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Climate Change and Precaution

A Concise Analysis of the Impact of the Precautionary Principle on the Climate Change Policy

by

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1. Introduction

Human beings, like other living organisms, have always influenced their environment. However, since the start of the industrial revolution, the surge in human activities has been impacting the lithosphere and pedosphere, the atmosphere, the hydrosphere, the cryosphere, as well as the biosphere[1] more deeply than we did in all previous periods combined. These are the major components of the climate system, which complex interactions have produced a rather stable equilibrium around which climate evolves.[2] The magnitude of these activities is affecting the face of the Earth in an unprecedented manner. Since the start of agriculture around 11,000 years ago, 70% of the Earth's land surface has been altered by human activities.[3] The anthropogenic mass has doubled roughly every 20 years. As a result, it is surpassing the global living biomass. Indeed, this is the first time in human history that we have altered ecosystems with such intensity, on such scale and with such speed.[4] It comes as no surprise that the Earth is at a cross over point.[5]

For over a century, industrial societies have viewed nature both as a rich reserve of resources and as a dump for the refuse produced by resource exploitation. Natural resources overexploitation as well as environmental pollution were belittled. Indeed, as pollutants were borne away by wind and water the solution to pollution was dilution. In addition, climate change issues were unknown. At the end of the 1960s, the public authorities in the Western world have tried to stem the threats posed by the growing environmental pressures. However, they fell short in endorsing a monolithic regulatory approach.

Since the inception of the environmental policy in the Western world,[6] policy measures intended to counter environmental damage have undergone a succession of radical modifications. A first phase took the form of remedial action, which translates into ex post intervention by the public authorities. At this stage damage has already occurred; the only possible course of action is remedy. This belated approach does not prevent the occurrence of environmental damage. It soon became apparent that this model was practicable only if it was buttressed by a preventive policy. For that reason, environmental policy evolved to include a preventive dimension, by which public authorities intervene prior to the occurrence of damage that is likely to take place if nothing is done to prevent it. This second stage is marked by a blind faith in science. In accordance with an 'assimilative' approach,[7] it is not absolutely necessary to eliminate discharges of polluting substances, since emission standards may easily

1 Since the start of agriculture around 11,000 years ago, the biomass of terrestrial vegetation has been halved, with a corresponding loss of >20% of its original biodiversity. See K.-H. Erb, al., 'Unexpectedly large impact of forest management and grazing on global vegetation biomass' *Nature* (2018) 553, 73–76 ; IPBES (2019). *Global Assessment Report on Biodiversity and Ecosystem Services*. Paris: IPBES Secretariat.
2 P. Lemke, 'Dimensions and mechanisms of global climate change'in G Winter (ed.), *Multilevel Governance of Global Environmental Change* (Cambridge, CUP, 2006) 37.
3 C.J.A Bradshow et al., 'Underestimating the Challenges of Avoiding a Ghastly Future' (13 January 2021) *Front. Conserv. Science*.
4 J.R. McNeill, *Nothing New under the Sun. An Enviornmental History of the Twentieth-Century World* (NY-London: WW Norton & Company, 2000) 3.
5 E. Elhacham et al., 'Global-human made mass exceeds all living biomasss', *Nature* (9 December 2020) 1.
6 This concept encompasses mostly OECD countries.
7 The assimilative capacity of a component of the environment can be defined as the amount of material that could be contained within this component without producing unacceptable biological impacts. See E.D. Goldberg, Ed., *Assimilative Capacity of US Coastal Waters for Pollutants Proceedings of a Workshop at Crystal Mountain,* WA, NOAA Working Paper No. 1 (US Department of Commerce, Washington, DC, 1979).

provide an appropriate response to any type of pollution by setting the exact level of a pollutant that an ecosystem can assimilate. It is assumed that as long as emissions do not exceed a certain critical threshold, receiving environments may absorb and disperse them. Ecological deterioration only takes place when the self-cleansing capacity of ecosystems is saturated as the result of too high concentrations or too rapid accumulations of polluting substances.[8]

In the course of the early 90s, the litany of environmental threats became alarming: destruction of the stratospheric ozone layer, climate change, ecosystem acidification, sheer loss of biological diversity, overexploitation of marine resources, increased technological risks, etc. The emergence of an array of increasingly unpredictable risks enticed the authorities to base their policy on an *anticipatory model*. This model can be linked to the understanding of the limitations of scientific expertise. While prevention is based on the concept of certain risk, the anticipatory model is distinguished by the intrusion of uncertainty. Metamorphosed into a factor for revealing uncertainty, science raises controversies as often as it offers robust knowledge. The entire foundation of the 'assimilative' approach, which rests upon a blind confidence in science, is thus crumbling under the pressure of uncertainty. In a nutshell, the differences between prevention and precaution are over how experts know what causes the phenomenon and what the decision makers' responsibility is in light of that knowledge[9]. Against this background, it became increasingly difficult to explain trends in global warming. Experts quickly took the view that mitigation should prevail over a curative approach. However, this statement does not resolve the issue as to the manner in which mitigation measures have to take into consideration uncertainties. Climate law does not ignore precaution. The precautionary principle was regularly invoked in the 1990s with respect to climate change issues, although the term precautionary *approach* rather than precautionary *principle* was favoured by Anglo-saxon countries. In 1992, the right to adopt precautionary measures was enshrined in the UN Framework Convention on Climate Change (UNFCCC). At that time, the recognition of precaution in a major international agreement was deemed to be a breakthrough.

