Black Swan examples mentioned by the author, such as the birth of the Internet, the development of personal laptops and the September 11,

2001 terrorist attacks all had an effect on the insurance industry (Taleb, 2010, p. XXIII). As a matter of fact, cyber risk, which would not exist without the internet or individual computers, is currently one of the highest ranked risks on the 2019 WEF Global Risk Report (World Economic Forum, 2019, p. 16) and led to the development of cyber insurance products such as coverage for first and third party liabilities or payment card theft (EIOPA, 2018, p. 7). As an additional illustration, the September 11, 2001 terrorist attacks surprised the insurance industry with humongous losses[42] *"coming from an entirely unforeseen peril for which no premium had been collected",* thus causing unprecedented losses *"not only in property coverage, but also for the first time in life insurance, disability and workers compensation lines. Aviation and liability insurers also suffered their worst-ever losses stemming from a single event"* (Hartwig, 2002, p. 10). The above examples offer a clear demonstration of the concrete and business-transforming effects of the highly improbable on the insurance industry. Indeed, The 9/11 event came as a strong challenge to the "all can be modelled" idea, which presupposes that if such a terrorist risk was perceived to be probable on September 10, 2001, the attacks would have been stopped, or at least a legislator would have passed a law imposing *"continuously locked bulletproof doors in every cockpit, just in case terrorists decide to use planes to attack the World Trade Centre in New York City"*(Hartwig, 2002, p. XXVII), which, sadly, was not the case. But what makes us so blind to the events "*that were not supposed to happen"*? And how does it impact the insurance industry's resilience to climate change? Taleb's detailed overview on the subject provides a comprehensive and useful addition to this paper. To continue this demonstration, the author's concepts of Mediocristan and Extramistan will be introduced and will be followed by an analysis of the multiple reasons to our blindness towards Black Swans.

2.2.2.1. Mediocristan vs. Extremistan

The concepts of Mediocristan and Extremistan as described by Taleb (2010, pp. 32-37), propose an interesting theoretical background to explain the global warming "red ocean"[43] in which the insurance industry is currently swimming.

[42] In addition to the great human losses, the September 11, 2001 attacks resulted in losses evaluated at USD 40 billion (in 2001) making it the largest losses sustained by the insurance industry from any natural or man-made event until 2001 (Hartwig, 2002, p. 10).

[43] Even though the concept of "red ocean" was designed and used in the context of aggressive business competition in the book *Blue Ocean Strategy* (Kim, W.C., Mauborgne, R., 2005), the described "bloody" environment perfectly suits the potential geo-political tensions brought by climate change and its consequent alterations of Earth's systems.

Indeed, the author makes a distinction between, on the one hand, "*the tame, quiet, and uneventful province of Mediocristan"* (p. 26) where *"particular events don't contribute much individually"* and where the supreme law consists in saying that *"when your sample is large, no single instance will significantly change the aggregate or the total"* (p. 32). In short, Mediocristan is a place where *"the largest observation will remain impressive, but eventually insignificant to the sum"* (p. 32) and incudes matters subjected to type one randomness[44] such as *"income for a baker, car accidents and mortality rates"* (p. 35). On the other hand, *"the Black Swan generating province of Extremistan"* (p. 26) in which *"inequalities are such that one single observation can disproportionately impact the aggregate or the total"* includes, amongst a very large list, matters subjected to type two randomness[45] such as damages caused by earthquakes, deaths in war, financial markets and economic data (p. 35).[46]

At this point, the reader may have already understood that both the global warming and financial environments, to which the insurance industry's exposure has been demonstrated, can be considered as proud citizens of Extremistan. Indeed, the complexity, connectivity and uncertainty of both the Earth and the financial systems perfectly fit the given description of Extremistan as a place *"where we are subjected to the tyranny of the singular, the accidental, the unseen and the unpredicted"* and where it becomes *"hard to predict from past information"* (p. 35). In addition, the author mentions that globalization (as described in this paper) creates an *"interlocking fragility, while reducing volatility and giving appearance of stability"* leading to a weaker financial ecosystem with "*gigantic, incestuous, bureaucratic banks"* contributing to increased systemic risk as in *"when one falls they all fall"* (p. 225). Taleb further confirms, when discussing climate change, that the models used to forecast global warming are difficult to trust as *"we are facing nonlinearities and magnifications of errors coming from the so-called butterfly effets"*[47] as *"small changes in input, coming from*

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[44] Type one randomness refers to the "pseudo random" where random numbers are generated by a deterministic process. For example, *"Card shuffling machines, if sufficiently precise in their operation, map each unique ordering of playing cards to a single final ordering. Learn how the machine works, and you will know how each initial ordering is transformed"* ("A classification scheme for types of randomness probability and statistics blog," n.d.)

[45] Type two randomness includes most "real world randomness". *"A typical example of Type 2 randomness would be predicting whether certain individuals will develop heart disease within the next 10 years. Without knowing any specifics about the individuals, it's very hard to make accurate predictions."* ("A classification scheme for types of randomness probability and statistics blog," n.d.)

[46] Please refer to appendix 5.4 for a complete overlook of both Extremistan and Mediocristan provinces.

[47] The author refers to the Butterfly effect as MIT meteorologist Edward Lorenz theorized that *"a butterfly moving it's wings in India could cause a hurricane in New York, two years later"*, theory generating much interest in the field of chaos theory (Taleb, 2010, p. 179).

measurement error, can lead to massively divergent projections – and that generally assumes that we have the right equations" (p. 315).

Consequently, it can be said that the current ecological and financial systems, and more precisely the insurance industry, should be considered as deeply exposed to Black Swans. Indeed, the insurance industry's exposure to extreme events (e.g., weather, terrorism, cyber crime) seems to make it highly vulnerable to Black Swans, thus deeply questioning its resilience. But what makes humans so blind to the improbable? Why can we not foresee the arrival of such society-changing events?

2.2.2.2. Why are we blind to Black Swans?

It has now been demonstrated that the insurance industry can be considered as fully integrated in an Extremistan type of setting and is therefore exposed to Black Swans. So as to further understand our visionless approach to improbable events we will briefly cover the most relevant cognitive biases that make humans think they live in a Mediocristan environment. While the goal here is not to go into too much detail as it has already been well explained in Nassim Taleb's book, it remains important to grasp that (re)insurances and their "experts" (and more generally all of our society) have a great difficulty admitting that some events simply cannot be planned ahead.

The problem of inductive knowledge

A first, and probably the most famous, bias invoked by Taleb to explain our lack of vision to the improbable is what is commonly known as the Problem of Induction (or Problem of Inductive Knowledge). As an example of this problem, the author discusses the case of a turkey (see figure 34) which goes as follows: *"consider a turkey that is fed every day. Every single feeding will firm up the bird's belief that it is the general rule of life to be fed every day by friendly members of the human race "looking out for its best interests" […]. On the afternoon of the Wednesday before Thanksgiving, something unexpected will happen to the turkey. It will incur a revision of belief"* (2010, p. 40).

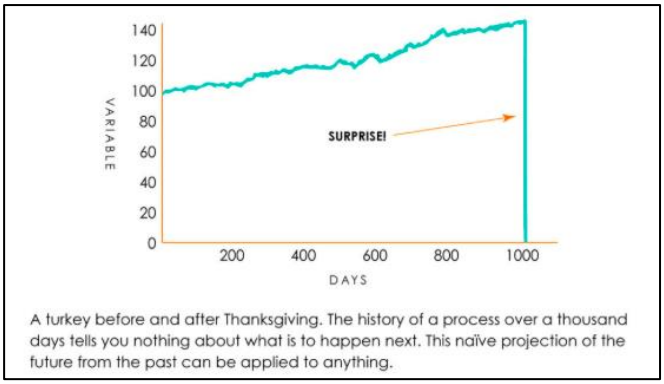

Figure 34: One thousand and one days of history.
Source: Taleb, 2010, p. 41.

The turkey scenario raises the philosophical question of the possibility to *"know the future, given knowledge of the past; or more generally, how can we figure out properties of the (infinite) unknown based on the (finite) known?"* (p. 40). Indeed, when looking at this poor turkey's destiny, his/her experience of the past seems *"at best irrelevant or false"* and *"at worse viciously misleading"* (p. 41) as she calmly went to her death without having any doubts that today might be different than yesterday (and the days before). Sadly, this turkey's unfortunate saga can be adapted to the human society and provides a textbook example of why it is absolutely impossible to plan the upcoming future. Indeed, models (e.g., financial, climate, etc…) are based on what experts deem to be "probable" according to the things or events that previously took place and do not take into consideration what has never happened (for the simple fact that it has never happened in human history), thus leaving huge and dangerous blind spots. Needless to say how anxiety-generating this *"learning backward"* approach is, not only for the insurance industry and its models, but also for the whole of society. Indeed, human's tendency to learn from observing the past[48] and consider it *"as something definitive or representative of the future is the one and only cause of our inability to understand the Black Swan"* (p. 42).

The error of confirmation

A second bias approached by Taleb to explain our blindness to Black Swans is what he calls the "error of confirmation". The author defines this bias as our *"focus on preselected segments of the seen and generalize from it to the unseen"* (p. 50). In short, and when looking back at figure 34, *"someone who observed the turkey's first thousand days (but not the shock of the thousand and first) would tell you, and rightly so, that there is no evidence of the possibility of large events, i.e., Black Swans"* (pp. 51-52). But, unfortunately, the author

[48] Interestingly, even science is based on such methodology as its first step is observation (Bradford, 2017).

explains that humans have a tendency to mix up two statements, *"there is no evidence of the possibility of Black Swans"* and *"there is evidence of no possible Black Swans"* (p. 52), which are completely different. Indeed, *"unless we concentrate very hard, we are likely to unwittingly simplify the problem because our minds routinely do so without our knowing it"* (p. 52). This "round trip fallacy", as to use Taleb's exact wording, demonstrates that *"our inferential machinery […] is not made for a complicated environment in which a statement changes markedly when its wording is slightly modified".*

In addition to this "round trip fallacy", the author mentions that humans have a tendency to look for instances that confirm their story and their vision of the world.[49] Indeed, finding confirmation for a thought is always easy but let us keep in mind that a series of corroborative facts does not necessarily constitute evidence, thus confirming that *"sometimes a lot of data can be meaningless"* (p. 57). This so-called "confirmation bias" can become dangerous as scientific research has demonstrated that once a person has obtained a certain vision of the world or what he believes to be the truth, it becomes increasingly difficult to consider data or knowledge that is outside of this belief (p. 59). On the subject of global warming, this "confirmation bias" has been the source of conflict between climate change skeptics and others, as scientists tend to look at *"different parts of the same data and never converge to the same opinion"*, thus creating a certain inertia towards key decisions to be made.

These various "confirmation bias" influencing our day-to-day decisions should be taken seriously by institutions, including (re)insurances, publishing a humongous amount of reports, since humans tend to use data in the way that fits their vision of the world and come up with potentially inadequate confirmations and assessments of the future. In this regard, the enormous amount of data gathered by (re)insurers to feed their models of the future seems somehow inappropriate as *"thousand days cannot prove you right, but one day can prove you to be wrong"* (p. 57) and indeed, tomorrow may bring a completely different story.

