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# 2°C: the history of a policy-science nexus

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## NO CLEAR ORIGIN FOR THE 2°C TARGET

An analysis of the first appearance of the objective to limit temperature rise to 2°C shows that it has no clear origin and that its adoption is due neither to compelling scientific evidence nor to the negotiators' informed choice based on scientific date. Before the UNFCCC negotiations seized on this value, 2°C was already used as a marker to concurrently address scientific, economic and political apprehensions about climate change.

## THE 2°C AS A SCIENCE-POLICY INTERFACE

The growing presence of the 2°C target resulted from the joint efforts of the scientific and political spheres to give structure to the debate, each enriching and exchanging with the other. This progression gave the 2°C target a meaning that varied according to the different contexts in which it was used. It thus became the interface between mitigation and adaptation, between scientific and political discourses and between the interests of the Parties.

## ADOPTION OF THE 2°C: A WEAKENING OF AMBITIONS?

Discussions on the long-term objective sifted through several formulations for targets. Among these, the stabilisation level for greenhouse gas concentrations was used as a benchmark for quite some time. Prior to Copenhagen, the debate focused on the choice of a set of parameters seen as being mechanically interlinked in order to bring actions into line. However, the Parties were only able to agree on the 2°C, which was not only the most readable formulation but also the vaguest and the least directly binding.

## A RAPPELLING ROPE FOR THE NEGOTIATIONS

The 2°C value has a precise scientific definition that makes it suitable for use as a rappelling rope and the measure of a level of ambition, with certain implications in terms of actions. It brings the global, long-term dimension of climate change down to a scale that is readable for policymakers, at the same time retaining the flexibility needed to integrate both scientific and political uncertainties. It is no longer simply a scientific indicator that been translated into policy terms, but a fully political target whose scope will be guaranteed by scientific evaluation.


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# I. INTRODUCTION

When discussing actions to address climate change on any scale, it seems quite natural nowadays to think in terms of a maximum rise in the average global temperature. The target of limiting this increase in temperature to 2°C, ratified in Copenhagen and pledged again in Cancun, is now part of the landscape and guides many of the climate change policies currently being implemented, particularly at a European level. However, this cap on the average global change in temperature is far from being a given. Temperature is above all a variable used to describe local conditions and, although it is considered more meaningful than other climate variables, it is difficult to concretely represent a global temperature, this being the aggregation of an infinite number of local atmospheric conditions. In addition to being hard to measure, global average temperature is of a magnitude whose evolution cannot be predicted without a high degree of uncertainty. The fact that such a vague entity has managed to become so overwhelmingly accepted is far from innocuous and warrants study.

Indeed, the choice of a temperature-based target and its 2°C cap have been picked up by all the players concerned by climate policy prospects and not just by the circle of climate negotiations. This is certainly due to its simplicity: indeed, to effectively communicate on such a complex issue as climate change, there was a hefty need for a meaningful indicator able to summarise simply and strikingly the policy direction adopted. What is sure is that this indicator did not just appear out of thin air, given the technicality and complexity of the question – yet it is rarely justified other than by referring to the recommendations of 'Science'.[1] Yet, scientists, wary of making prescriptive recommendations, have never clearly and explicitly stated that 'the rise in the global temperature should be limited to 2°C'. The figure of 2°C has been circulating for several years without its origin ever being clearly identified, like a self-evident truth waiting to be recognised as such without the need for anyone to take responsibility for it. The dissemination of the 2°C target raises two questions: what are its origins and trajectory and what are the reasons for its success? If 2°C is now accepted as a target, why are these reasons seemingly so rarely discussed, as if they were of minor importance and no longer needed to be justified– or challenged.

It is the astonishing development of this climate variable, able to link up science and climate policy, that we aim to trace in this paper. Contrary to what the Copenhagen Accord or certain other contributions to negotiations would lead us to believe, the 2°C target is not a recommendation from scientists supposedly consulted by negotiators in order to explicit the danger threshold of 'anthropogenic disturbance of the climate system'. Far from following such a linear development, its emergence is the fruit of a rather more intricate interaction between the work of negotiators and policymakers, and that of scientists studying climate and experts informing policy. We could suppose that the fact that neither the policymakers nor the scientists claim outright ownership of the 2°C target indicates that it is as much the result of the one as of the other (or perhaps we just don't know exactly who is responsible for this target). Following this assumption, the adoption of the 2°C target can thus be considered as the outcome of constant and complex interactions between research and scientific information and the different spheres of policy discussion and action. In order not to prejudge the nature of these interactions, we have attempted to treat the diverse contributions to the construction of the 2°C target on the same level, be they 'political', 'economic' or 'scientific', without

1. The Copenhagen Accord adopts it, 'recognising the scientific view that the increase in global temperature should be below 2°C ' (UNFCCC 2009).

however overlooking their individual characteristics or forgetting that they follow different logics and rules.

***Theoretical background***

The question of the interaction between science and policy (or knowledge production and decision-making) arises with particular insistence in the case of climate change, which because of its overarching and systemic nature[2] blurs the boundaries between human and natural domains and thus between scientists studying the environment and policymakers organising society. This stems as much from the fact that decisions related to the climate system imply knowing and understanding it (hence the need for the scientists who study it), as from the fact that, since human societies impact the climate (which is in fact the source of the problem), scientists need data on social trends to make their models reliable.[3]

International climate change policy has been quite widely studied in regard to questions on this policy-science nexus, and has focused on sometimes very different aspects. Some report on the start of climate negotiations (Agrawal, 1999; Boehmer-Christiansen, 1994; Miller, 2004); others trace the emergence of various tools and heuristics, arguing that some tools have become widely used due to their inherent ambiguity, their relative imprecision and their flexibility. It is precisely these features that make such tools both meaningful to the communities involved and easily adaptable to new developments in research and negotiations (Shackley & Wynne, 1996, 1997; van der Sluijset al., 1998; Boykoffet al., 2010). Finally, some researchers have specifically focused on the 2°C target (Tol, 2007; Randall, 2010) and investigated its origins.

In order to understand and analyse the different interactions observed during the emergence of the 2°C target – which is an example of 'how knowledge-making is incorporated into the practices of state-making…and, in reverse, how practices of governance influence the making and use of knowledge' (Jasanoff, 2004:4) – we take as our starting point the co-production framework proposed by Jasanoff (2004). In addition, certain concepts taken from the sociology of science and the actor-network theory, notably the 'boundary object' (Star & Griesemer, 1989), provide particularly relevant conceptual frameworks for deciphering the history of the 2°C target.

For Jasanoff, 'Science operates as political agents' (Jasanoff, 2004b:14) and the scientific and political spheres cannot be considered independently as they are intimately linked:

> 'The import of such studies has been to challenge the assumption of Science as an autonomous sphere whose norms are constituted independently of other forms of social activity' (Jasanoff, 2004b:30).

More specifically, scientific research can only be understood and analysed in a given social and political context:

> 'The resolution of any significantly new problems in science is seen as requiring situated and specific (re)structuring of social order, without which scientific authority itself would be put in jeopardy' (Jasanoff, 2004b:30).

In light of this, it is easier to understand why the IPCC and the scientific community in general need to rely on proposals from the political authorities and negotiating arenas to feed their research and make its scientific coherence more robust. This is the case for the 2°C target, which is cited by the IPCC as a European Union proposal.

Without this social and political basis, scientific authority and credibility could be challenged, again according to the co-production approach:

> 'In view of co-production, human beings seeking to ascertain facts about the natural world are confronted, necessarily and perpetually, by problems of social authority and credibility. Whose testimony should be trusted, and on what basis, become central issues for people seeking reliable information about the state of a world in which all the relevant facts can never be at any single person's fingertips' (Jasanoff, 2004b:29).

This blurs the dividing line typically drawn between scientific and political phenomena. However, this line is all the more present as it is perpetuated by the discourse of political leaders and in negotiating texts such as the one discussed prior to Copenhagen:

> '…recognizing the scientific view that the increase in global temperature should be below 2°C…' (UNFCCC, 2009).

2. The United Nations Framework Convention on Climate Change defines the climate system as 'the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions' (UNFCC 1992).

3. As the distinction between 'Science' and 'Policy' is difficult to determine, and one of the goals of this paper being to show that it is constantly being transgressed and blurred, the literature produced by researchers and generally peer-reviewed will, though somewhat tautologically, be defined as 'scientific' and that produced during or in preparation for the UNFCCC negotiations will be described as 'political' or 'policy-related'.

Finally, this approach gives a new perspective on scientific production, according to which 'doing science merges...into doing politics' (Jasanoff, 2004b :29), and enables a better understanding of how the 2°C target emerged and evolved between scientific production and political decision-making.

***Contextualisation of the framework for the series of negotiations: the difficulty of establishing a long-term objective***

Without wishing to gloss over the first appearances of the 2°C target, we focus here on the most recent series of negotiations between 2005 and 2010, which correspond to the still unfinished talks on Long-term Cooperative Action (LCA). Indeed, our interest in the 2°C target stems from the fact that this has gradually become recognised as the long-term objective for international climate action.