This article seeks to analyse the implications of the precautionary principle on mitigation measures. After highlighting the specific features of climate change risks and highlighting the lingering uncertainties (sections 3 to 5), it will explore how the decision-making process could better integrate uncertainties.

It concludes by outlining how limiting the most severe impacts of global warming will require the integration of uncertainties into the decision-making process.

2. False negative v false positive: the rise of precautionary principle in international climate law

Uncertainty affects both the likelihood of an event and when—and to what extent—it will produce damage. In a context of incomplete knowledge regarding climate change speed and impacts in the course of the 80s, the international community was confronted to the following dilemma. Should the public authorities opt for a delayed regulatory approach with the aim of reducing the margin of uncertainty? Should they give credence to climatologists who predict

8 N. de Sadeleer, *Environmental Principles*, 2nd ed. (Oxford: OUP, 2020) 121, 125-7.
9 Ibidem, 165-167, 170-175, 243-544, 253.

catastrophic natural disasters? Or should they endorse an immediate preventive approach to counter threats that were merely suspected?

By avoiding hasty and precipitate measures, the wait-and-see or business-as-usual approach appears to favour a more efficient allocation of economic resources than a pre-emptive approach which would sacrifice economic welfare for the sake of avoiding an event that was not likely to occur (false positive errors).[10] In effect, the accumulation of scientific knowledge resulting from this delay offers decision-makers some hope of counting on the long run on more advanced and cheaper technologies. However, the uncertainties inherent in scientific investigation could delay the adoption of essential measures to ward off irreversible damages in the absence of incontrovertible proof. It follows that the proponents of a delayed approach may conclude there is no impact when actually there is one (false negative errors).

The following table shows the distinctions between these two schools of thought.

Approach	**Business-as-usual approach**	**Anticipatory approach**
Advantage and disadvantages	A pre-emptive approach would sacrifice economic welfare	A pre-emptive approach would avoid the occurrence of irreversible damage
Investment in research	Should reduce the risk associated with premature and costly measures	Should reduce the level of uncertainty in order to foster optimal strategies
Paradigm	**Sound science paradigm:** Delay action until experts are able to provide strong evidence	**Precautionary paradigm:** Mitigate impacts irrespective of full scientific certainty
	Learn and then act	Better safe than sorry
Errors	False negative errors	False positive errors

At the end of last century, a number of States have nevertheless pushed for the adoption of a precautionary strategy, limiting GHG emissions in response to the threat they pose to climate stability and the Earth's system. In their view, the stakes were simply too high in order to delay the adoption of key international decisions. Any failure to act quickly would result in false negative errors. What is more, 'it may be less costly to spread the costs of averting climate change by beginning mitigation efforts early, rather than to wait several decades and take actions after the problem has already advanced much further'. [11]

This led to the conclusion of the UNFCCC in 1992. All subsequent international agreements - the 1997 Kyoto Protocol and the 2015 Paris Agreement – have emerged from the framework Convention. Whilst the UNFCCC defines the conditions under which precautionary measures can be implemented,[12] the later does not refer to precaution at all. Although the 1997 Kyoto Protocol does not mention the precautionary principle, precautionary action was nonetheless strengthened at a time when scientific knowledge was still giving rise to conflicting opinions.

10 Many critics were contending in 1992 that too bold an interpretation of the precautionary principle generates false positive errors leading to over-regulation at the expense of welfare considerations.

11 IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*, *Contribution of Working Group* III on mitigation, 1.2.4 The Role of Uncertainty.

12 N. de Sadeleer, *Environmental Principles*, above, 265-266.

The fact that, thanks to the reports of the Intergovernmental Panel on Climate Change (IPCC), a global consensus has been achieved regarding the anthropogenic cause of climate change perhaps explains the absence of any reference to precaution. Last, the Paris Agreement does not mention precaution at all. The following table highlights the manner in which uncertainties regarding the man-made origin of climate change have permeated these different agreements. Against this background, it was easier to reach a global agreement in Paris in 2015 than in 2009 in Copenhagen. Otherwise, one could also argue that the principle was embedded in a Framework Convention. As a result, there was not need to lay it down in further agreements.