The narrative fallacy

The following subject proposed by Taleb differs slightly from the two previous ones which focus on *"what could be inferred about the unseen"* and *"what lies outside our information set"*, whereas this third mostly looks *"at the seen, what lies within the*

[49] The fact that we tend to look for past instances to corroborate our theories and treat them like evidence is called "naïve empiricism" by the author (Taleb, 2010, p. 54).

information set" and studies how humans distort this data when processing it (p. 64). Indeed, the so-called "narrative fallacy" evolves around the human hunger for stories, summaries and simplification (p. 63).

A first, and interesting, aspect of humans' dependency on stories brought by the author is the biological and psychological need to rationalize and explain everything. Indeed, the scientific research mentioned by Taleb extensively details how the human brain functions to unconsciously create *"post hoc rationalization"* to the illogical or the unexplainable (pp. 64-68). It seems that the brain tends to construct stories or patterns proving that the *"perception of causation has a biological foundation"* (p. 68) and confirming the natural tendency to build up stories that "make sense". In addition to this psychological and biological attachment to narrate, Taleb indicates that *"information is costly to store"* and that *"the more orderly, less random, patterned, and narratized a series of words or symbols, the easier it is to store that series in one's mind"* (p. 68). As a consequence, humans *"have a hunger for rules"* and simplified stories as they help reduce *"the dimension of matters so they can get into our heads".* This is particularly interesting when studying current political and societal responses to the climate issue, which often constitute overly simplified narratives but which are arguably necessary to regroup enough people on the subject. As a matter of fact, while these overly simplified narratives using notions such as "Sustainable Development", as described in the 1987 World Commission on Environment and Development (WCED) report (most commonly known as the Bruntland Report), are meant at gathering as many people around the table as possible, they also have the negative effect of providing a simplified story resulting in simplified answers.[50] Finally, Taleb considers that our need to simplify stories *"pushes us to think that the world is less random than it actually is"* (Taleb, 2010, p. 69), hence causing us to leave out Black Swans for the sake of simplification.

Furthermore, when linking our thirst for narrative to the subject of the insurance industry, it is interesting to note that Taleb describes two varieties of rare events. On the one hand, the overestimated and well-discussed *"narrated Black Swans, those that are present in the current discourse and that you are likely to hear about on television"*, and on the other hand, the underestimated ones, *"those nobody talks about since they escape models – those that you would feel ashamed discussing in public because they do not seem plausible"* (p. 77). As an

[50] We would like to remind the reader that this thesis proposes an analysis based on a "strong sustainability" approach where the Environmental, Social and Economical capitals are not substitutable as opposed to the "weak sustainability" vision described in the 1987 Bruntland report (World Commission on Environment and Development, 1987).

example, societal collapse, as presented in the next section of this thesis, should still (but maybe not for long) be considered as a Black Swan of the second type as it is currently considered, by most political groups, as a catastrophist vision and it is of the utmost difficulty to be taken seriously when taking such a stance (Montfort, 2016). Furthermore, a second and more direct illustration of this dual pattern is the preference of people to insure themselves *"against small probable losses - at the expense of the less probable but larger impact ones"* (p. 77), thus contributing to widening the insurance gap in some sectors and increasing potential losses when the unexpected happens.

To conclude, the exposed *"need to fit a story or pattern to a series of connected or disconnected facts"*(p. 303) has a deep effect on the understating of events and strongly impairs human's perception of the future. Indeed, when taking this "simplification" issue into consideration, it seems almost impossible to fully comprehend the complexity of the Earth and the financial systems, hence causing a strong challenge to the insurer's possibility to model and understand what comes ahead. Moreover, as previously discussed, having only simple narratives in mind, only simple solutions can be brought to the table, whereas global issues such as global warming and biodiversity loss cannot be solved by simple solutions like driving electric cars, building wind turbines or recycling paper only.[51]

The distortion of silent evidence

According to Taleb, silent evidence represents the fact that *"history hides both Black Swans and its Black Swan-generating ability from us"* (Taleb, 2010, p. 100). In other words, silent evidence can be explained as the fact that history and past events are usually told by the ones who survived or who stood out. As an illustration, Taleb exposes the case of literature where only a minimal fraction of what has been written along history is "registered" as *"we do not see the tons of rejected manuscripts because they have never been published"* (Taleb, 2004, p. 3), hence deeply influencing who is considered as a successful writer. Indeed, a key to understanding success is *"the study of traits in failure"*, as for example *"some traits that seem to explain millionaires, like appetite for risk, only appear because one does not study bankruptcies. If one includes bankrupt people in the sample, then risk-taking would not*

[51] Other (and more complex) answers are given to climate change, but the goal is to demonstrate that the current solutions are overly simplified, not deep enough and follow a silo mentality. This thesis considers that a more complex and holistic approach would be better suited to the situation. Of course, the aim of this paper is not to discuss what narrative should be developed as to encourage a global and holistic response to environmental issues, but when looking at the current rate of environmental destruction, the actual narrative's efficiency remains to be proven.

appear to be a valid factor explaining success" (p. 3). As a matter of fact, this historical *"cemetery effect"* gives us a false idea of past events, thus deeply influencing the perception of Black Swans and providing a wrongful perception of a stable Mediocristan type of world.

So as to further develop his demonstration, Taleb turns to the intriguing notion of "luck" through the example of Giacomo Casanova. Indeed, when discussing the case of the Italian *"legendary seducer of women"*, who's survival depended on an inconsiderable amount of lucky events, the author mentions that *"it is those who survive who will tend to believe that they are indestructible; they will have a long and interesting enough experience to write books about it. Until of course…"* (Taleb, 2010, p. 114). This statement is of great interest when discussing our responses to both environmental and financial crisis as it seems to be mostly the luckiest that survive, thus providing a wrongful idea of our resistance and resilience to extreme events, since we tend to confuse resistance and luck. Indeed, Taleb confirms that *"we have enough evidence to confirm that […] we humans are an extremely lucky species, and that we got the gene of the risk takers"* and adds that us getting here by accident *"does not mean that we should continue to take the same risks"* (p. 116). As a matter of fact, *"risk taking made many species head for extinction*" (p. 117) and we, humankind, should be able to reach a certain maturity to appreciate the fact that luck has brought us so far and it is now time to stop playing Russian Roulette and become more conservative (p. 116).

This lack of complete and objective overview of past historic events due to the cemetery effect and silent evidence should be taken into account by modelers as it confirms that even modeling extreme events from the past is overly difficult since our historic perception can be skewed. In addition, the lines above could challenge what we is observe as a risk as our perceived environmental and financial resilience could be solely dependent on luck, a variable that is impossible to insert into models. Indeed, this serious resilience misconception could result in underestimations and overestimations of the probability of certain Black Swans, making the insurance industry less resilient than it seems.

To conclude, Nassim N. Taleb has provided us with extremely valuable inputs on the reasons we do not, and even psychologically cannot in certain cases, fully apprehend the highly improbable. Indeed, the author has demonstrated that human's blindness to Black Swans is influenced by several factors resulting in a perilous impression of stability in a clearly unstable environment. In fact, it seems that humankind is *"not skilled at intuitively gauging*

the impact of the improbable" (p. 79) as *"we learn from repetition, at the expense of events that have not happened yet"* (p. 78). The above should come as a strong warning to model-dependent economic sectors, including the insurance industry, as a wrongful perception of past events influences the vision for the future and makes humans take unnecessary risks. Finally, when looking back at the issue of environmental and financial crisis developed in this paper, one could actively question how realistic and useful it is to study them since *"thousand days cannot prove you right, but one day can prove you to be wrong"* (p. 57) and deeply unexpected Black Swan events could challenge each and every prediction made. Indeed, a sequence of unexpected Black Swan events could potentially deeply impact the insurance industry, and the whole of society, on a structural and systemic basis, hence causing the collapse of this fragile house of cards.

2.3. Societal collapse: The end of *the* world or the end of *a* world?

The previous sub-chapters have demonstrated how fragile our society is on both financial and environmental fronts. Indeed, a close observation of what we have called "worst-case" scenarios has revealed how the connectivity and complexity of the financial and Earth systems are one of the many reasons of their instability and fragility. These perturbing and alarming scenarios have exposed how unprepared our slow-moving and cheap energy-powered society is for such a global environmental threat, potentially putting the whole of humankind in jeopardy. Certainly, the addition of environmental "transcendental damages" to the financial sector's proven fragility triggers serious questioning on our ability to protect ourselves from a certain type of ending, even though the insurance industry's role as a societal stabilizer should not be forgotten. However, the scale of present and future global destruction seems way too important for one sector to bear and a potential society failure would probably include the fall of the insurance industry as we know it.

In this regard, the following section will address a niche but expending theory detailing how the human civilization might collapse. To discuss this specific line of thought, we will be using the term "collapsology" as developed by Pablo Servigne and Raphaël Stevens in their book *Comment tout peut s'effondrer* (2015). Undeniably, this book represents one of the most complete and multidisciplinary approaches to societal collapse and will serve as a basis for this section. For the sake of full disclosure, it is important to mention that the conclusions proposed by "collapsology" authors remain questioned by a portion of the scientific

community, as they offer a very particular and specific vision of our future. Having said that, the seemingly increasing proximity to points of no return (tipping points) of the Earth, social[52] and economic systems, have been widely covered throughout these lines and the fantasy of seeing a happy ending becomes more improbable every passing day. Additionally, the contribution to the collapse analysis from authors such as Joseph Tainter (1988), Jared Diamond (2005), John Michael Greer (2008) and Dmitry Orlov (2013) offers an eye-opening analysis on the fact that our society collapsing would not be the first nor the last to do so.

To begin this journey through collapsology, one should note that alarming and catastrophic warnings have been used all along our history and have recently expended by virtue of the larger reach of social media platforms (Tandoc & Eng, 2017). Indeed, alarming reports such as Rachel Carson's *Silent Spring* (1962) or the notorious Doomsday Clock provide perfect examples of such warnings. The interesting illustration brought by the Doomsday Clock, created in 1947 during the early stages of the Cold War to demonstrate the potentiality of a nuclear apocalypse (Benedict, n.d.), is worth diving into. Indeed, it is interesting to witness that the clock's purpose has evolved since its early days and it has broadened its expertise with an inclusive approach proposing yearly updates on humankind's proximity to destroying its world with technologies of its own making (e.g., Cyber threat, global warming, etc…).[53] Unfortunately for the human race, the clock's latest 2019 update does not propose an optimistic future as it highlights *"worrisome nuclear trends", "ominous climate change trends*" and *"threat of information warfare"* and concludes a current time of *"2 minutes to midnight*", midnight being the apocalypse (Benedict, n.d.). Interestingly, the clock has been displaying *"2 minutes to midnight"* for the past 3 years (since 2017), demonstrating the severity of the situation as this proximity to twelve o'clock has not been observed since 1953, a year where both the USA and the USSR successfully exploded their first thermonuclear bombs (Rabinowitch, n.d.). While the scientific accuracy of such an indicator is questionable, its educational purpose remains very relevant as it proposes a simplified version of the highly complex environmental and geopolitical contexts. Furthermore, Angela Merkel's reference to the doomsday clock in her notorious quote "*it's not five minutes to midnight. It's five minute*

[52] For additional resources on the current social inequalities and how this issue relates to environmental questions, please refer to Bourg, 2018; Bourg & Arnsperger, 2017; Jackson, 2009; Meadows, 2004; and Schwab, 2016 (amongst a very wide literature on the subject).