The need for a clear and readable future global target is tied to the long-term dimension inherent to the challenge of climate change. Not only can this change only be defined using distant projections at a global scale, but it also operates at magnitudes incommensurable with those characterising human and political actions, which also happen to be the main engine of this change. As such, the long-term perspective has been present, with more or less urgently, since the early days of climate policy; in setting an 'ultimate objective', Article 2 of the UNFCC Convention sets actions to be taken within a time-frame that stretches far into the future, without specifying where (or rather when) it places the 'ultimate' objective. As for the Kyoto Protocol, negotiations include the present and the near future: action is encouraged with no explicit reference to a time extension, thus temporarily relegating long-term management of the issue to the background. Tackling this aspect head-on in negotiations is a relatively recent development, present in Post-Kyoto and LCA negotiations.

This is a sensitive issue, if only because of the difficulty in defining what 'long term' means. From a scientific perspective, it may indeed be very long – from the reconstruction of paleoclimates to digital climate forecasts, the modellers of virtual Earths can fast-forward the planet several million years into the future. On the other hand, planning for action for a mere half-century period is almost inconceivable in the policy field and would even be considered as very much long term. This discrepancy affects how actions are evaluated. Despite the uncertainties, it is quite clear from a climate perspective that the decisions made and the actions undertaken today (or even yesterday...) place strong constraints on the state of the atmosphere in 2050, due to the inertia of the climate system (Wigley, 2005, Hare & Meinshausen 2006; IPCC AR4, 2007): from a climatological viewpoint, 2050 is tomorrow;[4] the need for consistency with scientific projections considerably reduces the range of options available. At policy level, however, it would be difficult to consider as binding any decision made for 2050: the vast majority of the original negotiators and governments will by then no longer be on the scene, and the uncertainties regarding the changing economic, social, technological and geopolitical situation are such that a long-term objective of this kind would likely be perceived as no more than symbolic. Moreover, there are relatively few examples of political programmes that explicitly project themselves far into the future: the most ambitious in this respect are the Millennium Development Goals, adopted in 2000 for 2015 (Pershing & Tudela, 2003).

The tension generated by the long-term dimension goes hand in hand with the issue of the global nature of climate change: when looking ahead albeit only half a century, it is necessary to take into account the likely changes in the international economic and political situation, and therefore the balance of power between States. It soon becomes clear that if action is limited to the industrialised countries alone, which are the historical emitters, this would not suffice in a world where their share of emissions is rapidly decreasing. Ultimately, climate change regulation must become a globalised concern and actively involve emerging countries, while continuing to recognise that their responsibility is different from that of developed countries. This is an additional constraint for any long-term objective, which needs to define at least partially how such involvement would operate.

The 2°C target thus proposes a response to the issues raised by the definition of a long-term global objective. As this was judged satisfactory by the Parties to the Convention, it may lead us to wonder why this is so and what it implies, which brings the number of questions guiding this paper up to three: Where does the 2°C target come from? Why do its origins appear to have been forgotten? What are the reasons for and consequences of its success?

4. 'About half of the early 21st century warming is committed (would occur even if atmospheric concentrations were held fixed at 2000 values). Choice of scenario becomes more important by mid-century (about a third of that warming is projected to be due to climate change that is already committed), and by late century, differences between scenarios are large, and only about 20% of that warming arises from already committed climate change.' (IPCC AR4 WG I ch. 10)

*Approach*
In order to answer these questions, we started off by studying the 2°C target in texts relevant to climate negotiations in the broad sense i.e. including the scientific and economic works that, we suggest, play a crucial role in building conceptual frameworks and technical tools for climate regulation.

As for the LCA, the focal point was the United Nations Framework Convention on Climate Change (UNFCCC), which is considered to be a crossroads where texts and information produced by a wide range of actors involved in climate regulation can be exchanged and compared: it deals with texts judged to be the most influential and formative from a climate or economic perspective. For the part upstream of the initial LCA discussions, before the long-term objective reached the agenda, we consulted scientific and expert papers that fuelled our thinking on the points we were interested in. Rather than viewing the negotiating process as a series of key texts marking strong inflection points to be studied in isolation, we chose to see it as a steady stream of documents, texts and information that clash, interact, build up, answer each other and thus gradually shape the landscape in which more visible milestones eventually emerge, are consolidated and influence and impact the negotiations more forcefully. But they are then corrected (or not) by subsequent negotiators who make deletions, take them apart in order to reconstruct them, partly rewrite them, combine them, etc.

This variously sourced flow of information was analysed in terms of negotiating dynamics and the way texts are produced and circulated. It also went through a meticulous reconstruction of the debates about the 'shared vision' on the basis of a genealogy of texts. We thus constructed a corpus comprising texts produced directly during the Convention (negotiating texts, session minutes, draft agreements, decisions, etc.), those produced for the Convention (submissions from the Parties, NGOs and IGOs) and those produced outside but fed into negotiations before, during or after the discussion at the heart of this paper (scientific articles, expert reports, meeting pronouncements from G20, G8 and MEF meetings, communications from EU institutions, etc.).

After categorising the corpus of texts, we ran it through the first version of a quantitative analysis tool. This allowed us to produce a frequency count for certain keywords used to track the evolution of the debate on shared vision. These were mostly short terms that had very few synonyms and were established enough in climate vocabulary to be used frequently in reference to a clearly identified issue with relatively little ambiguity. This tool allowed us see how the presence of the term '2°C' had evolved in the discussions compared to other terms related to the issue of integrating the long-term dimension into international climate change policy.[5]

# 2. MAKING 2°C THE LONG-TERM OBJECTIVE OR HOW IT BECAME AN INDISPENSABLE COMPONENT OF THE NEGOTIATIONS

## 2.1. Beginnings and emergence

### 2.1.1. Global temperature and climate sensitivity

It is difficult to pinpoint accurately when '2°C' first appeared in climate change talks: since the 1970s, the concept of a likely 'increase in the average global temperature of 2°C compared to pre-industrial levels' was taken up and mobilised in such a variety of discourses and contexts that it is difficult in retrospect to identify who first proposed it. It is more like a feature of the landscape that has gradually been transformed and enriched with new meanings in the course of its dissemination, rather than a concept that appeared at an identifiable time and in response to specific questions.

Estimating' climate sensitivity',[6] i.e. calculating the effect of a doubling of $CO_2$ concentrations by climate modelling, may nevertheless be considered the first seed in the development of globalised thinking on temperature change. This notion has guided climate studies from their infancy since Svante Arrhenius embraced it as early as 1910,

5. The tool in question, developed in partnership with Sciences Po's Medialab, is used to identify the frequency of a term and its synonyms for each group in a corpus of texts. The version used is still relatively embryonic and can be greatly improved. Therefore it cannot be assumed with certainty that it yields a completely exhaustive frequency count for a term (in particular because of the difficulty of identifying all the synonyms); the corpus, no doubt, could also have been enriched. It can nevertheless reliably track trends and changes in the literature and show the progression of the debate for simple keywords.
6. 'In IPCC reports, *equilibrium climate sensitivity* refers to the equilibrium change in the annual mean global surface temperature following a doubling of the atmospheric equivalent carbon dioxide concentration. Due to computational constraints, the equilibrium climate sensitivity in a climate model is usually estimated by running an atmospheric general circulation model coupled to a mixed-layer ocean model, because equilibrium climate sensitivity is largely determined by atmospheric processes. Efficient models can be run to equilibrium with a dynamic ocean.' (IPCC SYR 2007:78)

estimating its value at 4°C.[7] Calculation methods have since progressed and models have been enhanced and become vastly more complex, but the range of the most likely values for climate sensitivity (1.5 to 4.5°C) has stayed remarkably consistent in the literature. It has become recognised as both a benchmark and pivotal element in the climate debate (van der Sluijs et al., 1998), at a 'best guess' level of between 2.5 and 3°C.

From being a simple heuristic tool for calibrating and comparing models, climate sensitivity has metamorphosed into a measurable attribute of climate change (van der Sluijs et al., 1998:307). This evolution was the first step towards a conception of climate policy as a means of regulating the global thermostat, thus enabling temperature objectives to be set. The prominence of this concept led to relatively frequent references to 2°C, since it falls within the 1.5 to 4.5°C range constructed on the basis of climate sensitivities informed by the various models, and close to the 'best guess'. Finally, by proposing and anchoring in people's minds a climate change measure based on the doubling of atmospheric carbon dioxide compared to pre-industrial levels, the 550 ppm $CO_2$-eq value[8] became firmly entrenched in this arena. This latter value also gained in importance, and it is worth noting that it is often associated with a 2°C temperature increase.

### 2.1.2. 2°C as a heuristic tool for calibrating climate action

The 2°C value also made several rare appearances in the early stages of climate regulation talks, when the first drafts of the guidelines that now serve as recognised benchmarks were taking shape. Nordhaus (1977, 1979) suggested that for a cost-benefit analysis of climate-change the reference should be a doubling of carbon dioxide together with an average global temperature rise of 2 degrees Centigrade, even though this was heuristic choice for the purpose of devising an economic evaluation model rather than a stance on acceptable climate change levels (Randalls, 2010).