Multilateral Environmental Agreements	**1992 UNFCC**	**1997 Kyoto Protocol**	**2015 Paris Agreement**
Level of uncertainty	High	Moderate	Increased confidence

Needless to say, the proclamation of the precautionary principle in the UNFCCC has been a touchstone issue. Art 3(3) of the Convention provides for the following obligation: '*the Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost*.' Moreover, its Preamble calls upon Parties to prevent damages even if there are 'many uncertainties in predictions of climate change, particularly with regard to the timing, magnitude and regional patterns thereof'.

Precaution is coined in the UNFCCC neither as a *principle* nor as an *approach*. In order to avoid such a debate, Article 3(3) grants the right to the parties to enact precautionary measures; it does not compel them to do so. In other words, it encapsulates a right to take preventive measures and not an obligation to act. Moreover, the adoption of the precautionary measures under the UNFCCC is likely to be limited by a number of thresholds, such as the irreversibility and the seriousness of the damages, and the cost-effectiveness of the measures. In effect, precautionary measures must 'be cost-effective so as to ensure global benefits at the lowest possible cost.' Given that many damages won't be easily translated into monetary terms, the benefits of climate change policies are difficult to estimate accurately. So far, it is difficult to assess whether state authorities took advantage of that provision in order to adopt precautionary measures.

3. Large-scale adverse effects of climate change

Before the industrial revolution,[13] the amount of greenhouse gases (GHG) in the atmosphere remained relatively constant. Although the climate has been relatively stable over the past 8,000 years, since the last ice age, it is changing fast now as atmospheric concentrations of carbon dioxide (CO), methane (CH4), nitrogen oxides (NO and NO_2), and various manufactured synthetic GHG have all risen significantly. The causes are manifold. Cheap energy has been a key driver of the extremely fast economic and demographic growth. Industry as well as dwelling have been reckoning extensively upon coal and later on fuel combustion. From the

13 Article 2(1) a of the 2015 Paris Agreement, requires its parties to hold 'the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C,…'. However, the pre-industrial baseline is not defined.

1960s, road traffic became a significant source of GHG emissions. In addition, the industrialisation of agriculture and landfilling of waste have contributed to the doubling of the concentration of methane in the atmosphere since preindustrial times. Furthermore, land-use changes due to massive deforestation around the world and the expansion of agriculture have been contributing to the amplification of the phenomenon.

Although experts have been warning since 1979 that a doubling of the concentration of CO2 will result in average heating of between 1.5 and 4.5 degrees, little has been done in order to invert the tendency. Changes in temperature are occurring very rapidly. Whilst in 2020 the average temperature has only increased by around 1°C above pre-industrial levels, the situation has already become critical within the regions that are most exposed to risks of drought, heat waves and flooding. The rise of temperature is already causing unprecedented changes with catastrophic consequences for the Earth system. Moreover, rising temperatures do not represent the only problem; the oceans are also acidifying at an alarming rate. Whilst some animals seem to be adapting to changing conditions, the vast majority of species are unable to cope with the rise of temperatures, the change of precipitation patterns and the weather getting less predictable and more extreme. Given the need to settle in cooler ranges, some species might not been able to migrate (encountering physical obstacles or the lack of suitable habitats) while others not having the ability to migrate or with a too narrow range are likely to disappear.[14] In almost all cases, new information results in more pessimistic forecasts.

To sum up, the manifold impacts of climate change cover among others:

- decrease of snow covered areas,
- melting and shrinking of glaciers,
- retreat of the ice cap in the Arctic,
- ocean warming (serving as a huge energy pump) and their acidification,
- sea level rise,
- bleaching of coral reefs,
- increase of extreme weather events as heat waves and fires,
- increase of precipitation in the northern hemisphere and decrease in the subtropics,
- shift of wild species range for rising temperatures,
- species extinction.[15]

These impacts also mask other even more troubling surprises. Primary production, ecosystemic service stability and resource availability are all affected by this phenomenon

4. Specificity of climate change risks

The risks stemming from climate change are fundamentally different from earlier industrial types of risk. Indeed, climate risks are distinguished from industrial and technological risks both by their unpredictability over time and by the collective nature of the damage they are likely to cause. Indeed, their potential victims are less easy to identify than residents living near to a hazardous facility.

First of all, climate change has much broader and diffuse impacts than any other type of human activity. The regulatory response in order to prevent temperature rises is much more complex

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14 M. R. Caldwell and M. Loughney Melius, 'Coastal issues, in D.A. Farber and M. Peeters (eds.), *Climate Change Law, Elgar Encyclopedia of Environmental Law* (E. Elgar, 2016) 581.