[53] Climate change induced disruptions have been considered by the Bulletin (the official report of the Doomsday Clock) since 2007.

after midnight" (CRO Forum, 2019, p. 6) reminds us how serious the situation is and demonstrates that discussing the end of our civilization might actually not be a waste of time.

But what exactly is a societal collapse? Are there previous examples throughout our history? Why is this relevant for the insurance industry and where would this economic sector stand in case of a major collapse? The following sub-sections will address these crucial questions and provide an overview of the possibility of such a future.

2.3.1. Past collapses and how we tend to forget they happened

Even though this paper, and most importantly Nassim Taleb's *The Black Swan* (2010), has extensively criticized the study of the past to explain the future, it is believed that the awareness of previous collapses can assist in accepting that human civilizations have collapsed in the past and that it remains a possible outcome for the future. In other words, the study of previous collapses offers an insightful source of information on the reality and severity of societal collapses and demonstrates that our current society is not the first one with dreams of invincibility and would definitely not be the last one to disappear. In addition, to use Jared Diamond words: *"environmental damage that developed in the past could develop again in the present, so one might use knowledge of the past to avoid repeating the same mistakes"* (2005, p. 205).

For the sake of further clarification, the use in this paper of past collapse examples is not meant at developing models and forecasts of any type and this for two reasons: firstly, the fact that we simply cannot model the future from past events,[54] and secondly, because previous society collapses mentioned in this paper have evolved in a totally different historical context (economic, environmental, etc.), thus making it difficult to draw parallels and construct clear patterns between them and our current situation. However, the main outcome of what follows should be that "resilient", "strong" and "indestructible" civilizations have previously risen and fallen and that each new civilization believes to be smarter than the previous one and considers collapses as improbable Black Swans (this collective amnesia may be due to the distortion of silent evidence[55] or simply due to our humane deep fear of death[56]).

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[54] Please refer to section 2.2.2.

[55] Please refer to sub-section 2.2.2.2.

[56] The Socio-psychological school of thought named "Terror Management Theory" (TMT) explains how the human being is inhabited by a constant terror of death and acts in a specific way to manage this terror. For

A first prerequisite to understanding the potentiality of a future collapse is to study its definition and examine what key authors on the subject consider as such. The exact definition of a societal collapse seems to differ from one author to another depending on their field of study (archeology, history, etc.), thus demonstrating a certain questionable silo approach to this issue. This thesis strongly advocates for a systemic and holistic approach and considers that current societal issues, including social disparities (e.g., gender gap, highly unequal wealth distribution, etc.), environmental degradations (e.g., biodiversity loss, global warming, etc.) economic brittleness and others should be treated as one major societal problem due to their interconnectivity.[57] In addition, an inclusive approach would also be of interest to the (re)insurance industry as it would assist the sector to get a better overview of current issues and to create more complete and holistic products. Of course, one may say that reinsurers such as Swiss Re or Munich Re are known to have a global and detailed overview, however, the strong division (silo) and economic competition between the different lines of business within the industry (e.g., life vs. non life) do not help in developing holistic responses.

This paper will make use of two different descriptions: the first one being the one offered by most archeologists as *"a drastic reduction of the human population and/or of political/economic/social complexity, across a wide area and a long duration"*(Duterme & Servigne Pablo, 2016) and the second one, which seems more appropriate to the current globalized context, is proposed by Yves Cochet[58] as *"the process at the end of which basic needs (water, food, housing, clothing, energy, mobility, and security) are no longer provided to a majority of the population by state-controlled services"* (Cochet, 2011). Authors from different fields also appear to have different opinions on the timeframe of such civilization failures. On the one hand, Pablo Servigne suggests an abrupt collapse as near as the 2020-30 period (Montfort, 2017),[59] which is supported by Niall Ferguson, History professor at Harvard, when he writes that "*empires behave like all complex adaptive systems. They*

example, political ideologies, religions, and economic objectives (economic growth in our case) are said to be answers to our fear of dying. For further reading on the subject please refer to *The Denial of Death* (Becker, 1973) or *The worm at the core : on the role of death in life* (Solomon, Greenberg, & Pyszczynski, 2015).

57 Books such as the limits to growth report (Meadows et al., 2004) or Prosperity without growth (Jackson, 2009) clearly demonstrate the interrelation of these different themes.

58 Yves Cochet is a former minister for territorial planning and the Environment under Prime Minister Lionel Jospin of the French Republic. He currently presides the Momentum institute, think-Tank meant at discussing issues such as societal collapse.

59 Servigne's timeframe of a societal collapse should be nuanced as he mentiones several possibilities within his book (2015, pp. 192-194). Indeed when quoting work from David Korowicz, he discusses the possibility of *a "linear decline", "oscillating decline"* and *"systemic collapse"* all having different abruptness and timeframes (Korowicz, 2010).

function in apparent equilibrium for some unknowable period. And then, quite abruptly, they collapse" (2010). On the other hand, recent research from archeologists and historians tend towards a measured *"Rome did not fall in one day"* approach based on Edward Gibbon's renown *The History of the Decline and Fall of the Roman Empire* (1790). Given the global, complex and interrelated nature of our society, this thesis inclines to support a *"decline and transformation"* approach (Lawler, 2010).[60] However, the possibility of an abrupt collapse should not be totally left aside. A second step to understanding the essence of a collapse is to look at previous major events of this kind. Since this paper is not meant to be a history nor a collapsology study, only a brief description of past collapses should suffice to understand the potential threat of a collapse for the insurance industry as a whole.[61]

According to a study from the Center for the Study of Existential Risk of the University of Cambridge, a civilization can be defined as "*a society with agriculture, multiple cities, military dominance in its geographical region and continuous political structure"* and is said to have an average life span of 336 years, thus showing that no civilization can last forever (Kemp, 2019) (see figure 35).

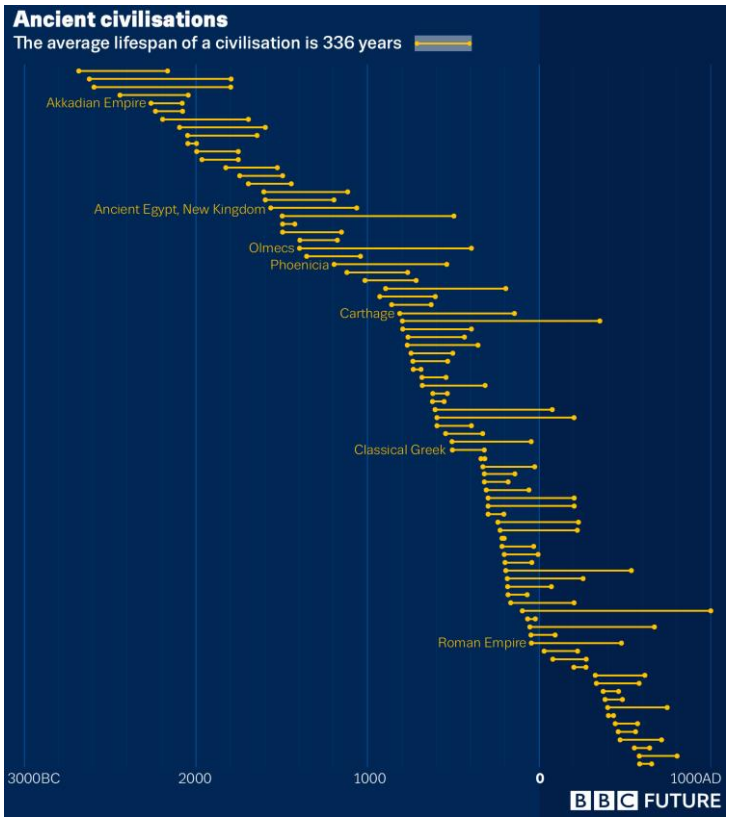

Figure 35: Life span of various civilizations. In this study, civilizations are defined as a society with agriculture, multiple cities, military dominance in its geographical region and continuous political structure. Please refer to appendix 5.5 for a full list of studied civilizations and the duration in years. Source: Kemp, 2019.

60 The conclusive chapter of this paper will emphasize the fact that the insurance industry and its various mechanisms could serve as "shock absorbers", thus slowing the pace of a collapse.

61 For further readings on the subject, please refer to the books mentioned in this sub-chapter (e.g., Diamond, 2015 ; Orlov, 2013 ;etc.).

The author of the study adds, when evoking the relevance of discussing past collapses to understand the present, that *"societies of the past and present are just complex systems composed of people and technology. The theory of "normal accidents"*[62] *suggests that complex technological systems regularly give way to failure. So collapse may be a normal phenomenon for civilizations, regardless of their size and stage"* (Kemp, 2019). In this regard, literature from the past twenty to forty years has increasingly drawn a correlation between the complexity of a civilization and the probabilities of a collapse (Ferguson, 2010; Shirky, 2010; Tainter, 1988). Indeed, Clay Shirky, Lecturer at New York University (NYU) summarizes Joseph Tainter's writing by stating that "*when the value of complexity turns negative, a society plagued by an inability to react remains as complex as ever, right up to the moment where it becomes suddenly and dramatically simpler, which is to say right up to the moment of collapse. Collapse is simply the last remaining method of simplification"* (2010). Having this in mind, the high complexity and dependency on new technologies that characterize today's society could make anyone nervous.

When looking back at the study of systemic risk in the financial sector and the insurance industry (see sub-section 2.1.3.3) one can observe that this anxiety will probably not disappear as *"our tightly-coupled, globalized economic system is, if anything, more likely to make crisis spread"* (Kemp, 2019). However, it is important to mention that civilization collapses are not a new "trend", or just a way to surf on the current green wave, as "*virtually all past civilizations have faced this fate. Some recovered or transformed, such as the Chinese and Egyptian. Other collapses were permanent, as was the case of the Easter Island. Sometimes the cities at the epicenter of collapse are revived, as was the case with Rome. In other cases, such as the Mayan ruins, they are left abandoned as a mausoleum for future tourists"*(2019). This statement is also confirmed by Jared Diamond's bestseller *Collapse: How Societies choose to fail or succeed* (2005), where the author, through a highly detailed study of past and present civilizations such as the Mayas, the Anasazi Indians (USA) and the Viking settlements in Greenland, offers a noteworthy parallel between these collapses and environmental degradations. Diamond underlines the importance of human's interactions with their environment and proposes an interesting five-point framework of possible factors

[62] The "Normal Accident Theory" (NAT) is a school of thought developed by Charles Perrow (1999) where accidents in complex systems are considered to be unavoidable as seemingly unrelated events accumulate and align to create major malfunctions that produce disastrous results. Perrow bases his study on examples such as plane crashes, marine accidents or the nuclear dysfunction at Three-Mile-Island and proposes an eye-opening reading of high risks linked to technologies (Perrow, 1999).

contributing to environmental collapses: environmental damage, climate change, hostile neighbors, friendly trade partners and society's responses to its environmental problems (2005, pp. 11-13). Even though Diamond's theories on environmental explanation for collapses have been criticized by some (Gause, 2014) and are said to be *"less rigorous and reasoned"* (Salerno, 2015, p. 386, our translation) than Joseph Tainter's approach (1988), they remain highly relevant when trying to draw a parallel between environmental mismanagement and civilization failures.