The proposal to set 2°C as the upper limit of an acceptable temperature rise emerged internationally at the conference of the Advisory Group on Greenhouse Gases in Bellagio in 1987 (Randalls, 2010). Soon after, Vellinga and Swart (1990, 1991) proposed a 'global strategy' based on three milestones: 'a goal, a route and a start'. This rationale was to gain ground, since it was more or less what was found in the LCA negotiations, where the challenge was to find a consistency between a long-term objective, emission reduction projections (and sharing mitigation efforts to respect them) and immediate actions. In an article that proposed a framework for integrating a long-term view into the development of climate control (Vellinga & Swart, 1991), the authors assessed climate change impact contingent on temperature rise, introducing a 'traffic light' system; they proposed a 2°C temperature rise as the threshold for dangerous climate change. As in Nordhaus' work, this was a heuristic choice aimed at illustrating a way to tackle the issue of long-term and dangerous climate change, but by simultaneously introducing the 2°C threshold and a coherent framework, they gave this target a political meaning. The 2°C value first appeared in climate change discussions as a possible threshold, chosen more or less arbitrarily, that was to serve as a basis for drafting and testing possible guidelines for issues and actions.

### 2.1.3. In search of an 'ultimate objective': Europe as a pioneer

In the wake of the adoption of the UNFCCC in 1992, the literature seeking to interpret its 'ultimate objective',[9] and thus clarify at what point 'anthropogenic interference with the climate system' becomes 'dangerous', began to develop more widely, more or less in direct response to the need to inform decision-making.[10] It was particularly in this context that 2°C was gradually disseminated in the literature closely connected to decision centres and mainly targeting a decision-making audience (OECD, 1992; WBGU, 1995). Finally, it was adopted by the European Council as a long-term objective associated with stabilising $CO_2$ concentrations at 550ppm (Council of the European Union, 1996).[11]

7. Arrhenius S. (1910), *L'évolution des mondes*.
8. The pre-industrial atmospheric concentration of $CO_2$ is around 270ppm ; doubling it thus gives 550ppm.
9. 'Article 2 - Objective: The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.' (UNFCCC, 1992)
10. Even though related developments before the UNFCCC also sought to resolve questions on the form of action to be taken, and fed into negotiations leading to the formulation of Article 2 as we know it.
11. 'Given the serious risk of such an increase and particularly the very high rate of change, the Council believes that global average temperatures should not exceed 2 degrees above pre-industrial level and that therefore concentration levels lower than 550 ppm $CO_2$ should guide global limitation and reduction efforts.' (Council of the European Union, 1996)

Using texts published in the 1990s, Tol (2007) retraced this rather disorderly emergence; a figure was quoted in various information-production spheres, almost simultaneously and not always for the same reasons, until the mass of citations and references produced an aggregate effect making it increasingly incontrovertible. It is undoubtedly this dynamic driving the convergence of stakeholders with very different objectives and questions about the same figure that in part makes it so difficult to identify clearly and precisely where it came from.

This is not, therefore, something that developed in isolation until finally gaining prominence in the debate; at this stage, no preferred framework had yet been adopted and the question was still at an experimental stage of exploring the various strategies for climate policy frameworks. Although stabilisation rhetoric was making headway (which was hardly surprising, since it had been formally adopted by the international community and the UNFCCC had expressed its objective of 'stabilising GHG concentrations'), three potential types of stabilisation existed side by side on an equal footing: stabilising emissions, stabilising carbon (concentration) and stabilising the climate (temperature) (Boykoff et al., 2007).

#### 2.1.4. Greenhouse gas concentration as a 'natural' reference for climatologists

During the 1990s, the increase in the average global temperature was mostly referenced in texts on the trends of climate policy action. Climate literature scarcely mentioned long-term objectives, focusing rather on stabilising concentrations (IPCC TP, 1997a, 1997b).

Climate change projections need a forcing scenario (perhaps an emission pathway or a particular atmospheric concentration of GHGs) that produces an image of the climate and enable likely impacts to be assessed with varying degrees of accuracy. There are different types of more or less complex scenarios, but schematically the sequence of variables is as follows:

> Emissions of Greenhouse gases (GHG) → atmospheric GHG concentrations → radiative forcing → change in local and average (such as average global temperature) atmospheric conditions (temperatures, rainfall, pressure, etc.) → impacts, a cycle used by Pershing and Tudela (2003).

Each step adds its own uncertainties: for example, depending on the effectiveness of carbon sinks, similar emissions will not result in the same concentrations, or depending on the mix of GHG concentrations, similar concentrations will not lead to the same radiative forcing, etc. The steps related to climate sensitivity (and therefore temperature), which remain irreducible beyond a certain level, have been widely studied (Frame et al., 2007; IPCC, 1996, 1997, 2007).

Concentrations have several heuristic advantages. First of all, they are easy to measure precisely and are evenly distributed within the atmosphere. In addition, they play a good intermediary role in the chain: one can estimate them for emissions scenarios but also, once stabilisation profiles are calibrated by emissions scenarios, one can choose to study an emissions projection leading to concentration stabilisation at a given level to estimate the consequences in terms of radiative forcing. Based on a concentration profile, one can then integrate impacts and mitigation costs, which would in principle favour assessment based on concentration, as this is physically more robust than the global average temperature (IPCC, 1996).

### 2.2. The first steps in the debate on Cooperative Long-term Action (LCA)

#### 2.2.1. Kyoto opts for the short-term

The question of a long-term objective, though already present, was still relatively marginal in the climate debate at the end of the 1990s (Fig. 1 and 2). With a view to economic and political feasibility, Kyoto opted in favour of immediate action, giving industrialised countries reduction target for 2012 (Oppenheimer & Petsonk, 2002) and at the same time holding on to the vague 'ultimate objective' for its long-term vision. In the years following the signing of the Kyoto Protocol (from 1997 to the early 2000s), negotiations focused on immediately implementing emission reductions (the 'start', to use Swart and Vellinga's terminology), thus side-lining the debate on long-term action, and with it the 2°C target and concentration stabilisation. This concern for actionability is reflected in the scientific literature of our corpus, including several studies from this period on concrete emission reduction scenarios (timing, mitigation, the role of technology, etc.), which are often taken as starting points for action (e.g. Hansen et al., 2000; Van Vuurren & De Vries, 2001; Winkler et al., 2002; Criqui et al., 2003).

The Kyoto Protocol, while providing a 'top-down' logic (i.e. framed and controlled), constrained only a minority of the Parties to the Convention over the short run (thus hardly global or long term). In its wake, negotiations therefore tended to focus on implementation issues and on the implications of immediate choices. This does not, however, mean that the other suspended issues simply disappeared. Problems such as defining the danger threshold for climate change, assessing impacts and interpreting Article 2 continued to mobilise the scientific literature (e.g. Parry et al., 1996; Schneider, 2001; O'Neill & Oppenheimer, 2002; Swart et al., 2003). What's more, because the Kyoto Protocol was limited in time but made sense only as a kick-starter for policy action due to continue long after 2012, negotiations on the 'Post-Kyoto' were clearly inevitable.

### 2.2.2. The IPCC Third Assessment Report, the long-term and the ambiguity of the policy-science nexus

The IPCC Third Assessment Report (TAR), published in 2001, clearly displayed a concern for the long term and the need to clarify the vagueness of Article 2 of the Convention. It also mentioned the tensions involved in delimiting the boundary between the scientists' 'exclusive domains' and those of politicians, which were to crystallize around the word 'dangerous'. The boundaries became increasingly blurred and certain questions (particularly, how to interpret 'dangerous anthropogenic interference with the climate system') were seemingly almost impossible to answer without crossing the dividing line. At the same time, the IPCC stated in its Summary for Policymakers and subsequently confirmed (Workshop 3004, AR4) that its conclusions were in no way prescriptive, at the same time taking care not to make overt recommendations (Corfee-Morlot & Höhne, 2003). Yet, despite these precautions, the Summary explained particularly well how the intermeshing of knowledge production and political indecisiveness was a driving factor in climate negotiations. Presented in the form of responses to nine questions 'identified by governments and subsequently agreed by the IPCC', it provided not only a view of the state of affairs in research but also an overview of the framework under preparation aimed at integrating climate change and major agenda issues into policy.

These issues related essentially to assessing the consequences and the climatic, environmental and socio-economic impacts of climate change; comparing different scenarios for stabilising greenhouse gas concentrations; reconciling the time scales involved; and discussing the potential of the technical, political and economic tools developed so far.

### 2.2.3. Consolidating long-term considerations: cost-benefit analyses based on concentrations, impact studies based on temperature increases

In the IPCC's responses, two approaches appeared side by side: cost-benefit analysis and impact studies. The first, which was mentioned frequently enough in the TAR Summary for Policymakers to be regarded as decisive, involves comparing a range of climate change stabilisation scenarios with respect to the (mitigation and adaptation) costs of stabilising at that level and its benefits (in terms of avoided impacts). This approach is useful when comparing concentration stabilisation profiles, even though they are often equated with an associated temperature range: moreover, its most mature form, developed by Sir Nicholas Stern (Stern, 2006), was based on concentrations.