15 IPCC, 2014. ARC 5 Summary for Policymakers.

than within the traditional environmental field. In fact, the issue is more a question of the accumulation of GHG in the atmosphere due to mass production, globalization and free trade, intensive agriculture, along with increased transportation by road and air, than of emissions from a limited number of industrial plants whose pollution can be easily controlled and reduced.

Secondly, as climate change is caused by an array of natural and human activities, experts cannot pinpoint the exact contribution of each of these activities to the phenomenon. For instance, methane - the second largest contributor to human-induced global warming – is emitted by both intensive agriculture as by natural sources which include wetlands, freshwater bodies, wildfires, and permafrost. To make matters more complicated, some gases have more powerful heat trapping effects than others. This is the case of Nitrous oxide (N2O) which heat trapping effect is about 310 times and methane which is 25 times more powerful than CO2. Halocarbons are hundreds to thousands times more potent than CO2 and remain in the atmosphere for centuries.

Thirdly, the changes are unprecedented, at least since the end of the last ice age. The pace of change is swift compared with ordinary historic rates of climate change, and is also outpacing the ability of ecosystems to adjust.[16] In contrast to industrial risks, we cannot learn from past experience. Given the novel nature of the threat, it would appear appropriate for decision makers to act in accordance with the precautionary principle, which applies precisely where experts cannot reckon on former experience.

Fourthly, the anticipated winners and losers from climate change are distributed unevenly throughout time and space,[17] an issue which gives rise to difficult questions of equity (e.g. principle of common but differentiated responsibility).

Fifthly, irrespective of the considered scenario, the IPCC underlines how it is 'virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales as global mean temperatures increase. It is very likely that heat waves will occur with a higher frequency and duration'.[18] That being said, although the growing body of expertise gathered since the creation of the IPCC has enormously increased our knowledge of the climate system given its scope and novelty, climate change issues are still permeated by uncertainty. In effect, scientists are unable to determine with precision the regularity, frequency and magnitude of impacts, regardless of the quality of their models. The impacts climate change may provoke are thus likely to vary in terms of

- time of latency between the increase of temperatures and the actual impact of damage (gradual or abrupt),
- speed (acceleration or deceleration),
- frequency of natural events (storms, floods, droughts, wildfires, erosion),
- duration (persistent, reversible, slowly reversible, irreversible, multigenerational),
- magnitude (cumulative or synergistic, serious or insignificant),

16 J.P. Holdren, 'Introduction', in S Schneider and al., *Climate Change Science and Policy* (Island Press, 2009) 5.

17 H. Grassl and B. Metz, 'Climate change: science and the PP' in *EEA Report 2013* 309.

18 IPCC, 2013. Climate Change 2013: the physical science basis - Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M. (Eds.). Cambridge University Press.

- localization (e.g., change in the regional distribution of precipitation, acidification of oceans, Arctic region warming more rapidly than the normal mean, warming over land larger than over the ocean, increase concentration of ozone),
- effects (human health, vulnerable countries, biodiversity loss, agricultural yields, tourism),
- and scale (global, continental, or regional).[19]

To further complicate matters,
- although the accurate quantification of anthropogenic and natural climate drivers is crucial for Earth system models, it is fraught with uncertainties,
- natural fluctuations in global temperature are ever-present, leading to multi-decadal and longer-term changes throughout the last-millennium[20],
- variability is linked to natural forcings, particularly volcanic eruptions and anthropogenic aerosols.

Uncertainty permeates all of these factors. In particular, it affects the calculation of the speed of the phenomenon as well as the nature and scope of the adverse-effects it may entail. Against a backdrop of uncertainty, experts propose scenarios rather than assertions. The IPCC language of certainty is thus testament to the fact that there are many unknowns in the timing, magnitude, regional patterns of climate change,[21] although many uncertainties have decreased over time. For instance, the 2019 IPCC special report on the Ocean and Cryospshere describes with 'a very high confidence' or ' a high confidence' a number of impacts of climate change (reduction in snow cover, increased permafrost temperature, shrinking of Arctic ice extent, etc.) and assess as within a 'likely' or 'very likely' range forthcoming scenarios (ocean warming, sea-level rise, etc.). The fact is that temperatures are rising.

Furthermore, the impacts are uneven. By way of illustration, at the North Pole, the observed temperature increase is twice as important as in lower latitudes. The most vulnerable regions vary across Europe. The intensity of precipitation has increased in the past 50 years in Northern Europe whilst droughts are projected to increase in length and frequency in southern and south-eastern Europe. To make matters worse, the developing countries are likely to be more impacted than developed countries. In particular, climate change will exacerbate the problems in countries that experience chronic water shortages. In addition to having the least capacity to adapt, sub-Saharan Africa is expected to experience particularly harsh repercussions from climate change.[22] Within countries, low-income communities – notably the ones established in coastal areas - are likely to be more severely impacted by sea level rises and hurricanes.