To conclude, it is clear that societal collapses have happened in the past and should therefore not be seen as highly improbable Black Swan events. Indeed, the complexity and fragility of our society as detailed within this paper should come as a good reason to take action and stop thinking that our cheap oil-powered (thermo industrial[63]) civilization is invincible. Indeed, the fate of the Mayas, the Rapa Nui people on the Easter Island or the Greenland Vikings settlements should come as a reminder that no civilization lasts forever and that the potentiality of a global collapse is tangible and not a movie fiction.

Now that the reality of societal collapse has been well established, the next step will be to understand the different elements that could trigger such an event in the current civilization and analyze its impact on the insurance industry.

2.3.2. Elements of collapse and its impact on the insurance industry

As mentioned in the above section, drawing parallels between historic civilization collapses is extremely difficult due to their different contexts. However, the recent works of Pablo Servigne (2015) and Dmitry Orlov (2013a; 2013b) provide an up-to-date overview of what a collapse could look like if it happened in the years to come. As a matter of fact, Orlov's *The five stages of collapse: survivor's toolkit* (2013a) and a consequent blog post (2013b), adding a 6th level to the process, offer a comprehensive picture of the possible sequence of such events and deserves specific attention. Naturally, the VUCA environment of our thermo industrial civilization makes it extremely difficult to propose a generalizable sequence of events, but Orlov's literature has the benefit of providing multiple doors of entries to collapse triggers (e.g., financial, environmental, commercial, etc.). The author's genuine interaction with the societal collapse of his home country, the USSR, further helped

[63] The "thermo Industrial civilization" neologism is commonly used by collapsology authors and refers to the profound dependency of our society on fossil energies (oil and gas).

in the conception of a strong theoretical background compatible with the analysis of the current state of the world as described in this paper.[64]

Before deep diving into Orlov's collapse taxonomy and for the sake of transparency, it is essential to mention that there is close to zero scientific literature studying the direct link between collapsology and the insurance industry and the following analysis will therefore refer to both the hard evidence presented in previous sections but also common sense and intuition. As a matter of fact, intuition seems to be important in this specific field of study as Pablo Servigne confirms in his book: *"in collapsology, it is intuition - nourished by solid knowledge - that will be essential"* (Servigne, 2015, p. 142). With this in mind we will now turn to the six different stages of collapse proposed by Dmitry Orlov which and their potential impact on the financial sector, and most importantly on the insurance industry.

The first stage of collapse is a *"financial collapse"*, with the trigger being the failure of financial markets in which *"faith in "business as usual" is lost"* and *"the future is not longer assumed to resemble the past in any way that allows risk to be assessed and financial assets to be guaranteed"* (2013a, p. 14). We may recall in this regard the frightful parallel between "financial collapse" as portrayed above and the diminished financial sector's resilience that followed the 2008 crisis. Indeed, the case of the 2008 crisis strongly resembles a financial collapse and a similar crisis in the years to come could trigger the downfall of this fragile house of cards. A full scale and global "financial collapse" would be very hurtful to the insurance industry as the absence of risk assessments possibilities and a lack of access to financial assets would strongly limit the sector's opportunities. In fact, when looking back at the 2008 crisis, a complete financial collapse was avoided mainly through public funding from European countries and the U.S., assistance that may prove to be important once again when the next systemic crisis takes place. Indeed, a future global financial failure would necessitate massive public assistance as insurers and reinsurers would no longer be able to increase their capacities through financial markets and tools such as ILS (refer to section 1.1.4.) due to the unavailability of funds. As a consequence of such a drastic financial halt, institutions including banks, brokers and private insurers would most likely encounter solvency issues similar to AIG in 2008, triggering massive "bailouts" from central banks and States, thus further weakening overall societal resilience.

[64] The author mainly focuses on the case of the USA, his home country since he was 12 years old. Indeed, his book *Reinventing Collapse: the Soviet experience and American prospects* (Orlov, 2011) proposes a parallel between the two great cold war powers and how a USSR type collapse could impact the USA.

According to Orlov, a second phase of collapse, closely related to the financial collapse phase, is characterized by a total loss of trust in markets, causing drastic monetary devaluation, stockpiling of commodities and breaking down imports and retail chains. This so-called *"commercial collapse"* would cause *"widespread shortages of survival necessities"* (2013a, p. 14) and would surely impact certain insurances' lines of business. For instance, as previously mentioned by Swiss Re, a drastic reduction of world trade would surely cause the end of marine cargo insurances (2018a pp. 7-10) while the lack of oil supplies would deeply hurt motor insurances. At this stage, insurance companies would probably already be encountering deep difficulties, as their sources of revenue would start disappearing one after the other. Moreover, as discussed in the earlier sections of this chapter, a monetary devaluation would strongly impact the insurance industry's business model as compensation claim mechanisms and premium payments are all effectuated in national currencies, hence leading to serious difficulties. At this point, it seems necessary to briefly mention the "peak oil"[65] theory studied by authors such as Yves Cochet (2005) and Pablo Servigne (2015), as it could become a potential trigger to the slowing down of global commercial exchanges. Indeed, conventional oil has historically been an, easy to stock and transport, productive source of energy used for almost 95 per cent of our transportation and has assisted our civilization to develop into what it is today (Servigne, 2015, p. 42). However, recent documents from international organizations such as the International Energy Agency (IEA) demonstrate that a peak has been reached, with 80 per cent of conventional oil having been extracted by 2006 and the stocks have been declining since then (p. 43). Naturally, human's ingenuity has made us turn to other types of oil, including Alberta's tar sands, the productivity of which is however proven to be significantly lower than conventional oil[66] and the environmental impact of its extraction is consequent. As a result, the thermo industrial civilization will have to adapt to a less productive energy, which seems compromising when looking at current and future global production and consumption trends. As a matter of fact, the "peak oil theory" (it is in fact more than just a theory) comes as a serious challenge to our business as usual vision for the future.

Going back to Orlov's collapse taxonomy, in some cases of financial and commercial collapses, a third *"political collapse"* stage follows. Within this stage people will tend to lose

65 A peak is defined as the moment where the extraction rate of a resource reaches a ceiling before declining.

66 The Energy Return on Energy Invested (EROI) ratio of tar sand ranged from 2 to 4 whereas the one of conventional oil was between 11 to 18 in 2005 and over 100 in the 1930's (Murphy & Hall, 2010, p. 109).

faith in the fact that *"governments will take care of you"* (p. 15) and *"as official attempts to mitigate widespread loss of access to commercial sources of survival necessities fail to make a difference, the political establishment loses legitimacy and relevance"* (p. 15). Interestingly, it is at this stage that the USSR/Russian Federation "transition" ended as *"there was considerable trouble with ethnic mafias and even some warlordism, but government authority won out in the end"* (p. 15). The current example of Venezuela provides a good case study for such "three phase collapse": the country faces a financial and commercial collapse with hyperinflation (the bolivar has lost 99 per cent of its value since 2013), plunging oil production (production fell from 3 million barrels/day in 1999 to 1.3 million barrels/day in 2018) and unpayable debt (external debt has reached USD 157 billion in 2018 being about 150 per cent of the GDP) which will most probably lead to a political collapse with the struggle for power between Nicolas Maduro and Juan Guaido (Martin & Laya, 2019). With regard to the insurance industry, reaching this stage would probably mean the unviability of the said market as the sector necessitates a certain stability to operate. Indeed, the absence of capital markets and State contribution would surely be the source of bankruptcies, as insurances would see their revenues and diversification options disappear. Finally, the state of a nation affected by stages one, two and three of a collapse would strongly resemble a conflict zone (if a civil war explodes) and as a reminder, insurances tend to suspend their activities in conflict regions since "*damages become systematic and affect the entire society"* (Bourg, 2018, p. 58), thus making the diversification of risk impossible and significantly lowering the area's insurability.

To continue, stages four, *"social collapse"* and five *"cultural collapse"* respectively represent the loss of *"faith that "your people will take care of you" as social institutions […] run out of resources or fail through internal conflict"* and loss of *"faith in humanity"* as *"people lose their capacity for kindness, generosity, consideration, affection, honesty, hospitality, compassion, charity. […] The new motto becomes "may you die today so I can die tomorrow""*(p. 15).[67] At these stages, the absence of room for the insurance sector seems more than evident as the much-needed mutual aid criteria necessary for such a system to operate appears to be long gone.

[67] It is important to mention that all Collapsology experts do not agree on such egoistic and chaotic human behavior when facing difficult situations. As an example, Servigne mentions that recent research on the "sociology of disaster" shows that most humans tend to demonstrate altruistic, calm and settled behaviors when facing events such as the 2005 Hurricane Katrina in New Orleans (2015, p. 211). However, further scientific research is necessary to draw parallels between "the sociology of disaster", which is based on single disastrous events (e.g. tornadoes and bombings) and the long process of a civilization collapse.

Finally, and of most value to this thesis, Orlov's addition of a sixth environmental stage in one of his blog posts (2013b) offers a constructive addition to his writings. Indeed, in this text, Orlov examines the severity of environmental deteriorations and discusses the advantages and disadvantages of a civilization collapse as a protection measure for the environment. Interestingly, and counter intuitively, as one would think that humankind's disappearance (or at least drastic reduction in population) would benefit other animals, the author concludes that a civilization collapse could lead to the extinction of humankind, as well as its surrounding environment. As a concrete example, the four hundred operating nuclear plants located across 31 nations as shown in figure 36 (Carbon Brief, 2016) would be in deep trouble in the case of a *"swift and thorough"* (Orlov, 2013b. p. 6) civilization collapse. Indeed, the loss of the technical knowhow for operating a nuclear plant could result in catastrophic scenarios leading to the inhabitability of large regions if not the entire planet,[68] hence confirming the idea that *"letting global industrial civilization collapse and all the nuclear power plants cook off is not such a good option"* (p. 7).

Figure 36: World Map of Operating Nuclear power plants.
Source: Carbon Brief, 2016.

To conclude, the extensive study of literature from collapsology experts has had the advantage of providing a precious, multiple-angle overlook of the various issues mentioned in this paper and demonstrated their interconnections. Indeed, looking at issues like financial instability, social inequalities and environmental degradations separately does not help moving forward as all are closely interlinked and should be treated in a holistic manner. This

[68] Cases from the past decades such as Three Mile Island (1979), Chernobyl (1986) or Fukushima (2011) come as perfect examples of the potential destructive power of nuclear accidents.

study has also demonstrated how fragile an economic sector such as the (re)insurance industry can be when facing such a turn of events. Unfortunately, the lack of scientific research from (re)insurances on this specific subject (probably due to the industry's disinterest in such extreme scenarios) demonstrates the difficulty for these financial entities to choose between comforting their shareholders and taking drastic, significant and necessary measures in answer to the sector's catastrophic data as reported in this thesis.[69] However, it would be entirely logical for an industry in charge of risk evaluation and modeling of the future to lead research in such an important field as collapsology. While the actual probability of a global and systemic collapse can be further questioned and studied, when looking at the hard data provided in this thesis and using some intuition one can feel slightly nervous. To sum up, Orlov (sadly, but not surprisingly) concludes that *"it seems that there may not be a happy end to my story of The Five Stages of Collapse, the first of which (financial, commercial, political) are inevitable, while the last two (social, cultural) are entirely optional but have, alas, already run the course in many parts of the world. Because you see, there is also the sixth stage which I have previously neglected to mention – Environmental Collapse – at the end of which we are left without a home, having rendered Earth (our home planet) uninhabitable"* (2013b, p. 7). We are in a sorry state indeed.