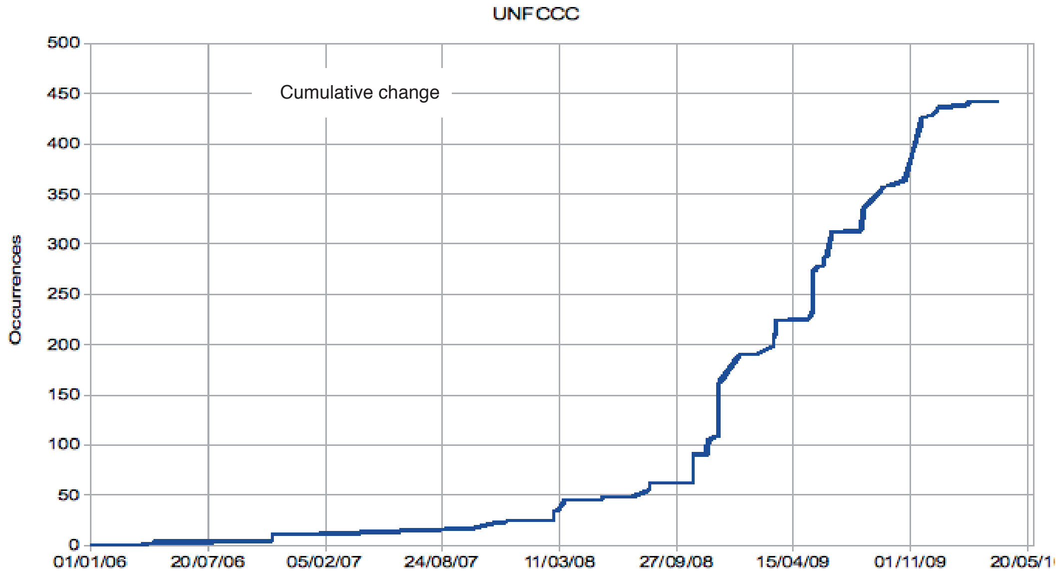
The second approach aimed to ascertain the threshold where projected climate change impacts would become unacceptable. In this perspective, the TAR helped to establish two impact representation diagrams: first, the five 'reasons for concern' that allowed potential impacts to be classified according to five indicators and, secondly, the graph known as 'the burning embers', which was a twist on the 'traffic light' approach of Vellinga and Swart and assessed the danger level associated with the temperature rise for these five indicators. In the TAR version, most of the indicators turned red for a 2°C rise (compared to 1990 levels rather than pre-industrial levels, as the graph shows). Following this logic, 2°C is a serious contender for the danger threshold of climate change.

### 2.2.4. The symbiosis of science and policy…

Unhappy about revealing the political side to climate research, the report proposed a unified perspective of climate sciences, with each giving its opinion on all aspects of the climate system that were included in the negotiation results. It was the political process surrounding climate change that fed the research that informed the process, thus becoming *one of the parameters* of the system studied. This reversal of perspective, as well as the close collaboration between research and negotiation activities in shaping the framework for addressing climate change, is obvious in the way the TAR refers to the 550ppm and 2°C thresholds proposed by the European Union in 1996:

> 'The concentration of 550 ppmv was used as a benchmark for stabilization in the previous studies on mitigation scenarios. This number may be related to the frequent references made to it in political discussion. The adoption by the EU of a maximum increase in global average temperature of 2°C above pre-industrial levels is roughly equivalent to a stabilization level of 550 ppm $CO_2$eq or 450 ppm $CO_2$. It does not imply an agreement upon desirability of stabilization at this level. In fact, environmental groups have argued for desirable levels well

**Figure 1.** Cumulative frequency of 'long-term goal' in the whole corpus




> below 550 ppmv, while the interest groups and some countries have questioned the necessity and/or feasibility of achieving 500 ppm.'(Working Group 3. 2001: 124)

The various components of the climate system, including human activity, are thus seen as a continuous and connected whole. This was already more or less the case on account of the use made of a range of socio-economic scenarios, but empirical evidence resulting from developments in the negotiations can now be added to these theoretical scenarios.

The tools used for assessing climate change and for fine-tuning goals such as the 2°C target, and which help to make this continuity more readable, were fleshed out as a result. This view of climate change called for the choice of a long-term objective, since by reinforcing the linkage between human activity, GHG emissions, climate change and impacts, it held the promise of connecting up short-term actions and long-term consequences (and thus becoming a subject of discussion) in a politically meaningful way (Pershing & Tudela 2003).

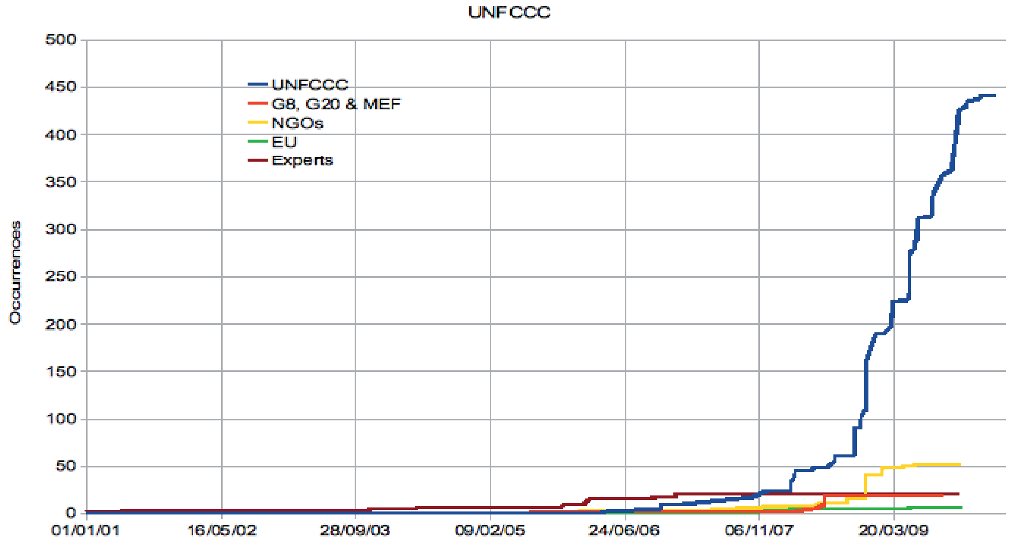
### 2.2.5. ...which leads to negotiating a long-term objective

The early 2000s were therefore marked by a growing number of studies and reports that, in the wake of what had emerged in the TAR, neatly consolidated this unified vision. This consequently reinforced the idea of setting a long-term objective for climate policy, still based on the two approaches advocated by the TAR: estimating the danger of potential impacts (IPCC, 2004; MET Office, 2005) or measuring the costs of doing nothing (Stern, 2006). This shift became apparent in the scientific literature, which now took a more actionable direction; there were more articles and reports based on potential long-term objectives, expressed either as concentrations or temperatures.[12] Milestones for the debate on the long term gradually stabilised. This basically required revisiting, expanding and improving proposals already loosely present in the literature. However, it was still not possible to say that one proposal was strongly predominant: it was rather a phase that crystallized the debate, during which certain ideas, values or expressions firmed up and became anchored in the discussions; they were being disseminated more widely, while also being enriched with different meanings and taken up by different players – until the whole was stable and mature enough to be propelled onto the negotiation agendas.

Quantitative analysis of the corpus texts tends to confirm this hypothesis, suggesting that the idea of a 'long-term goal' emerged in scientific and expert literature between 2001 and 2006, before appearing half-heartedly and then taking off in negotiations (Fig. 1 and 2).

12. The first scientific text in the corpus to directly address the question of a long-term temperature objective, 'Moving beyond concentration: the challenge of limiting temperature change', is dated 2004 (Richels et al. 2004). Thereafter, there was a proliferation of this type of paper, e.g. den Elzen & Meinshausen, 2005; Corfee-Morlot et al., 2005; Hansen et al., 2006. Corfee-Morlot & Höhne, 2003, may be mentioned in the same vein.

**Figure 2.** Cumulative frequency of 'long-term goal' in the corpus, by group of actors




### 2.2.6. Actually negotiating the long-term objective and the EU's leading role

In 2005, seven years before the end of the first phase of the Kyoto Protocol commitments, the question of the 'long term' was (re-)propelled into the arena of international negotiations. At Gleneagles, the G8 took climate change seriously for the first time, announcing the setting up of a dialogue on climate change, clean energy and sustainable development and committing to 'move forward [within the UNFCCC] the global discussion on long-term co-operative action to address climate change' (G8, 2005). Following the recommendations of the UN Summit of September 2005 (UN, 2005:12), the eleventh session of the Conference of the Parties of the UNFCCC in Montreal decided to initiate a non-binding dialogue on LCA (UNFCCC, 2005, decision 1/CP.11).The shared vision and the eventual long-term objective were not yet on the agenda, but these were brought to the table by some of the Parties (Japan, Norway, the European Union, AOSIS) during the two years of the Dialogue.