5. Lingering uncertainties

Uncertainty is neither an absolute, static or clear-cut concept. As this term is subject to different interpretations, it is not an easy task to grapple with it. Scientific uncertainty exists whenever

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19 N. de Sadeleer, *Environmental Principles*, above, 262-263.
20 A.P. Schurer, 'Importance of the Pre-Industrial Baseline in Determining the Likelihood of Exceeding the Paris Limits' 7(8) (Aug 2017*) Nat Clim Chang* 563–567.
21 P. Birnie, A Boyle and C. Redgwell, *International Law & the Environment,* 3rd ed. (Oxford: OUP, 2009) 337.
22 O. Serdeczny et al., 'Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions' 17 (2017) *Region. Environ. Change* 1585–1600.

there is no adequate theoretical or empirical basis for assigning probabilities to the occurrence or the extent of a risk.

As far as climate change risks are concerned, there is a strong deficit in predictive capability. Although evidence that climate change has a man-made origin has strengthened continuously since the 1995 IPCC report (with 'very high confidence' in the IPCC Assessment Report AR4 to 'extremely likely' in AR5), 'the connections between emissions of GHGs and climate change are not yet fully understood'.[23] Despite the efforts of the scientific community there is still no hope of fully understanding the complexities of the interactions of the atmosphere, the oceans, and GHGs.[24] The following examples are illustrative of the hurdles faced by experts.

- Ecosystems do not respond in a linear way to the impacts of climate change. The absence of mitigation measures for ecosystems increases their vulnerability to degradation and collapse.[25]
- The complex chain of feedbacks between climate and wildfires displays a large set of uncertainties. The adaptation of vegetation and ecosystems to fire is a complex topic. The effects of climate change on wildfire are likely to vary considerably according to the vegetation and by fuel availability or flammability (as a result of intense drought). The effect of wildfires in areas with different levels of species richness may be uneven. [26] Forests with higher levels of protection for biodiversity conservation may display lower fire severity values whilst plantations are likely to be less resilient.[27]
- Although oceans play a major role in global climate dynamics, considerable uncertainties remain regarding their influence on the climate systems[28]. Their role as mitigating factor has been significantly underestimated.[29]
- The cooling and warming effects of aerosols is dogged by uncertainty and accordingly complicates thus the assessment of climate sensitivity. [30]
- With respect to the fate of many ecosystems and species, we are entering uncharted territories.

In particular, although oceans and forests can undoubtedly reabsorb some portion of GHG emissions, increased evaporation of water from the ocean into the atmosphere is likely to result in more warming.[31] To make matters worse, natural catastrophes such as fires are likely to become more frequent, in turn are giving rise to further emissions that have not been hitherto adequately accounted for in climate models. If warming accelerates evaporation, resulting in the formation of clouds, the latter could in turn strongly amplify the warming phenomenon (by

23 IPCC**,** 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*, *Contribution of Working Group* III on mitigation, 1.2.4 The Role of Uncertainty.
24 IPCC, *The Ocean and Cryosphere in a Changing Climate. Summary for Policymakers* (2019).
25 R. Kundis Craig, 'Ocean adaptation', in D.A. Farber and M. Peeters (eds.), *Climate Change Law, Elgar Encyclopedia of Environmental Law* (E. Elgar, 2016) 569.
[26] European Commission, *JRC Technical Report. Forest fire danger extremes in Europe under climate change: variability and uncertainty* (Luxembourg: Publications Office of the EU, 2017) 17, 30.
[27] M. J. Spasojevic, C. A., Bahlai, B. A. Bradley, B. J. Butterfield, M.-N. Tuanmu, S. Sistla, R. Wiederholt, K. N. Suding, 'Scaling up the diversity-resilience relationship with trait databases and remote sensing data: the recovery of productivity after wildfire' 22 (4) (2016) *Global Change Biology* 1421-1432.
28 IPCC, *Climate change 2014*, 417.
29 IPSO, IUCN, *The State of the Ocean 2013, Perils, Prognoses and Proposals* (2013).
30 M. Mastrandrea and S. Schneider, 'Climate Change Science Overview, in S. Schneider and al. *Climate Change Science and Policy* (Island Press, 2009) 17-19.
31 Ibidem, 21.

trapping infrared radiation) rather than serving to stabilise it (by reflecting solar rays). In exploring such issues, scientists put forward scenarios rather than assertions.

Moreover, other uncertainties are still lingering due to irreducible ignorance or disagreement between what is known and unknowable. For instance, epistemological uncertainty arises as a result of gaps in scientific knowledge. In other words, scientists know the effects of a situation, but are unable to ascertain the likelihood of their occurrence. Several factors might compound epistemological uncertainty.