[69] Please refer to the previously mentioned reports from CRO Forum, 2019; McHale et al, 2012; and SwissRe, 2016, 2018b for examples.

3. Conclusive chapter: The future of the insurance industry: A thin line between resilience and collapse

The previous two chapters of this thesis have demonstrated how difficult it is for any industry to be resilient in the current and future environmental, financial and geopolitical contexts. More specifically, this document has emphasized the upcoming difficulties the (re)insurance industry is about to face if most of this sector's lines of business are profoundly impacted by climate change.

Chapter one has detailed the complexity of the industry's business model and witnessed its interconnectivity to and dependency on the global financial sector's well-being, through Insurance Linked Securities and as a major investor within stock markets. This first chapter has also demonstrated the close relationship between the insurance industry and climate change, thus proving the importance of discussing the global warming issue in the context of this specific economic sector. Certainly, current Earth system modifications have already started to impact the industry with vast and multiple effects including alterations in severe weather events pattern (e.g., stronger and wetter tropical cyclones, more wildfires, droughts and floods, etc.), health related issues (heat stress, epidemics, mental health) and (in)direct economic effects (direct impact on economic growth, loss of productivity in the workplace, etc.) and these effects come as a strong challenge to the insurance business model. Accordingly, this document has provided some examples of climate change mitigation and adaptation (re)actions taken by the industry, showing that the economic sector is aware of these issues and has understood the seriousness of the situation.

However, chapter 2 has introduced further data to create an additional theoretical stress test of the insurance industry's resilience towards a probable catastrophic scenario. Indeed, the combination of the "business as usual" RCP 8.5 pathway with the current financial sector's weaknesses has revealed to be an explosive and potentially fatal cocktail. As a matter of fact, the strong and unpredictable impacts of such a severe climate scenario will not only present a challenge for the insurance industry's resilience but will also consist in a serious test for humankind's own survival. Furthermore, an analysis of this scenario through the glasses of "collapsology" has revealed the tangible potentiality of a societal collapse in which no industry whatsoever could display any kind of resilience. Indeed, resilience seems to be extremely difficult to achieve in circumstances where social disparities, global warming, peak oil and financial fragility are followed by the shadow of a civilization collapse. In addition,

the philosophical questioning of key notions and tools used by the insurance industry, such as risk and models, has shown that the sector as a whole may contribute to an unhealthy "modern" paradigm in which humans control and dominate nature. Unfortunately, it seems that the VUCA environment brought by climate change and enhanced by the potentiality of Black Swan events will necessitate deeper modifications in the way the insurance industry functions and how it perceives its surrounding.

At this point, it is important to remind the reader that the issues discussed within this paper are not the sole responsibility of the financial and insurance sectors, but of the society as a whole (consumption habits, lifestyle, etc.). Therefore, it is of the utmost importance not to pillory financial entities only, as this global problem requires an inclusive response incorporating all sectors of our complex societal web. One should also recall that the study of the multiple issues faced by the insurance industry provides a fascinating overview of the current and future states of the world, as this industry has developed a consequent knowledge of its customers by gathering significant intimate and personal data on a wide array of their lives, from the way they eat and live (H & L insurance) to the way they travel (car insurance, travel insurance, etc.) or how they protect their businesses and homes (casualty insurance). To a certain extent, one would not be wrong in saying that an insurer knows more about someone's life than most of his or her family members. Certainly, the debate on how far the insurance industry should be allowed to study and enter its customers' lives is of major importance and a must in any democracy,[70] but the gathered data, which cover a vast scale of our habits, could become extremely useful when looking at current trends and potential paradigm transitions.

Having all of the above in mind, this conclusive chapter's main objective is to open the discussion on the potential future roles and responsibilities of the insurance industry. Accordingly, the following sections will show that the insurance industry will be walking on a very thin line between, on the one side, a safekeeping role of the current societal model that brought humankind to the brink of collapse and, on the other side, a paradigm "transitioning" role providing potential collapse assistance aimed at supporting humans in the difficult voyage toward a more sustainable civilization.

[70] Such a debate took place in Switzerland during 2018 as Swiss citizens had to vote on a revision on the "law of surveillance" giving more freedom for insurers to investigate their customers (rts.ch, 2018).

3.1. The safe keeper of a broken model

To begin, let us recall that the objective of the following sub-chapter is not to pillory and blame the insurance industry for all the existing issues faced by our society, but a transparent, frank and objective discussion of the insurance industry's influence within the current socio-economic model is necessary as it may help in the development of new environmentally friendly alternatives. The current thermo industrial civilization's harmful impact due to its trespassing of major planetary boundaries (W. Steffen et al., 2015) has already been carefully detailed within this thesis and the unsustainability of such a system should not come as a surprise to the reader. Indeed, as Dominique Bourg rightly summarizes, *"the mastery we thought we had exercised over nature comes back to us as a boomerang, exposing us to a number of incapabilities"* (2018, p. 11, our translation). As a mater of fact, the profound Earth system modification, commonly referred to as "Anthropocene", has created an atmosphere of great uncertainty, enhancing humankind's difficulties to work on potential answers. But alas, the negative impact of our civilization is not limited to environmental degradations. Indeed, as explained by Bourg (2018), Jackson (2009) and Servigne (2018), our dependency on, and belief in, infinite economic growth has led us to a point of probable no return. Of course, it would be dishonest to say that economic growth has never showed any beneficial effects as the "thirty glorious years [71]" have demonstrated the contrary. Indeed, this post-WWII period (1946-1975) has been the witness of substantial economic growth (e.g., a 5 per cent average in France between 1950 and 1973) leading to tangible improvements in the quality of life (e.g., lower wage inequalities, additional holidays, generalization of new equipment such as television or washing machines[72]) (Larousse, n.d.). However this "*golden age of economic growth"* (Vonyo, 2008) has come to a sudden halt in the 1980s and the advantages of such a system have become more than questionable in the 2000s. As previously mentioned, it is not this paper's objective to detail the current societal impact of economic growth as this would require a lot more space than available and, for instance, Tim Jackson's *Prosperity without growth*: *Economics for a finite planet* (2009) already offers a very comprehensive coverage of the limits of economic growth. Consequently, what one should recall is that such a system has probably reached its limits and that stubbornly

[71] The French expression "les trente glorieuses" was born from the work of Jean Fourastié and corresponds to the golden era of economic growth from 1946 – 1975 (Fourastié, Cohen, & Impr. Maury, 2011).

[72] In France, the household equipment rate of televisions and fridges has passed from 10 per cent in 1954 to 70 – 90 per cent in 1975 (Larousse, n.d.).

insisting on continuing on the same path may bring additional and extreme environmental and societal consequences.

So as to further demonstrate the insurance industry's influence on the socio-economic system, a reference can be made to a metaphor brought by Dominique Bourg during one of his classes at Lausanne University (UNIL) (personal communication, 2018).[73] When describing the current state of the thermo industrial society within its VUCA environment, Bourg uses the metaphor of the society as the driver of a car. Everything goes well until the car starts gaining speed in an exponential way (please refer to figure 13: "the great acceleration" for such exponential growth). The driver seems to have an issue with the breaks, which do not respond anymore, as the economic growth cannot be stopped (unfortunately, stopping and even slowing economic growth is not a viable option for the current economic system as many factors such as employment rate or debt reimbursements would fail if such evolution is halted[74]). In addition, and as if the problem with the breaks was not enough, the steering wheel begins to answer in unpredictable and erratic ways (the complexity of Earth's systems causes one action to potentially trigger a totally unexpected response). However, even with all this drastic information in mind, the driver (the society) keeps on accelerating in this increasingly warm and uncomfortable car (as demonstrated, an RCP 8.5 "business as usual" scenario does not increase humankind's comfort on planet Earth). Suddenly, the GPS warns the driver of a potential wall in the upcoming kilometers (planetary boundaries and system tipping points are located all around our society) but does not know its exact location (once again the complexity of Earth's systems makes it very difficult to know the exact location of the current system's tipping points). This metaphor perfectly summarizes the current state of our socio-economic system.

What is the role and influence of the insurance industry on this system if we keep on driving down the "business as usual" road? When coming back to Bourg's analysis of the inadequacy of using the notion of risk mentioned in chapter 2 (2013; 2018), one can conclude that the insurance industry seems to be guilty of conveying inadequate and even dangerous messages to the society. Indeed, the analysis in terms of risk has the tendency to favor a silo approach, as we tend to separate one risk from another (e.g., Hurricane risk and health risk caused by

[73] The original metaphor from Dominique Bourg has been slightly enhanced as to fit all items necessary for this chapter's demonstration but the core remains the same.

[74] The current case of China's slowing economy and how it could impact the rest of the economic world provides a tangible reminder that a slow or no-growth environment would be catastrophic for such a system (Nath, 2019).

global warming result in two different products) whereas a holistic approach would be more adequate in the case of global issues. In addition, while it is true that speaking in terms of risk conveys the comfortable impression that an easily applicable solution is at reach and it is therefore not necessary to worry, it is in fact all the contrary as the complexity of Earth systems makes it extremely difficult (if not impossible) to design a "silver bullet" solution to an issue such as global warming. As a result, investing in wind turbines or improving a circular economy may only be a small part of the required effort.

In addition to what we may now call the "risk notion fallacy", the insurance industry has the tendency to carry the idea that it can actually plan the future with enough precision to understand upcoming risks. This thesis has already deeply criticized our unconditional trust in modeling and it is also important to emphasize that this image delivered by modelers presents a wrongful idea of humans in total control of their destiny. Unquestionably, modelers tend to pledge that we understand and control our surrounding, wrongfully attesting that we will always have the time and the skills to act accordingly. This misleading, albeit comforting, idea of control could be correlated to the lack of concrete societal reaction towards climate change. If we once again use the car metaphor, it can be said that these previously mentioned insurance industry's tools and products provide the driver with the wrongful impression that his GPS works perfectly fine and that both the break and the steering wheel will be repaired in time to avoid impact.

Unfortunately, the insurance industry's influence on our perception of urgency does not end here, as the industry, through its various range of products, encourages individuals to take risk they would not necessarily take without coverage. In fact, would someone really purchase a house or invest in a flood sensitive region without the reassuring P&C insurance coverage? Would an investment banker take the same decisions without D&O coverage? Or would a mining company, such as Vale, take the risk of constructing mines that could easily result in a catastrophe[75] without the help of the insurance sector? Although, this "counterfactual history[76]" type of questioning does not constitute hard proof, it is not very difficult to intuitively draw a correlation between the safety net offered by insurances and the additional risk taken by individuals. However, it should also be emphasized that this safety

[75] As a reminder, the 2019 tragic collapse of a mining dam operated by Vale caused several deaths, more than 400 unaccounted people and a widespread red iron ore waste contamination in the Brazilian state of Minas Gerais (Phillips, 2019).