In early 2005, after nearly ten years of silence on the question, the European Union re-launched its 2°C proposal (European Commission, 2005; European Council, 2005)[13] and stated the need to translate this into policy form,[14] before presenting the likelihood of meeting the target for a range of GHG concentration stabilisation levels. The EU proposed this objective several times within the framework of the UNFCCC, adding constraints to the emissions pathway (peak emission reductions by 2050) that presaged the logic framed in later negotiations on objectives (UNFCCC, Dialogue; WP6, 2006; WP10, 2007; WP16, 2007). In spite of its relative insistence, the EU remained isolated in its initiative to quantify long-term objectives – AOSIS alone revisited the 2°C limit, only to denounce it as insufficient (UNFCCC, Dialogue; WP14, 2007).

It was however to bear fruit: following the report on the Dialogue (UNFCCC, 2007), a consensus appeared to have been reached on the relevance of defining a long-term objective. Although its formulation remained an open question, the proposal of a temperature target and the 2°C cap captured attention. The Bali Action Plan (decision 1/CP.13, UNFCCC 2007) included the definition of 'a shared vision for LCA, including a long-term global goal for greenhouse gas emission reductions, in the work programme compiled for the AWG-LCA.

## 2.3. From consolidation to official adoption

With the Bali Conference and the setting up of the AWG-LCA, the UN negotiating machine swung into full motion towards an agreement, which greatly

13. '[The European Council] confirms that, with a view to achieving the ultimate objective of the UN Framework Convention on Climate Change, the global annual mean surface temperature increase should not exceed 2°C above pre-industrial levels.' (March 2005)

14. 'The 2°C objective needs to be translated into policy terms.' (European Commission 2005)

**Figure 3.** Synthesis of the characteristics of stabilisation scenarios

*the sea level rise component from thermal expansion only.[a] {Table 5.1}*

| Category | $CO_2$ concentration at stabilisation (2005 = 379 ppm)[b] | $CO_2$-equivalent concentration at stabilisation including GHGs and aerosols (2005 = 375 ppm)[b] | Peaking year for $CO_2$ emissions[a,c] | Change in global $CO_2$ emissions in 2050 (percent of 2000 emissions)[a,c] | Global average temperature increase above pre-industrial at equilibrium, using 'best estimate' climate sensitivity[d,e] | Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f] | Number of assessed scenarios |
|---|---|---|---|---|---|---|---|
| | ppm | ppm | year | percent | °C | metres | |
| I | 350 – 400 | 445 – 490 | 2000 – 2015 | -85 to -50 | 2.0 – 2.4 | 0.4 – 1.4 | 6 |
| II | 400 – 440 | 490 – 535 | 2000 – 2020 | -60 to -30 | 2.4 – 2.8 | 0.5 – 1.7 | 18 |
| III | 440 – 485 | 535 – 590 | 2010 – 2030 | -30 to +5 | 2.8 – 3.2 | 0.6 – 1.9 | 21 |
| IV | 485 – 570 | 590 – 710 | 2020 – 2060 | +10 to +60 | 3.2 – 4.0 | 0.6 – 2.4 | 118 |
| V | 570 – 660 | 710 – 855 | 2050 – 2080 | +25 to +85 | 4.0 – 4.9 | 0.8 – 2.9 | 9 |
| VI | 660 – 790 | 855 – 1130 | 2060 – 2090 | +90 to +140 | 4.9 – 6.1 | 1.0 – 3.7 | 5 |

Notes:
a) The emission reductions to meet a particular stabilisation level reported in the mitigation studies assessed here might be underestimated due to missing carbon cycle feedbacks (see also Topic 2.3).
b) Atmospheric $CO_2$ concentrations were 379ppm in 2005. The best estimate of total $CO_2$-eq concentration in 2005 for all long-lived GHGs is about 455ppm, while the corresponding value including the net effect of all anthropogenic forcing agents is 375ppm $CO_2$-eq.
c) Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. $CO_2$ emissions are shown so multi-gas scenarios can be compared with $CO_2$-only scenarios (see Figure SPM.3).
d) The best estimate of climate sensitivity is 3°C.
e) Note that global average temperature at equilibrium is different from expected global average temperature at the time of stabilisation of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilisation of GHG concentrations occurs between 2100 and 2150 (see also Footnote 21).
f) Equilibrium sea level rise is for the contribution from ocean thermal expansion only and does not reach equilibrium for at least many centuries. These values have been estimated using relatively simple climate models (one low-resolution AOGCM and several EMICs based on the best estimate of 3°C climate sensitivity) and do not include contributions from melting ice sheets, glaciers and ice caps. Long-term thermal expansion is projected to result in 0.2 to 0.6m per degree Celsius of global average warming above pre-industrial. (AOGCM refers to Atmosphere-Ocean General Circulation Model and EMICs to Earth System Models of Intermediate Complexity.)

Source: IPCC, 2007a:20.

influenced the content of contributions, starting with the scientific contributions. Discussions on the long term moved on from the exploratory stage to enter an active phase of negotiations. The goal was to reach an agreement before the end of the Working Group's two-year mandate; the agenda was thus to identify and clarify existing proposals with in view of coming to a final decision.

### 2.3.1. The Fourth IPCC report (and long-term objective): more actionable scientific information

This shift became apparent in the IPCC Fourth Synthesis Report (AR4), whose publication was staggered over 2007 prior to the Bali Conference. The report was to serve as scientific reference for the Post-Kyoto negotiations. Simple but effective, the Summary for Policymakers addressed one by one the major strands of the climate issue (observed changes, causes of the changes, projected impacts, mitigation and adaptation options, long-term perspective).

More importantly, the report – and its most cited and circulated elements – was far more actionable than its predecessors: the goal was no longer to alert, nor even assess the role of political leadership with respect to the climate issue, but indeed to assist in developing and implementing policy, as was made clear by the IPCC during its conference at the start of the Copenhagen COP (IPCC, 2009). To achieve this, the report reviewed the tools available (including different types of models, scenarios, frameworks and criteria for economic analysis and risk management), refined its predecessors' conclusions, described the uncertainties in precise terms and assessed different emission projections together with their impact on the climate system.

Although there were still significant uncertainties particularly regarding climate sensitivity, which is a key parameter for moving from radiative forcing to average global temperature, the IPCC proposed a 'best guess' and the most probable climate change paths for different scenarios reported in the synthesis tables.

Some of these tables, which summarise the IPCC synthesis, usefully structured the negotiations and served as templates for debates on the quantification of long-term objectives. In particular, two tables aligned the characteristics of trajectory ranges leading to different concentration stabilisation levels. Some compared the parameters of changes in emissions (peak date, difference between 2000 and 2050 emissions) and the variables characterising impacts (global temperature variations and

**Figure 4.** $CO_2$ emissions and equilibrium temperature increases for a range of stabilisation levels

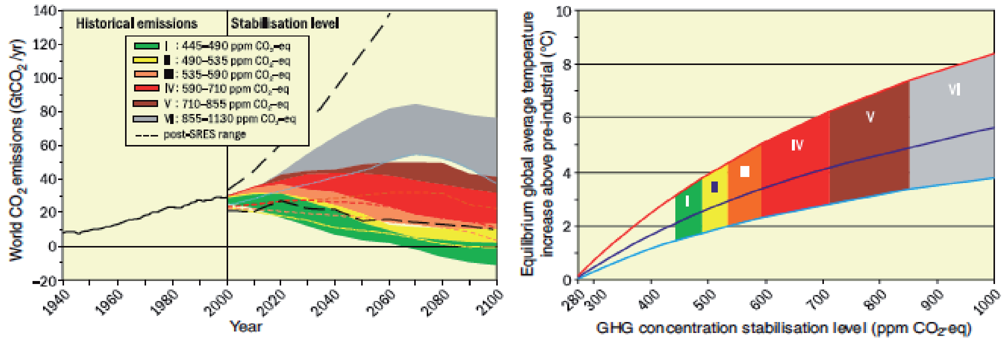



*Figure SPM.11. Global $CO_2$ emissions for 1940 to 2000 and emissions ranges for categories of stabilisation scenarios from 2000 to 2100 (left-hand panel); and the corresponding relationship between the stabilisation target and the likely equilibrium global average temperature increase above pre-industrial (right-hand panel). Approaching equilibrium can take several centuries, especially for scenarios with higher levels of stabilisation. Coloured shadings show stabilisation scenarios grouped according to different targets (stabilisation category I to VI). The right-hand panel shows ranges of global average temperature change above pre-industrial, using (i) 'best estimate' climate sensitivity of 3°C (black line in middle of shaded area), (ii) upper bound of likely range of climate sensitivity of 4.5°C (red line at top of shaded area) (iii) lower bound of likely range of climate sensitivity of 2°C (blue line at bottom of shaded area). Black dashed lines in the left panel give the emissions range of recent baseline scenarios published since the SRES (2000). Emissions ranges of the stabilisation scenarios comprise $CO_2$-only and multigas scenarios and correspond to the 10th to 90th percentile of the full scenario distribution. Note: $CO_2$ emissions in most models do not include emissions from decay of above ground biomass that remains after logging and deforestation, and from peat fires and drained peat soils. {Figure 5.1}*

Source: IPCC, 2007a:21.