- Indeterminacy. The causal relations are understood but the intensity of the relation between cause and effect cannot be estimated because the experts do not know all the factors influencing the causal chains. In this connection, climate change experts are unable to determine with precision the release of GHGs concurring to change in average temperature of the atmosphere.
- Ambiguity. The extent of any uncertainty is influenced by the way in which experts interpret the available scientific data. When considering the same data, two different experts may arrive at different conclusions as to whether or not there is any uncertainty. Contradictory results give rise to ambiguity.
- Inconclusiveness. The realities of science dictate that scientists, whatever the quality of their investigations, will never be able to eliminate some uncertainties; for instance, there may be too many unpredictable variables to enable the identification of the relative influences of each factor.
- Incommensurability. Given that the increase in temperature gives rise to manifold impacts, a multitude of hazards give rise to a problem of incommensurability.

Regarding climate change, these sub-categories are highly correlated. By way of illustration, the IPCC working group on mitigation has been stressing that 'evaluation of uncertainty and the necessary precaution is plagued with complex pitfalls'. These include 'the global scale, long time lags between forcing and response, the impossibility to test experimentally before the facts arise, and the low frequency variability with the periods involved being longer than the length of most records'.[32]

The remaining uncertainties are likely to be compound by natural factors: resilience of ecosystems (their ability to bounce back from disturbances), reversibility or irreversibility of the damages, etc.

The precautionary principle has real implications for risk-managers when confronted with tipping points, beyond which abrupt and dramatic changes may occur. Some of these non-linear changes are related to positive feedbacks in the climate system and can therefore accelerate climate change.[33] If a tipping point is crossed, the development of the system is no longer determined by the time-scale of the forcing, but rather by its internal dynamics, which can be much faster than the forcing.[34] A variety of tipping points have been identified. By way of

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32 IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*, *Contribution of Working Group* III on mitigation, 10.4.2.2 Precautionary Considerations.

33 Joint EEA-JRC-WHO Report, *Impact of Europe's changing cliamte-2008 indicator –based assessment* (EEA, 4/2008) 34.
34 IPPC, *Climate Change 2007: Impacts, Adaptation, and Vulnerability* (2007) 83.

illustration, large-scale singular events that are components of the global Earth system (slowdown of the AMOC, the El Niño–Southern Oscillation and the role of the Southern Ocean in the global carbon cycle) 'are thought to hold the risk of reaching critical tipping points under climate change, and that can result in or be associated with major shifts in the climate system'.[35] Another example of non-linear irreversible change will be the increase in ocean acidity which would deplete marine biodiversity or the melting of permafrost caused by rising Arctic temperatures that could lead to an increase in methane emissions. Another case in point is the melting of snow and ice that have a high reflectivity (albedo). Up to 90% of the incident solar radiation is reflected by snow and ice surfaces. As the snow and ice are melting at higher temperatures, the oceans are likely to absorb the solar radiation and contribute to a greater extent to the heating of the climate system. How close are we to these tipping points[36]? What will happen if they are reached? The risks associated with these major events become 'moderate' or 'disproportionately high' depending upon the increase in temperatures above pre-industrial levels.[37] The level of scientific understanding of thecrossing of these tipping-points is low.[38] The prospect of reaching a potential tipping point should enhance precaution in this field.

Last but not least, uncertainties can stem from more than a simple lack of data or inadequate model of risk assessment. Aspects of uncertainty are associated with each link of the causal chain of climate change, beginning with GHG emissions, covering damage caused by climate change, followed by a swath of mitigation and adaptation measures. Accordingly, the IPCC reports project various GHG concentrations, varying due to a range of scenarios that are underpinned by different political, socio-economic, technological and demographic developments. In particular, damage estimates are prone to low confidence as they involve uncertainty in both natural and socioeconomic systems.[39]

By way of illustration, there are a number of sources of uncertainty in wildfire modelling, as fire occurrence may additionally be linked with other, non-climatic factors (e.g. size and population density) that are also likely to evolve in the future. For example, fires near densely populated regions tend to be extinguished faster. Given the challenge of reliably projecting population, land use and cover, and their associated uncertainty under climate change scenarios, these relationships are difficult to assess[40].

Although observed warming is unequivocal, for long-term impacts scientists are thus facing a high level of uncertainty compound by an array of anthropogenic factors.

- Regarding the demographic trends, by 2050 the world population will likely grow to 9.9 billion, and continue to grow well into the next century. This demographic growth is likely to increase the combustion of fuels and the emissions of GHG.

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35 IPPC, *Special Report Global Warming of 1,5°C,* chapter 3 (2018) 83.

36 According to the IPCC 2018 report, tipping points 'refer to critical thresholds in a system that, when exceeded, can lead to a significant change in the state of the system, often with an understanding that the change is irreversible'. IPPC, *Special Report Global Warming of 1,5°C,* 262.