[76] Counterfactual history is a *"form of historiography that attempts to answer « what if » questions known as counterfactuals"* (Rodwel, 2013).

net has a more positive counterpart, as it allows for the development of new environmentally friendly technologies through the coverage of associated risks and remains important in the race for tools such as CDR. Nevertheless, when coming back to our headless driving car, this additional individual risk capacity provided by the insurance's pooling of risk could make the driver think that it is worth accelerating for a couple more minutes as he may be able to develop an alternative type of steering wheel or a new and more efficient technology for car breaks. Once again, taking such a bet on technology developments seems extremely dangerous as we recall that humans have no control over the various Earth system tipping points that could be triggered at any time resulting in dreadful cascading effects.

Finally, the insurance industry's role in increasing resilience and stability during financial crisis (see chapter 2) can be perceived as a two-edged sword. Indeed, on the one edge, the increased resilience due to the industry's conservative investment strategy has helped save jobs and assisted in stabilizing a collapsing banking sector. However, on the other edge, it seems to have offered an underestimated perception of the financial sector's exposure to systemic risk and an overestimated view of its resilience. Certainly, without the insurance industry, the global financial collapse would have been far more important and lessons learned would have probably lasted longer, thus leading to potentially deeper modifications in the way the society manages its economy. Using the car metaphor, the increased societal resilience capacity provided by the insurance industry could be seen as a reinforced structure for the car or the possibility to push the wall at a further distance. However, since we do not know where the wall is, this option seems improbable and at the extreme speed the car is going (and still increasing in an exponential manner) any type of structure would finally hit the wall in a devastating way ending in the wreckage of the vehicle and the probable end of the thermo industrial civilization.

To sum up, this vulgarized car metaphor has detailed how the insurance industry influences the perception of risk and how it may be one of the several causes of societal inaction. Indeed, (re)insurance and their multiple products have participated in making, what is believed to be, a broken model more resilient, hence slightly increasing its life span. This additional time offered by the insurance industry can be seen in both positive and negative ways. On the one hand, this precious time could be used to reinforce global warming mitigation and adaptation measures so as to increase the society's readiness (and resilience) for the difficult future to come. Unfortunately, it does not seem that this additional time is being used adequately and taken seriously as the necessary drastic measures have still not

been taken until today (this paper is being written mid 2019). Even more frighteningly, recent data from the Stockholm International Peace research Institute (SIPRI)[77] demonstrates that world leaders are definitely not focusing on socio-environmental issues as *"world military expenditure is estimated to have been $1,822 billion in 2018, accounting for 2.1 per cent of world gross domestic product (GDP) or $239 per person".* Total world military expenditure *"grew for the second consecutive year and exceeded $1.8 trillion for the first time; it was 2.6 per cent higher than in 2017 and 5.4 per cent higher than in 2009"* (2019, p. 6). Furthermore, the shocking 13,865 nuclear weapons spread over nine countries (including some of the largest carbon dioxide emitters such as the USA and China) of which *"3,750 were deployed in operational forces*" (SIPRI, 2019, p. 10) does not send an extremely peaceful message in these times where the global focus should be on uniting forces to find solutions for *"transcendental damages"* (Bourg, 2018).

However, on the other hand, the additional time provided by the insurance industry can also be considered as more time to increase environmental destruction, thus making damages more irreversible. In fact, as previously seen in chapter 2, the thermo industrial civilization's hunger for extracted resources increases every passing day and does not show any sign of steadiness. Indeed, the increasing extraction and demand for key resources does not seem to slowdown, as examples including the 2019 global estimates for demand of crude oil reaching about 100.6 barrels per day (B/D) (Garside, 2018) and the 1.8 billion metric tons of crude steel produced in 2018 (Wagner, 2018) point exactly to the opposite. As a matter of fact, it seems that the insurance industry's desperate search for additional societal resilience may actually become one of the key triggers of societal collapse.

As a conclusion to the above, the insurance industry's current role as a stabilizer to the thermo industrial society becomes increasingly apparent and requires deeper questioning within the industry itself. Indeed, the industry's adaptation and mitigation measures given as examples in chapter 1 have demonstrated the difficulties for this industry to develop "out of the box" solutions. While reducing the impact of its employees or investing in ESG solutions may seem revolutionary when compared to the actions (or inaction) from the rest of the financial family (e.g., banks, brokers, etc.), they remain extremely limited when looking at the upcoming challenges. The tight interconnectivity between the insurance industry and its

[77] SIPRI is an independent international institute dedicated to research into conflict, armaments, arms control and disarmament (SIPRI, n.d.).

financial partners and shareholders may be one of the explanations for the absence of revolutionary and game-changing engagements. Indeed, one should remember that the current economic system requires businesses to serve their shareholders' "best interest" (Stout, 2015), which, have an exceedingly short-term nature when seen from an environmental point of view. Surely, BlackRock Inc's[78] 5.03 per cent share participation in Swiss Re Ltd's capital (Swiss Re, 2018a) is a perfect illustration of the insurance industry's dependency on large investors and confirms the difficulties (or inability) to question solutions brought by a mainstream economical approach.[79] In fact, as a prominent member of the existing capitalistic economic system, the insurance industry has worked within a very specific and restricted frame and has developed environmental solutions that fit this specific paradigm. Unfortunately, this socio-economic model characterized by notions such as "sustainable development" or United Nations' "Green Economy" (UN Environment, 2018) has shown its limits and the continuous degradation of our planet comes as concrete evidence of the necessity to innovate and opt for an "out of the box" approach. Fortunately, the following sub-chapter will demonstrate that not all is lost for the insurance industry as the future reserves plenty of new opportunities, even in a collapsing context.

3.2. Collapsing world opportunities

One of the main questions when studying societal collapse in the framework of environmental degradation is whether it would be opportunistic to freely let the human world fall apart, thus decreasing its negative impact on nature. Even though, a societal collapse would result in fewer humans on the planet with a lower environmental impact due to the absence of oil-powered destructive technologies (amongst many other impacts), it seems extremely dangerous to take such a bet, not only due to the extreme pain that such a societal collapse could cause, but also due to humankind's deep interconnections to its home planet. A flagrant example, among many others is the case of nuclear reactors. Indeed, as discussed in chapter 2 and emphasized by Dmitry Orlov (2013b) and Pablo Servigne (2015, p. 197), humans have developed a global web of nuclear reactors necessitating particular attention as most of them require "*weeks, if not months of work, energy and handling to cool down and*

[78] BlackRock Inc. is an asset management firm managing USD 5.98 trillion assets worldwide in 2019 (BlackRock, n.d.).

[79] Indeed, alternative solutions such as Ecological Economy or Social and Solidarity Economy exist but are most commonly disregarded by mainstream economists and international organizations.

switch off" (Servigne, 2015, p. 197). Consequently, when looking at the destruction radius and impact on humans of past nuclear accidents such as Chernobyl and Fukushima, a "let's let the world collapse" approach would lead to massive threat to humans, the environment, the Fauna and the Flora and would be completely absurd since the fundamental objective remains survival and not mass suicide. Therefore, it appears to be of the utmost importance to work on solutions that would make an almost inevitable societal collapse less painful as well as develop a specific intelligence to plan and restructure a new society with solid and sustainable basis. Fortuitously, it seems that the insurance industry could participate, or even be a leader, in such a movement by virtue of its knowledge and leadership.

The present section will thus propose a few alternative pathways available to the insurance industry in their search for added societal resilience. For clarification, the objective of this section is to propose "truly" alternative approaches on a "strong sustainability" basis and not to discuss new insurance mainstream opportunities or products brought by climate change as this has already been reviewed in chapters 1 and 2. Indeed, this section will look at opportunities for the insurance industry to act as a key paradigm modifier towards a truly sustainable future. Finally, the below proposals are meant to be useful in preparing for a collapsed environment as the ultimate goal is to render alternative and sustainable lifestyles attractive. While the scope of pathways and new subjects made feasible by a collapse situation are almost infinite, the three following points could serve as pillars for the insurance industry to assist it in the development of a new deeply sustainable society.

3.2.1. Pillar I: Thinking "out of the box" and openness to alternatives

The insurance industry's financial leverage as a major investor within stock markets and its "knowledge" leadership position on climate change has been observed in chapter 1 and could be used as a leverage towards more "environmentally friendly" alternatives. Even though the exact definition of "sustainability" used by the insurance industry remains to be discussed in-house, this thesis highly advocates for a "strong sustainability" (vs. the current "weak sustainability") approach, as it seem to be the only one that proposes an inclusive and holistic vision. The well publicized "sustainable development" approach as exposed within the Bruntland Report (1987) and circulated by major international organizations (e.g UN, IMF, WB, etc.) remains too weak and has by far not proven its efficiency. Therefore, as a leader within financial markets and a societal risk assessor, it should be the insurance industry's primary role to push new sustainable narratives (new economic story telling) as

they could assist in a smoother transition towards a more sustainable future and therefore diminish risks. Surely, such an "open minded" approach regarding the very basis of economics may represent a serious challenge to an industry that has developed in (and nurtured) this specific economic paradigm of possible (and necessary) infinite growth. However, the insurance industry should take advantage of the previously exposed human's attachment to narratives (see "Narrative fallacy" from Taleb, N. in sub-section 2.2.2.2 to develop new and more sustainable alternative stories in order to enhance our societal resilience. It is important to mention that such alternative economic narratives do already exist but are usually put aside by mainstream economists, as they do not fit the current primary economic paradigm. While a detailed discussion of the multiple advantages of alternative approaches to economy such as Ecological Economics developed by authors like Herman Daly or Robert Costanza (Douai & Plumecocq, 2017) is not possible due to time constraints, what one should recall is that alternatives to mainstream economy do exist and that now seems like a perfect time to study their valuable addition towards building a more environmentally friendly economy. As a concrete approach, the insurance industry could not only hire heterodox economists within their pool of consultants, but also disseminate these approaches during seminars and in key reports.