**Figure 5.** Efforts to be made in reducing emissions for Annex I countries and Non-Annex I countries over different time horizons

**Box 13.7 The range of the difference between emissions in 1990 and emission allowances in 2020/2050 for various GHG concentration levels for Annex I and non-Annex I countries as a group[a]**

| Scenario category | Region | 2020 | 2050 |
|---|---|---|---|
| *A-450 ppm $CO_2$-eq*[b] | Annex I | –25% to –40% | –80% to –95% |
| | Non-Annex I | Substantial deviation from baseline in Latin America, Middle East, East Asia and Centrally-Planned Asia | Substantial deviation from baseline in all regions |
| *B-550 ppm $CO_2$-eq* | Annex I | -10% to -30% | -40% to -90% |
| | Non-Annex I | Deviation from baseline in Latin America and Middle East, East Asia | Deviation from baseline in most regions, especially in Latin America and Middle East |
| *C-650 ppm $CO_2$-eq* | Annex I | 0% to -25% | -30% to -80% |
| | Non-Annex I | Baseline | Deviation from baseline in Latin America and Middle East, East Asia |

Notes:

[a] The aggregate range is based on multiple approaches to apportion emissions between regions (contraction and convergence, multistage, Triptych and intensity targets, among others). Each approach makes different assumptions about the pathway, specific national efforts and other variables. Additional extreme cases – in which Annex I undertakes all reductions, or non-Annex I undertakes all reductions – are not included. The ranges presented here do not imply political feasibility, nor do the results reflect cost variances.

[b] Only the studies aiming at stabilization at 450 ppm $CO_2$-eq assume a (temporary) overshoot of about 50 ppm (See Den Elzen and Meinshausen, 2006).

*Source: See references listed in first paragraph of Section 13.3.3.3*

Source: IPCC 2007d:776.

sea level) (IPCC, 2007a:20; 21). Another went further into policy translation and drafted an initial apportionment of mitigation efforts for the 2020 and 2050 time horizons by associating three stabilisation levels with ranges of emission reductions; quantitative for Annex 1 countries and qualitative for the others (IPCC, 2007d: 776).

This shows how the scientific literature directly contributed to framing and formulating policy commitments: it proposed an assessment intended to enable a choice between several options including temperature, stabilisation level and constraints on the pathway (peak date, emission reduction over shorter or longer time periods) *probably* consistent. The report went as far as comparing different possible 'targets', while noting that 'policy-makers are not required to make once-and-for-all decisions, binding their successors over very long term horizons, and there will be ample opportunities for mid-course adjustment in the light of new information' (IPCC, 1007c:233). However, concentrations were still used as a reference and presented as the pivotal factor on which the choice should be based.

The preoccupation with Post-Kyoto and the need to map out future climate actions were mostly seen in scientific papers where climate and economic considerations were increasingly intertwined (e.g. Michaelowa et al., 2005; Höhne et al., 2005; Höhne, 2006). A good number of servers had been put to work and much ink had flowed in order to analyse comparative advantages and disadvantages of the various approaches for formulating targets (Bowen & Ranger, 2009) as well as possible pathways, and to estimate the most likely ensembles of quantified targets. In a sense, the logic and formulations proposed for negotiations were re-appropriated by the scientific literature, which enhanced and consolidated them while at the same time adding the precautions and precisions on uncertainties required by scientific rhetoric. As a 'laboratory' that tested the possible consequences of different choices for policy frameworks, research was actively involved in negotiations, all the while seeking to affirm its unswerving neutrality and objectivity.

### 2.3.2. The AWG-LCA negotiations and the growing importance of 2°C

A similar process took shape and operated within the AWG-LCA, though it dealt with a different subject. During the negotiations, the Working Group had been tasked with a specific mission, part of which involved reaching an agreement on the shared vision. Once the discussion framework had been defined, the first step was to work on collecting and identifying the relevant information, starting with all of the Parties' positions – which were partly based on the available scientific literature. These positions, which frequently reiterated the series of targets recognised by the IPCC, were compiled by the Convention Secretariat to facilitate discussions in the hope of ensuring a coherent and consensual negotiating process. Most of the work consisted in aligning the various options proposed so as to minimise any controversy and uncertainty over the outcome of negotiations. The Parties sometimes sought additional detailed information from research sources to finalise their position, as for example when the European Union proposed linking the 25-40% reductions by 2020 compared to the 1990 baseline for Annex 1 countries with a 15-30% deviation below BAU by 2020 for non-Annex 1 countries, on the basis of a paper that had been circulated in 2008 at Poznan (Den Elzen & Höhne, 2008; Gemenne, 2009).

In this process of assessing the options for quantifying long-term objectives for climate action, carried out jointly by researchers and negotiators, the 2°C was to come to the fore. It was one of the parameters used to characterise the emissions pathways now most often associated with stabilising GHG concentrations at 450ppm (and not 550ppm as was the case a few years earlier). In this respect (but also others), 2°C was one of the possible quantifiers of the long-term objective in negotiations. But it had a more complex and ambiguous status than formulations based on concentration or emission reduction, which although more concrete, were also less flexible.

Indeed, if 2°C appeared frequently in the literature and in particular the AR4, it was also because it was being used in different contexts within which its meaning could be suitably adapted. Representing a rise in the average global temperature, compared to either the 1990 or the pre-industrial baseline, it served as a benchmark for comparing the different stabilisation options (and thus pathways)[15] as well as for categorising different levels of impacts.

### 2.3.3. Dissenting voices fail to undermine 2°C

However, as scientific research progressed and time passed, its value was modified. As both the AR4 impact assessments (SPM.7) and certain contemporaneous scientific studies (e.g. Meinshausen, 2006; Hansen et al., 2007) moved several indicators into the red zone well before

15. In view of the uncertainties, the temperature rise for a given level of concentration stabilisation is expressed as a more probable range together with a 'most likely value', which means that 2°C is consistent with more than one concentration, according to the degree of uncertainty and risk one is prepared to accept.

temperature had reached the 2°C rise, the danger threshold expressed as temperature should have been revised downwards accordingly. In parallel, analysis of the various possible pathways seemed to indicate that hitting the 2°C target was less and less likely given the current emissions trend, and would anyway have required concentration stabilisation at very low (thus unrealistic) levels.[16]

Both too lax and too ambitious, the potential 2°C target might well have been jeopardised, yet it retained its benchmark status even in the IPCC's conclusions.[17] The level of concentrations associated with 2°C had changed (450 instead of 550ppm) making it a more challenging target. But although the interpretations of 2°C had changed, the figure stayed put: it was now sufficiently stabilised and anchored in the debates to survive despite the changes to its meaning; at the same time, advantage was taken of the flexibility afforded by the vagueness and uncertainty surrounding it to redefine its contours. In a sense, it was already almost fully adopted, since it had become a sort of upper limit: the possibility of claiming that it might not be dangerous to allow temperatures to rise by more than 2°C was hardly ever mentioned from then on (Baptiste Legay, 2010, interview).

### 2.3.4. The debate on pathways polarises around temperatures

Far from being weakened, 2°C was about to take a key place in the climate arena. As noted before, negotiations on a long-term objective had been grounded on a logic that connected multiple markers (trajectory characteristics, stabilisation level, impacts) in a chain able to link short-term action with a long-term perspective, while retaining some flexibility. This involved determining a 'roadmap' by choosing from the various options available for each milestone (temperature, concentrations, date of peak emissions, reductions by 2020, reductions by 2050, apportionment of these reductions among Annex I and non-Annex I countries).

Yet these milestones are interlinked in that the components of the pathway selected must have some degree of consistency, which excludes scientifically absurd combinations. Due to the uncertainties inherent in climate modelling, it is impossible to go beyond hierarchizing the combinations in function of their probability: what is too unlikely to be feasible is 'absurd'. However, undoubtedly due to the fact that policy discussions most often eclipse pathway-related probabilities, the links having to some extent to follow the same movement, one ends up considering it sufficient to choose one of them to constrain all the others: ticking a box in a paragraph of the draft agreement would then ensure almost automatic support for related points in the remainder of the text.

In fact, it was temperatures that were to attract attention and become the keystone of the debate on the long-term objective, the latter being what the agreement's actual content would depend on and without which nothing could be built. This shift is probably explained by a combination of converging factors in favour of temperature. Firstly, the idea of this type of target, and the value most often proposed to achieve it, were already part of the landscape. The debate on the direction of long-term climate action was thus launched on the basis of the 2°C (EU, 1996, 2005). Secondly, in the literature, temperature is linked either to reduction paths or to impacts, which means that it can intermediate between these two inextricably linked strands of the negotiations, which are themselves representative of the mitigation-adaptation tensions, cost-damage tensions, etc. The temperature variable is also simpler, more understandable and meaningful – in short, more easily communicated than atmospheric greenhouse gas concentrations. At the same time, it is less accurate and less clearly measurable than concentrations, which affords it an ambiguity that is very useful in the negotiation process: we can point relatively precisely to the moment when 450ppm of atmospheric GHGs are to be expected, but much less precisely to the moment when the average global temperature will have risen 2°C above the pre-industrial baseline.