37 IPPC, *Special Report Global Warming of 1,5°C,* 83.

38 OECD, *Environmental Outlook to 2005. The Consequences of Inaction* (Paris, OECD, 2012) 87.

39 IPCC, *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects, Contribution of Working Group* III, 10.4.2.2 Precautionary Considerations.

[40] European Commission, *JRC Technical Report. Forest fire danger extremes in Europe under climate change: variability and uncertainty* (Luxembourg: Publications Office of the EU, 2017) 3.

- Increase in trade and GDP growth, consumption patterns and energy policy choices are likely to lead to an increase of GHG emissions.
- Negative-emission technological innovations (carbon storage, ocean fertilization) could absorb some of the negative effects. However, given that these measures have not been tested on a large scale, their positive and negative impacts cannot be assessed; they may thus entail risk trade-offs.
- Last but not least, potential effects of mitigating measures (investment in renewables, decarbonisation of the economy, abatement policies) could play a positive role..

Many ecosystems respond to anthropogenic stressors in a non-linear way.[41] As a result, the intermingling of these natural and socio-political factors prevents clear-cut answers from being made. No matter how sophisticated are the climate modellings, they will never capture fully the reality.

So long as science surrounding climate change is encumbered with a high level of uncertainty the principle will have real implications for risk-managers, in particular when they are confronted with the risk of crossing tipping points. They should therefore incorporate non-linear, unpredictable and extreme events, worst-case scenarios as well as impacts beyond 2100 into their climate change abatement and mitigation strategies.

6. Shaping mitigation measures

Needless to say, the transition to more resilient societies will require both adaptation and mitigation measures. The dividing line between these two categories of measures is a fine one. The former ones aim 'at reducing unavoidable negative impacts already in the shorter term, reducing vulnerability to present climate variability, and exploiting opportunities provided by climate change' [42] whilst mitigation measures aim at minimizing GHG emissions in order to limit the long-term adverse impacts of climate change.

As stressed in the IPCC 5th ACR, when the overwhelming evidence is so compelling and the costs are mounting, 'substantial and sustained reductions of GHGs emissions' are required to limit further climate change.[43] While there is no single recipe for a successful climate policy mix, there are certainly some instruments that are likely to be more effective than others.[44] Given that the precautionary principle does not command any specific measure, each mitigation measure has to be determined on a case-by-case basis taking into consideration the different socio-economic contexts. These measures may take the form of *inter alia* bans, restrictions, authorizations, emissions abatement, notifications, surveillance, requirements of BAT, cap and trade, carbon taxes, fees, removing fuel subsidies, etc. Moreover, the activities likely to be subject to precautionary climate change measures may range from listed installations to aviation.[45]

As risk assessment interacts constantly with risk management, opposing science to precaution is unproductive. In climate change, uncertainty is the rule, rather than the exception. Scientists

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41 M. R. Caldwell and M. Loughney Melius, 'Coastal issues' in D.A. Farber and M. Peeters (eds.), *Climate Change Law, Elgar Encyclopedia of Environmental Law (*E. Elgar, 2016) 581.
42 Joint EEA-JRC-WHO Report*, Impact of Europe's changing cliamte-2008 indicator –based assessment* (EEA, 4/2008) 35.
43 IPCC**,** 2014: Summary for Policymakers. In: *Climate Change 2014*, 19.
44 OECD, *Environmental Outlook to 2005. The Consequences of Inaction* (Paris, OECD, 2012) 91.
45 See Case C-366/10 *ATAA* (2011) C:2011:864.

are not called on to remove uncertainties. However, in approaching the long-term adverse effects of this phenomenon, they must inform the decision markers that the situation is shrouded in scientific uncertainty. As we are facing the possibility of irreversible large-scale effects, they play a key role in apprising the decision-makers, although they are more likely to put forward scenarios than assertions.

In this context, risk assessors should not discount long-term non-linear effects that are subject to greater uncertainty; they have to take into consideration all the uncertainties involved. In particular, environmental impact assessments (EIA) and strategic environmental assessments should not only reduce uncertainty but also explicitly acknowledge sources of uncertainty that remain, instead of burying these in mere assumptions.[46] Both quantitative and qualitative dimensions of uncertainty have to be explained thoroughly. As a result, the identification of any lingering uncertainties should trigger a greater level of caution amongst decision makers. An even more important step would be for the EIA procedure to force decision-makers to consider a number of reversible courses of action in order to take advantage of new knowledge. Even if it means forgoing a project, the author of an EIA should recommend reversible options in preference to those that are irreversible. The search for variants should become his principle task.[47]

Whilst the precautionary principle makes it difficult to delay adopting measures to prevent environmental degradation on the grounds that scientific certainty has not been established, scientific certainty or 'sound science' can no longer, *a contrario*, be considered as the absolute benchmark for long-term decision making. Indeed, as has been acknowledged by the IPCC, uncertainty is not an argument for delaying action. Accordingly, decision makers must take full account of the various scenarios set forth by experts and asked themselves how those potentially impacted can take steps to reduce the adverse impacts through better ecosystemic management.[48] In particular, they should pay heed to the considerably extended timescales, as uncertainty prevails mainly during the period between a cause and the subsequent manifestation of a harmful effect. A full integration of the quantitative and qualitative dimensions to uncertainty should help them to address more adequately long-term risks.