In addition to openness to alternative economic story-telling, the insurance industry could have a tangible impact on the development of what are commonly known as "transition" projects. Indeed, using its long experience with micro insurance in developing countries, the industry could develop a line of products meant at insuring "transition" projects and in this way encourage the search for alternative and more resilient lifestyles. As a matter of fact, trial and error on alternative lifestyles is of the utmost importance when discussing societal resilience as it tests various pathways to our existence. In this regard, it should be one of the insurance industry's responsibilities to promote and encourage such testing and develop new products accordingly. Potential influence of such game-changing products or systems can easily be found in recent literature. For instance, Sophie Swaton's Revenu de Transition Ecologique (translated as Ecological Transition Revenue) (RTE)[80](2018) proposes a solid alternative in building a more sustainable and solidary society by assisting and guiding

[80] From the French "revenus de transition écologique". As per Swaton, the RTE is not a simple complementary income as it comes with conditions. Indeed the RTE is strongly linked to a transitional activity and is meant at providing tailor made solutions for various projects. The RTE consists of *"three levels meant at allowing a simultaneous change of scale at the collective and societal level. It's a comprehensive measure that fits into the economy, because if the economy is part of the problem, it has to be part of the solution"* (Swaton, 2019, our translation).

individuals and groups in developing transitional activities. In this regard, insurance products aimed at protecting such "transitional projects" could pair with an RTE type of revenue and reduce subsequent financial risks, thus pushing a higher percentage of the population towards alternative and more sustainable lifestyles. In a concrete approach, such assistance could consist in lower premiums for truly sustainable projects as they directly contribute to lowering societal risk by proposing alternative approaches. Moreover, the amount of work and study to be invested in these products is not as large as it seems. Indeed, similar systems already exist within the micro insurance line of business and lower premiums are already given to "risk reducing" citizens in the car insurance sector. Therefore, the only important subject to be addressed remains the exact definition of what the insurance industry should consider as "truly sustainable" projects as it does not sound realistic to "sponsor" all and every existing project. As concrete examples, lower premiums could be given to permaculture and agro-ecology projects as they propose future and more sustainable alternatives to feeding tomorrow's world. Another tangible proposal could be to limit insurance coverage to projects that remain within the planetary boundaries (W. Steffen et al., 2015). This would imply, for instance, to gradually remove "oil and gas" related products from the insurance range of proposals. The development of this type of activities and strategies would necessitate a strong and unanimous decision from the whole of the industry, as it would correspond to massive reductions in premium revenues.

To continue our "out of the box" approach, Servigne (2018) highlights the importance of developing altruism and mutual aid as key elements of our society as we enter a difficult and painful collapse period. Indeed, a future involving mutual aid and renewed links between community members sounds a lot more attractive than the individual survivalist "hide in my bunker with loads of weapons" approach, especially when facing the difficulties of a collapse. In this matter, the insurance industry already possesses an interesting business model connecting individuals together with the pooling of risks. However, there is an important item missing, which is the tangible human and emotional relationship between community members. As a result, the insurance industry could work on a future system that not only allows the pooling of risk, which is clearly necessary in a collapsing environment, but also creates renewed links among humans and between humans and nature.

3.2.2. Pillar II: A new approach to business ethics and human-nature relationship

The second pillar detailed below exposes the idea of renewing the insurance business's approach to sustainability and increasing a much-needed renewed human-nature relationship. Indeed, as previously mentioned in this document, our "modern" culture tends to convey the idea that Humans are meant to dominate nature, thus implying that utilizing the environment as desired is a normal thing to do. For the sake of transparency, it should however be mentioned that this approach is not the only one as French anthropologist Philippe Descola has shown that other ontologies do exist. Indeed, in his book *Par-delà nature et culture* (2005) Descola proposes four major approaches to nature: *(i) naturalism*, the modern occidental ontology that introduced the human-nature duality and in fact developed the concept of nature; *(ii) animism*, the total opposite of naturalism, witnessed in parts of south and north America, as well as Asia; *(iii) totemism*, ontology where different types of beings are classified by their physical, psychic and moral properties; and *(iv) analogism*, where each and every being is different. This wide array of ontologies clearly demonstrates the multiple existing visions of other living beings and proves that potentially less harmful approaches may and should be explored both by the society and the insurance industry so as to design and develop alternative products.

Another important area that should be further discussed within the industry is its ethical background for doing business. Indeed, this approach has already started to evolve through higher ESG investments and in house projects (such as SwissRe's CO_{you2}) as mentioned in chapter 1, but it remains very shy when looking at the scale of the needed actions. Indeed, "light" ESG investments and a few projects cannot come as the sole answer to the drastic and required changes to the way people live. In fact, the insurance industry should go one step further by fixing tougher ethical investment criteria from a social and environmental point of view, which could be found by working with professionals and researchers from the field of environmental ethics. This could bring new perspectives to the way of doing business in full respect of nature, or at least finding less harmful ways of doing so. To further deep dive into the subject, the reader may wish to consult the book *Ethiques de la nature* (2013) from University of Lausanne professor Gérald Hess who proposes a holistic and global overview of environmental ethics. Another angle from which to look at alternative investing could be to explore what Florian Barras refers to as eco-social banks and their respective investments strategies (2017). Indeed, Barras explains that *"eco-social banks are financial entities that*

use a sustainability based system of values to operate. Their criteria and processes are directed toward a maximization of sustainability, in opposition to traditional banks that maximize profit" (p. 5). By functioning in this way, eco-social banks provide well-structured and sustainable investment strategies, which could potentially serve as an example to the various insurance banking activities, as well as for their investments.

An additional issue that should be confronted by the insurance industry is its dependency on the notion of short-termism. Indeed, the industry's obligation to answer to its shareholders, as well as its interconnection to financial markets, explains the sector's proneness to short-term decision-making, which is in opposition to the environmental longer-term approach. Solving this discrepancy is complex as it involves a deep structural modification to the industry's financial model and to the way it manages its businesses. Nevertheless, a few proposals can be put forward. A concrete action within the insurance industry would be to create or enhance the Chief Sustainability Officer (CSO) position and empower this role with concrete and effective means of action. In fact, the CSO should not only have a complete access to top management (e.g., CEO, managing board, etc.), but he or she should also have powerful tools to make sure that all decisions are made in a sustainable way. Indeed, this person should represent the non-human, as well as future generations impacted by the company's activities and could use tools including the right to veto non-sustainable or harmful decisions. Inspiration on such a role could come from the Hungarian Ombudsman for Future Generations, a role that *"promotes the right to a healthy environment, and the right to the preservation of physical and mental health, while it also takes into account the interests of future generations in any decision or report it makes"* (Ombudsman for Future Generations, n.d.). This innovative approach to doing business by incorporating the impact on future generations and on non-human entities into the decision-making process could be made possible by the use of the precautionary principle and what Jean-Pierre Dupuy refers to as enlightened doom saying.

3.2.3. Pillar III: The precautionary principle and enlightened doom saying

The previous chapters of this thesis have already vastly covered the difficulties brought by climate change and its related uncertainty. In Philippe Vallat's words *uncertainty* causes paralysis as it creates a tendency to gather and analyze data in an excessive way (2014), hence leading to a certain waiting game and political inaction. This uncertainty-related inertia of both public and private sectors should be perceived as an additional risk by the insurance

industry and should therefore trigger a serious reaction. As a result, the analysis of alternative approaches to the way society perceives the probabilities of catastrophes or the way it identifies risk should be a priority for the insurance industry in its search for increased resilience. Indeed, as previously discussed[81] the current approach to risk and catastrophes should not be set in stone, as other approaches generating healthier responses from a sustainability point of view already do exist.

A first response to this inertia can be found within the general principles of environmental law. Indeed, amongst the numerous environmental principles including "sustainable development", "polluter pays" or the "integration" principles, one principle is highly appropriate when referring to the issue of inaction in a state of uncertainty - the "precautionary principle". This principle, to be cautiously differentiated from the prevention principle,[82] has already been vastly discussed by sustainability professionals and seems perfectly built to navigate in a contemporary scientific paradigm as defined earlier in chapter 2. For the sake of clarity, the European Parliament defines the precautionary principle as one that *"enables decision-makers to adopt precautionary measures when scientific evidence about an environmental or human health hazard is uncertain and the stakes are high"*(Bourguignon, 2015), thus confirming the relevance of this approach when addressing global warming and its related uncertainties. Therefore, developing and integrating a tailor-made version of the precautionary principle into the insurance industry's decision-making process would represent a helpful additional layer to the already massively used prevention principle. Indeed, until today, the insurance industry mostly acted by preventing the certainty of existing risks such as protecting flood and hurricane prone regions, but adding precaution to such an existing model would allow to build additional resilience as it opens the door to a paradigm of uncertainty. Of course, some will challenge this approach as the precautionary principle is also considered to be an obstacle to progress and economic growth, however, it may also prove to be extremely useful when looking at the industry's long-term resilience.

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81 Refer to the discussion on "transcendental damages" and prerequisites of the risk notion in Chapter 2.

82 As a reminder, the precautionary principle strongly defers from the prevention principle and its demanding epistemological presuppositions. Indeed, the prevention principle evolves in a "modern" paradigm including logic of control and scientific certainty. In fact, the prevention principle assumes the knowledge of three central elements: the wrongful action committed, the ecological damage and causal link (Alain Papaux, personal communication, 2017). These three elements can be found easily for simple pollution cases, but remain extremely difficult to identify for global issues such as climate change. On the contrary, the precautionary principle evolves in what Alain Papaux refers to as a "contemporary" scientific paradigm with strong uncertainty, thus matching the current climate change uncertain societal effects as described in this thesis.

Here once again, the insurance industry will have a drastic decision to make between short-term economic gain and long-term resilience, the second one being beneficial for both business and environment in the long run. It would also seem as a logical decision for an industry that bases its work on risk reduction to act in a precautionary manner and therefore participate in reducing the impact of a societal collapse, even if it is uncertain.

However, even if the precautionary principle were to be put in practice by the insurance industry, this paper's description of Nassim Taleb's Black Swans (2010) combined with the below analysis of Jean-Pierre Dupuy's *Pour un catastrophisme éclairé* (2002) demonstrates that it would not suffice in certain cases. Indeed, it seems that certain events (e.g., climate change, nuclear explosions, etc.) and their horrifying consequences are simply impossible to grasp attesting that societies' inaction does not only depend on scientific uncertainty. As Dupuy explains *"the prophet of doom is not heard because his words, even if they issue from sound knowledge and true information, do not manage to penetrate the system of beliefs held by those to whom they are addressed."* (2012, p. 8). A concrete past example of such "denial" given by the author is the refusal of many European Jews to believe in the atrocious reality even on the railway platform at Auschwitz-Birkenau leading Primo Levi to quote an old German adage: *"Things whose existence is not morally possible cannot exist."* (p. 9). Consequently, Dupuy adds that *"our ability not to see when faced with the obviousness of suffering and atrocities is the principal obstacle that the prophet of doom must at least find a way around, if he cannot actually overcome it"* (p. 9). Surely, it seems as a very sensitive thing to compare the (certain, perturbing and horrifying) impacts of Holocaust and the future (uncertain) results of climate change, but the main purpose of drawing such parallel is to show that *"it is not enough to know in order to accept what one knows and then to act on it"* (p. 8). This provides an additional explanation to our inertia towards the catastrophic scenario as described in this thesis. It is in this respect that Dupuy's *"enlightened doom saying"* proposes an innovative approach to the way the "impossible" is perceived. In short, the author's main demonstration is based on the paradox of doomsaying which *"arises from the fact that the prospect of catastrophe can be made credible only if we can be persuaded first of its reality - of its existence as part of a fixed future"* and the goal should therefore be to enable the *"irruption of the possible into the impossible"* (p. 11). Indeed, according to the author, the current *"reversed temporality"* where catastrophes become possible only in retrospect is considered as a major issue to understanding the risks of climate change and societal collapse. As an answer, Dupuy recommends to consider catastrophes not as potential

risks or fatalities but as certainties (Servigne, 2015, p. 143). In the case of societal collapse, recognizing it as a certainty and not as a potential and far away risk would surely open new opportunities to finding solutions and avoid the worst effects of such a scenario. As for the insurance industry, this approach would necessitate profound modifications in the way it functions due to its deep relationship to the notion of risks and probabilities. The exact adaptation of the "enlightened doomsaying" position within the insurance industry would therefore definitely require additional work, but should unquestionably be considered as an interesting lead with regard to increased societal resilience.