### 2.3.5. 2°C comes out on top

In the final twists of the pre-Copenhagen negotiations, temperature targets took (by far) the upper hand over all other proposed alternatives, as if they alone were able to extricate themselves from the sphere of technical debate and engage with policy. As shown by the curves tracing how the frequency of the different targets evolves, 2°C had pervaded

16. 'For example, respecting constraints of 2°C above pre-industrial levels, at equilibrium, is already outside the range of scenarios considered in this chapter, if the higher values of likely climate sensitivity are taken into account, whilst a constraint of respecting 3°C above pre-industrial levels implies the most stringent of the category I scenarios, with emissions peaking in no more than the next 10 years, again if the higher likely values of climate sensitivity are taken into account.' (IPCC WGIII 2007 ch. 3:59)

17. 'It is very likely that all regions will experience either declines in net benefits or increases in net costs for increases in temperature greater than about 2-3°C.' (WG 2 SPM); 'stabilisation of atmospheric concentrations of greenhouse gases below about 400 ppm CO2 are required to keep global temperature increase likely less than 2°C above pre-industrial level' (WGI ch. 10); 'Avoidance of many key vulnerabilities requires temperature change to be below 2°C above 1990 in 2100.' (WG III ch. 3)

the non-expert literature much more than concentrations had done (Figs 7 to 9). Its dramatic take-off is striking in the analysis of the corpus: around 2007-2008, its frequency drops off, as do those for concentrations, which coincides with the start of LCA negotiations. Whereas both had previously evolved on a similar pattern, 2°C suddenly overtook concentrations. These were gradually forgotten to the point of disappearing in the COP 15 draft agreement authored by Michael Zammit Cutajar (UNFCCC, 2009). At the same moment, temperature rise values of 1.5°C (AOSIS, 2009; Bowen et al., 2010) and 1°C (Bolivia, 2009) began to appear, which highlighted that the debate had clearly shifted to temperatures and that it was now unthinkable for the originally proposed value to reign supreme without first coming under discussion, as is shown by comparing the frequency trends of the different proposed objectives in the corpus (Fig. 6).

The issue of pathways opened up both the time and space horizons of negotiations: from the moment a long-term perspective linking immediate actions with future consequences, however distant, was adopted and the decision was made to constrain the present in function of the future desired, it became virtually impossible for emerging countries – historically low emitters but fast becoming mainstream – to avoid joining the discussion. In the long term, climate stabilisation cannot be achieved solely by the action of Annex 1 countries and, for the large emerging countries, agreeing on a pathway implies eventually agreeing to participate in mitigation efforts and to do so within the framework of the model proposed by the European Union.

China's attempts to reframe the debate by proposing energy efficiency as a benchmark (Legay 2010, interview) received scant support, particularly as the poorest and most vulnerable countries in the G77 were calling for a 1.5°C cap on temperature rise. The 2°C cap however was too well anchored in the discourse to be swept to one side; at the same time, a temperature target, even an ambitious one, was less restrictive than a concentration target, as it was imprecise as to the exact amount of carbon that one agrees to release into the atmosphere: it thus gave more leeway to define the allocation of the carbon budget and reduction efforts. So, caught in the middle, the large emerging countries eventually came to support the 2°C target: first, at the Major Economies Forum in July 2009 (MEF 2009) and finally during the night of 17th to 18th December in Copenhagen (Copenhagen Accord, UNFCCC 2009), when the objective 'to reduce global emissions so as to hold the increase in global temperature below 2 degrees Celsius' (Copenhagen Accord, UNFCCC 2009) was (more or less) officially instated. Meanwhile, all other parameters were dropped and temporarily relegated into the background.

## 3. STRUCTURING NEGOTIATIONS AROUND 2°C: WHICH MEANING(S) SHOULD IT BE GIVEN?

During the Copenhagen conference and the few months preceding it, the 2°C cap prevailed over all the other alternatives being considered for the formulation of a long-term objective. At the same time, it was severing its ties with the rest – as if, once propelled to the front of the stage, it had to rid itself of its teammates that were too heavy to reach final adoption.

### 3.1. Theoretical framework: 2°C as a 'boundary object'

In the preceding paragraphs, a series of hypotheses has been outlined that may explain why, out of all the possible types of quantification, the formulation of an acceptable threshold for average global temperature rise had captured the attention and taken over the debate, even though from a purely technical point of view it was not necessarily more robust or effective than other options (Bowen & Ranger, 2007). In some way, it was the proposed 2°C threshold that reconfigured and centred the debate on the question of temperature because this limit had become indispensable, and not vice versa (i.e. temperature rhetoric was the first to take root and it then opened the way for the 2°C value): the discussion on pathways, which included temperature, focused on 2°C. This value eventually diverted the debate on to the choice of an acceptable temperature increase that would then serve as a basis for calibrating the other parameters. But many of the explanations given above ultimately imply that the reason 2°C 'succeeded' (if success is understood to mean clearing a path through the labyrinth of negotiations to reach the front of the stage) was because it was able to aggregate the actors and resonate in the texts much more strongly than its rivals. Sufficiently vague to allow several interpretations, 2°C also made sense in the context of several questions raised by long-term climate trends and the debate on the LCA.

The 2°C target thus successfully interlinked the different climate change issues, notably the question of impacts and emissions pathways. It was also frequently mobilised, though not always for the same reasons, which only served to reinforce

**Figure 6.** Cumulative frequency evolution of different objectives in our corpus

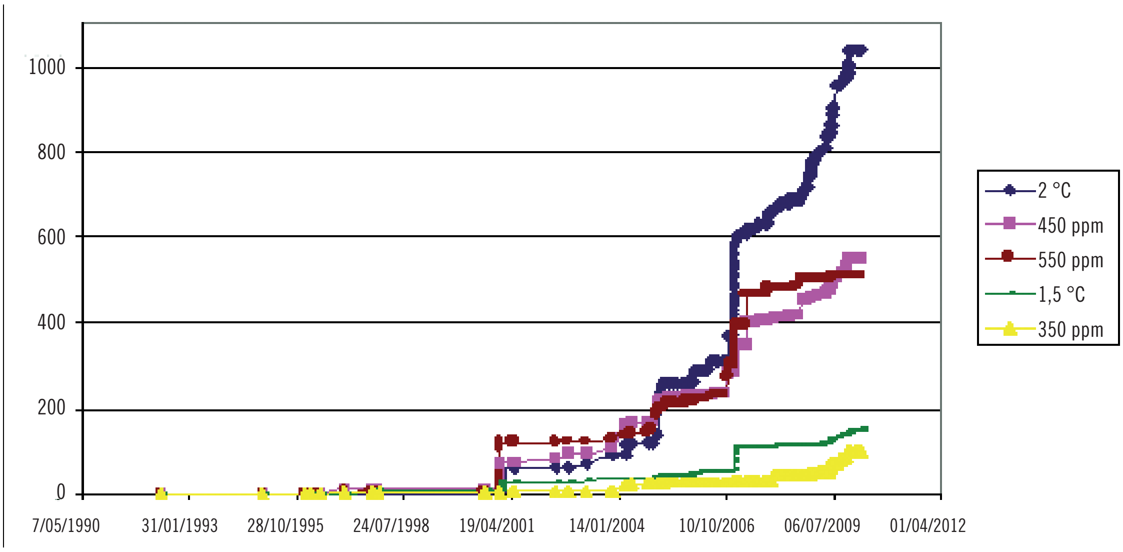



**Figure 7.** Frequency distribution for '450 ppm' by group of actors

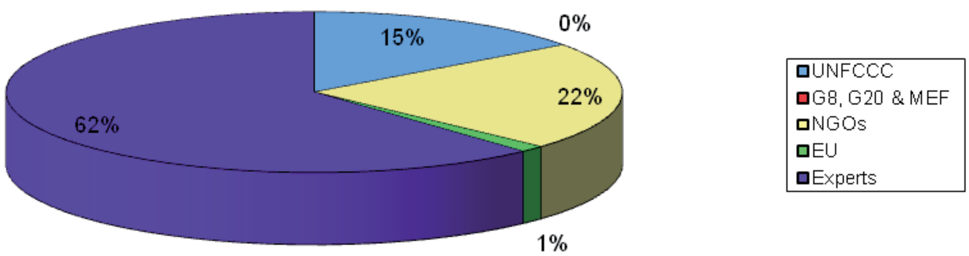



**Figure 8.** Frequency distribution for '550 ppm' by group of actors

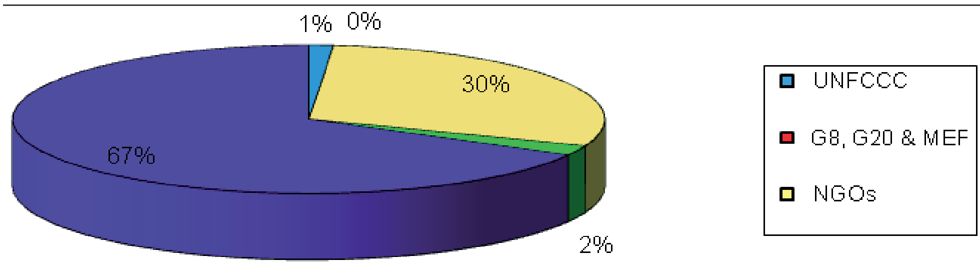
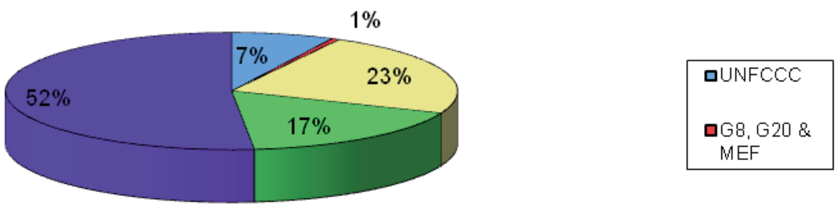



**Figure 9.** Frequency distribution of '2° C' by group of actors



its presence in negotiations, where repetition is a particularly effective weapon.