By way of illustration, ocean warming has contributed to an overall decrease in maximum catch potential, compounding the impacts from overfishing for some fish stocks.[49] Regarding fisheries that have been subject to over-exploitation, precaution should entice the agencies to err on the safe side.

Regardless of the quality of the mitigation measures adopted so far, the build-up of GHG in the atmosphere is causing temperatures to rise. What matters is that precautionary measures are put in place with a view to achieving the level of protection stipulated by the Parties in the Paris Agreement. The issue of how to determine an acceptable risk level has been fraught with controversies as the UNFCCC aims to stabilize GHG concentrations in the atmosphere 'at a level that would prevent dangerous anthropogenic interference with the climate system'.[50] This objective was further clarified in 2015. The Paris Agreement aims to prevent 'the increase in the global average temperature to well below 2°C above pre-industrial levels' and 'pursuing

46 N de Sadeleer, *Environmental Principles,* above, 341.
47 Ibidem, 342.
48 A. Dan Tralock, 'Water availability and allocation' in D.A. Farber and M. Peeters (eds.), *Climate Change Law, Elgar Encyclopedia of Environmental Law (*E. Elgar, 2016) 546.
49 IPCC, *The Ocean and Cryosphere in a Changing Climate. Summary for Policymakers* (2019) 13.
50 UNFCCC, Art 2.

efforts to limit the temperature increase to 1.5°C'.[51] Although such an objective strengthens the global response to the threat of climate change, these safe levels are nonetheless problematic due to lingering uncertainties. Any threshold is thus questionable.

Finally, the precautionary principle could buttress the duty to cooperate 'in a spirit of global partnership to conserve, protect and restore the health and integrity of the Earth's ecosystem'.[52] The mention of the Earth's ecosystem implies the oneness of that system in contrast to the division of the earth into territorial states.[53] Within the context of cooperation, developed countries should bear a larger responsibility in making abatement technologies available to developing countries.

On a final note, it should be pointed out that the precautionary principle does not play any role in deciding how to allocate the costs of the preventive and mitigation measures. This issue must be resolved with reference to the precautionary principle and the principle of common but differentiated responsibility.[54]

7. Concluding remarks

Although there is no doubt that the observed climate change is for a significant part attributable to the growth in human activities in the aftermath of the industrial revolution, the contribution of each activity to the phenomenon, the timing and the magnitude of the adverse effects are still heavily encumbered with uncertainty. Although the uncertainty has decreased over recent decades dues to better methodologies and the work of the IPCC, the uncertainty is still significant for long-term impacts, partly resulting from a lack of knowledge of the climate systems and the limitations of scientific research. So far, there is no way to quantify the probability of the occurrence and the magnitude of each of the manifold impacts, in particular at local level. In particular, experts are facing difficulties to express the probability of the occurrence of a number of adverse effects. They have to reckon on a rather vague terminology such as 'low-probability', 'poorly-known-probability', etc. Accordingly, the experts have to address both the quantitative and qualitative dimensions of the climate risks. Risk assessment has to integrate extreme events as well as worst-case scenarios.

Whilst the scientific research community has been gathering more accurate and reliable evidence regarding the actual and potential impacts of climate change, it is much more difficult to calculate the risk of reaching or passing critical tipping points that entail possible large-scale and irreversible impacts.

Despite the increasingly overwhelming evidence regarding the impacts of climate change, action is still sluggish. As a result, the international community is still falling short of adopting a robust GHG abatement strategy. Political decisions are not consistent with the emissions ceilings proposed to achieve the UNFCCC and the Paris Agreement objectives, and perhaps will not be also in the near future.[55] Admittedly, there is a fundamental incongruence between

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51 Art 2 (a).
52 Principle 7, Rio Declaration.
53 M. Bothe, 'Whose environment? Concepts of commonality in internatioanl environmental law' in G Winter (ed.), *Multilevel Governance of Global Environmental Change* (Cambridge, CUP, 2006) 544.
54 UNFCC, Art 3.
55 Grassl and Metz, above, 336.

the speed of the Promothean exploitation of the biosphere and the slow implementation of mitigation measures.[56] Therein lies the paradox.

56 G. Winter, 'Introduction', in G. Winter (ed.), *Multilevel Governance of Global Environmental Change* (Cambridge, CUP, 2006) 3.