To sum up, this conclusive chapter has not only demonstrated that the insurance industry's current business model will require deep modifications in the face of upcoming difficulties, but it has also shown that alternative opportunities that could enable a smoother collapse scenario do exist. In addition, it has been established throughout this thesis that the insurance industry's use of the notion of risk may be inadequate as it does not allow to grasp environmental and societal issues in a holistic way due to its silo approach. This issue will probably represent one of the main challenges for the insurance industry during the years to come, but, when looking at the industry's evolution through time,[83] there is reason to believe that it is flexible enough to adapt to its changing environment and could therefore become a strong pillar in holding the society together in the midst of a collapse. As a matter of fact, an innovative business model including an adapted version of the existing "pooling of risk" coupled with a precautionary spirit influenced by the work of Jean-Pierre Dupuy could serve as a sound basis to tackle catastrophes such as climate change and probable societal collapse. This thesis has also opened doors to additional research on a number of subjects, including the relations between system science and the insurance industry, the future role of the insurance industry as it faces climate threat and the development of collapse insurance products to reinforce its overall resilience. To conclude this thesis, we would like to refer to Donella and Dennis Meadows' wise words: *"Humanity cannot triumph in the adventure of reducing the human footprint to a sustainable level if the adventure is not undertaken in a spirit of global partnership. Collapse cannot be avoided if people do not learn to view themselves and others as parts of one integrated global society. Both will require compassion, not only with the here and now, but with the distant and future as well.*

[83] For further reading on the insurance industry's history, the reader may refer to Swiss Re's *A History of Insurance* (Viggo Haueter, 2013) and *A History of US Insurance* (Swiss Re, 2011a) as cited in the bibliography.

Humanity must learn to love the idea of leaving future generations a loving planet" (Meadows et al., 2004, p. 282-283).

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5.2. Direct and indirect impact of macroprudential policy as per the EIOPA

<table>
<tr><th>Triggering events (Examples)</th><th>Risk profile of the company</th><th>Potential systemic risk drivers</th><th>Main transmission channels</th></tr>
<tr><td rowspan="8">• Macroeconomic factors
○ Unemployment
○ Inflation
○ Bubbles (e.g. housing)
○ Others
• Financial factors
○ Yield movements
○ Market prices (equity, fixed income, etc.)
○ State of the banking system
○ Financial innovation
○ Others
• Non-financial factors
○ Demographic changes (mortality/ longevity)
○ Natural catastrophes
○ Legislative changes
○ Political changes
○ Technological changes
○ Consumer/ policyholder behaviour (e.g. mass lapses, etc.)
○ Cyber attack
○ Others</td><td rowspan="8">• Market risks
○ Interest rate
○ Equity
○ Property
○ Etc.
• Health risks
○ Mortality
○ Longevity
○ Lapse
○ Etc.
• Default risks
• Life risks
○ Technical provision
○ Mortality
○ Longevity
○ Lapse
○ CAT
○ Etc.
• Non-life risks
○ Premium reserve
○ Lapse
○ CAT
• Operational risk (incl. fraud)
• Model risk</td><td colspan="2">Entity-based related sources – Direct sources
➢ Deterioration of the solvency position leading to:
a) Failure of a G-SII, D-SII
b) Collective failures of non-systemically important institutions as a result of exposures to common shocks</td></tr>
<tr><td>• Size
• Global activities
• Interconnectedness
○ Counterparty exposure
○ Macroeconomic exposure
• Substitutability (incl. market niches)</td><td>• Exposure channel
• Lack of supply of certain products
• Expectations and information asymmetries
• Asset liquidation</td></tr>
<tr><td colspan="2">Activity-based related sources – Indirect sources (i)
➢ Involvement in certain activities or products with greater potential to pose systemic risk
➢ Potentially dangerous interconnections</td></tr>
<tr><td>• Derivative trading (non-hedging)
• Financial guarantees (incl. monolines)
• Asset lending (e.g. securities lending) and management activities
• Direct lending
• Lapsable products and products that entail maturity transformation
• Guaranteed products
• Variable annuities</td><td>• Exposure channel
• Asset liquidation channel
• Bank-like activities channel (maturity transformation and leverage)</td></tr>
<tr><td colspan="2">Behaviour-based related sources – Indirect sources (ii)
➢ Collective behaviour by insurers that may exacerbate market price movements (e.g. fire-sales or herding behaviour)
➢ Excessive risk-taking by insurance companies
➢ Excessive concentrations
➢ Inappropriate provisioning (e.g. under-pricing as a result of competitive dynamics)</td></tr>
<tr><td>• Concentrations in certain asset classes and common exposures on the asset side
• Excessive risk taking
○ 'Search for yield'
○ Too-big-to-fail/moral hazard problems
• Heightened competition potentially leading to insufficient technical provisions or premiums</td><td>• Exposure channel
• Asset liquidation channel</td></tr>
</table>

Source: EIOPA, 2019, p. 13.

5.3. Additional microprudential tools and measures under consideration by EIOPA

Tool	Type of tool	Proposed for further consideration?
Enhanced reporting and monitoring		
Leverage ratio	Capital and reserving-based	Yes
Enhanced monitoring against market-wide under-reserving	Capital and reserving-based	Yes
Additional reporting on liquidity risk **(*)**	Liquidity-based	Yes
Liquidity risk ratios	Liquidity-based	Yes
Enhancement of Prudent Person Principle (PPP) **(*)**	Exposure-based	Yes
Enhancement of own risk and solvency assessment (ORSA) **(*)**	Exposure-based	Yes
Recovery plans **(*)**	Pre-emptive planning	Yes
Resolution plans **(*)**	Pre-emptive planning	Yes
Systemic Risk Management Plans (SRMP) **(*)**	Pre-emptive planning	Yes
Liquidity Risk Management Plans (LRMP) **(*)**	Pre-emptive planning	Yes
Intervention powers		
Counter-cyclical capital buffer	Capital and reserving-based	No
Capital surcharge for systemic risk	Capital and reserving-based	Yes
Liquidity requirements	Liquidity-based	No
Temporary freeze on redemption rights	Liquidity-based	Yes
Concentration thresholds	Exposure-based	Yes

(*) Considered specifically in the European Commission's Call for Advice (See Section 2).

Source : EIOPA, 2019, p. 19.

5.4. Detailed comparison of Mediocristan and Extremistan

Mediocristan	*Extremistan*
Nonscalable	Scalable
Mild or type 1 randomness	Wild (even superwild) or type 2 randomness
The most typical member is mediocre	The most "typical" is either giant or dwarf, i.e., there is no typical member
Winners get a small segment of the total pie	Winner-take-almost-all effects
Example: audience of an opera singer before the gramophone	Today's audience for an artist
More likely to be found in our ancestral environment	More likely to be found in our modern environment
Impervious to the Black Swan	Vulnerable to the Black Swan
Subject to gravity	There are no physical constraints on what a number can be
Corresponds (generally) to physical quantities, i.e., height	Corresponds to numbers, say, wealth
As close to utopian equality as reality can spontaneously deliver	Dominated by extreme winner-take-all inequality
Total is not determined by a single instance or observation	Total will be determined by a small number of extreme events
When you observe for a while you can get to know what's going on	It takes a long time to know what's going on
Tyranny of the collective	Tyranny of the accidental
Easy to predict from what you see and extend to what you do not see	Hard to predict from past information
History crawls	History makes jumps
Events are distributed* according to the "bell curve" (the GIF) or its variations	The distribution is either Mandelbrotian "gray" Swans (tractable scientifically) or totally intractable Black Swans

* What I call "probability distribution" here is the model used to calculate the odds of different events, how they are distributed. When I say that an event is distributed according to the "bell curve," I mean that the Gaussian bell curve (after C. F. Gauss; more on him later) can help provide probabilities of various occurrences.

Source: Taleb, 2010, p. 36.

5.5. List of civilization and their duration in years

The following list represents the full list of civilisations studied by Kemp, 2019 and the duration in years [XXX**]**.

Ancient Egypt, Old Kingdom [505]	Ptolemaic Egypt [302]
Ancient Egypt, Middle Kingdom [405]	Classical Greek [265]
Ancient Egypt, New Kingdom [501]	Hellenistic [177]
Norte Chico Civilisation [827]	Maurya Empire [137]
Harappan Civilisation (Indus Valley Civilisation) [800]	Seleucid Empire [249]
Kerma [400]	First Chera Empire [500]
Akkadian Empire [187]	Early Chola Empire [500]
Elam Civilisation (Awan Dynasty) [157]	Maghada-Maurya [90]
Minoan Civilisation (Protopalatial) [500]	Parthian Empire [469]
Xia Dynasty [500]	Satavahana Dynasty [450]
Third Dynasty of Ur [46]	Qin Dynasty [14]
Old Assyrian Empire [241]	Xiongnu Empire [184]
Middle Assyrian Empire [313]	Han Dynasty (Western Period) [197]
Neo Assyrian Empire [322]	Numidia [156]
Elam Civilisation (Eparti Dynasty) [210]	Teotihuacans [735]
First Babylonian Dynasty [299]	Kingdom of Armenia [442]
Old Hittie Empire [250]	Hsiung Nu Han [120]
Minoan Civilisation (Neopalatial) [250]	Sunga Empire [112]
Shang Dynasty [478]	Andhra [370]
Mycenae [400]	Aksumite Empire [1100]
Vedic Civilisation [1000]	Kanva Dynasty [45]
Middle Hittite Kingdom [70]	Three Kingdoms of Korea [725]
Elam Civilisation (Middle Elamite Period) [342]	Saka [140]
New Hittite Kingdom [220]	Roman Empire [525]
Olmecs [1000]	Han Dynasty (Eastern Period) [195]
Phoenicia [661]	Kushan [200]
Zhou Dynasty (Western Period) [351]	Bactria [70]
Kingdom of Israel and Judah [298]	Ptolemaic [290]
Chavin Culture [700]	Liu-Sung [250]
Urartu [225]	Gupta [90]
Kushite Kingdom [1150]	Hun [100]
Etruscans [404]	Byzantine [350]
Zhou Dynasty (Eastern Zhou Spring Period) [330]	Yuen-Yuen [30]
Zhou Dynasty (Eastern Zhou Warring States Period) [411]	Toba [130]
Ancient Rome [244]	White Hun [100]
Elam Civilisation (Neo-Elamite Period) [203]	Visigoth [240]
Phrygia [43]	T'u Chueh Turk [90]
Lydia [144]	Avar [220]
Magadha Empire [364]	Western Turk [70]
Chaldean Dynasty (Babylon) [87]	
Medean Empire [66]	
Orontid Dynasty [540]	
Scythians [800]	
Mahanjanapadas [200]	
Carthage [667]	
Achaemenid Empire [220]	
Roman Republic [461]	
Nanda Empire [24]	