The sociology of science and technology provides some interesting tools useful for understanding and analysing the progression of the 2°C target considered as an aggregator of knowledge and interpretations. The co-productionist approach (Jasanoff, 2004a, 2004b) was useful for disentangling the interactions between understanding (by producing knowledge and building a scientific and technological tool) and composing (by comparing information and position with a view to decision-making) the world; the actor-network theory (ANT) (Callon, 1986) and the related concept of 'boundary object', theorised by Star and Grisemer (1989) can shed light on the negotiating game that gradually built up around the 2°C limit. 'Boundary objects' are physical or conceptual objects used to facilitate co-operation between different social worlds. Their particularity is that they are flexible enough to adapt to the constraints and languages of actors from diverse communities, while at the same time retaining a meaning or an identity that is stable and robust enough to ensure a continuing exchange of information. Climate negotiations are obviously fertile ground for implementing such objects, given the tremendous diversity of actors that meet together at negotiations, feed into them and interact (scientists, Sherpa negotiators, ministers, NGOs, lobbies, economists...). Faced with a system where understanding and regulating it are more inextricably linked than ever, it becomes impossible to address, en bloc and through a single prism, the issues and questions this raises. Consequently, there is a pressing need for scientific-technical tools that can be mobilised at policy level and which have the capacity to carry part of the complexity, change and incertitude inherent to climate issues.

Constructing and maintaining the particular range for climate sensitivity or for calculating Global Warming Potential are good examples of this; although somewhat vague, both have become a stable and crucial element in discussions, a fact that cannot be explained simply by their scientific robustness (which is, in fact, relatively weak, and both are still widely contested within the climatologist community) (Shackley & Wynne, 1997; van der Sluijs et al., 1998). Both share a degree of vagueness and ambiguity that allows them to retain their relevance despite the progress made in research, the instability of the political context and diversity of viewpoints – all the while maintaining a clearly identified role. A similar pattern seemingly emerges for the 2°C value, which, as and when the negotiations required, became associated with various challenges and problems as a point of contact between them.

## 3.2. The meanings of 2 °C

As seen earlier, if the origin of 2°C is difficult to pinpoint with certainty this is partly because it was (and still is) used in different contexts. The corollary of this ubiquity is the fact that it is associated with a wide range of meanings and interpretations while maintaining a basic steadfastness as a marker for future evolution of the global climate.

### 3.2.1. The Parties' positions with regard to the 2°C

In negotiations, 2°C was first suggested as a long-term objective by the European Union. European proposals never put forward this as the sole objective: even if the composition of most likely pathways had changed, the target in degrees was always accompanied by a level of concentration stabilisation at least, then later, by additional constraints (peak date, emissions reductions in the short, medium and long term), and then finally by the first move to apportion efforts between Annex I and non-Annex I countries (European Commission, 2007). However, despite the 2°C target becoming a structuring factor in negotiations, not all the Parties rallied behind the very stringent and highly structured European vision. The LDCs and island states, because of their vulnerability and minimal contribution to emissions, focused on the impacts related to temperature change more than its implications in terms of mitigation costs. They considered the 2°C target inadequate and called for 1.5°C (AOSIS) or 1°C (Bolivia). Others favoured more flexible and scalable frameworks than that proposed by the EU. This is the case of the United States, which had never rejected 2°C, yet not defended it either, and Brazil, The large emerging countries did not give a clear opinion on limiting the rise in temperature, and adopting 2°C would make it impossible for them to evade action (action from industrialised countries alone might be adequate for the Kyoto Protocol springboard objective, but not sufficient to stabilize the climate), and this vision has opened up the debate on the issue of fairness and responsibility. However, the 2°C is not only protean in the negotiating arena.

### 3.2.2. A scientific value that is not unequivocal

Scientifically speaking, the 2°C value is not unified, in the sense that it is not the response to a unique question: it is hardly surprising that a temperature range appears in several contexts when it comes to climate change. It is seen as a possible value in climate sensitivity; as a marker of dangerous climate change (for example, it represents the lowest value of the temperature range above which there is a risk of total deglaciation in Greenland, as well as an estimated tolerance threshold for the majority of terrestrial ecosystems); as a more or less likely estimate of the rise in temperature for a stabilisation level of atmospheric $CO_2$ concentrations or greenhouse gas emissions; and as an objective from which to calibrate emissions and stabilisation pathways.

To complicate matters, it is not always the same 2°C. In fact, behind this simple figure there are a host of detailed parameters, the main one being the base year: whether it be the pre-industrial era (variably, 1750 or 1850) or the average of 1980 to 1990, knowing that it was on average 0.6°C warmer on Earth at the end of the 20th century than at the beginning of the 19th century. It might be a question of temperature change at equilibrium (after stabilisation) or in 2100, the latter being lower in concentrations due to climate system inertia (IPCC, 2001:22).[18] These distinctions and details are rigorously listed in all the scientific texts, leaving no ambiguities for the careful reader. This no longer holds true the closer one comes to the heart of negotiations, where probability estimates, caution in managing uncertainty or the detail of methods and references are considered too bothersome. Added to the vagueness that casts uncertainty over the possible climate change projections, this proliferation of 2°C provides an added degree of flexibility: by merely playing down the strict details, you can choose which '2°C' to use and what to make it say, while remaining in line with the scientific findings (with a minimum respect for the rules of plausibility).

### 3.2.3. Policy consequences: the weakening of 2°C as a resource

This lack of clarity opened a strategic avenue. The moment it became clear that sidestepping the debate on a long-term objective and its temperature-based formulation was impossible, the 2°C became the primary resource for those wishing to avoid an over-restrictive roadmap. The United States, with their politically limited capacity to reduce their emissions in the short-term, or the large emerging countries (China and India at the fore) refusing any commitment in the absence of significant involvement of Annex I countries, just might have supported the 2°C target provided that it did not automatically point to *one* stabilisation level, *one* trajectory and *one* predetermined apportionment of efforts. In fact, committing to limit 'the increase in global temperature below 2 degrees Celsius' was not necessarily as restrictive as might be suggested by the aggregate targets packaged by the European Union and used to structure the 'shared vision' strand of the negotiations: everyone could, in good faith, associate '2°C' with precise parameters (needed to interpret it) of their own choice from out of the range found in the literature. Even if one simply keeps to a chain of targets that theoretically only need to be implemented once one of the parameters has been chosen as a basis for calibrating the others, '2°C' is ambiguous as it is compatible with at least two stabilisation levels (IPCC, 2007a:20) which depend on the level of risk one has accepted of not exceeding it (and zero risk is impossible given the atmospheric concentrations of greenhouse gases already reached).

Since the scientific literature is unable to provide much more than an increasingly accurate quantification of uncertainties and of the likely ranges of climate system responses depending on the forcings used, it is still possible to navigate through the grey areas and maintain conflicting interpretations of policy implications of the same objective: nothing is set in stone, even if the logic of the European position might suggest otherwise. Where climate is concerned, it is for that matter likely that nothing will be set in stone as long as nothing has happened.[19]

It is therefore possible to set a target and mark out a pathway guaranteeing a good probability of meeting it, but not to determine with certainty the best course to follow. As well as being politically untenable, an excessively strict and rigid definition of a pathway over the first 50 or even 100 years masks irreducible scientific uncertainties that a climate policy should in fact be managing. In other words, even if we give ourselves a target with the aim of ensuring that it remains realistic, the way set still has to be negotiated, almost every step of the way. What can be negotiated depends on the constraints that current happenings impose on the future, and on what the ceiling we have set ourselves for the long term permits. It is here the scientific expertise can intervene, as scientists are

18. Although not always specified, negotiations within the UNFCCC rather tend to focus on transient change (i.e. by 2100), the long-term policy does not cover much further than the century – but the Copenhagen Accord made no statement on this point, leaving interpretation open.

19. Unlike meteorology, which predicts a fairly accurate image about atmospheric conditions in the immediate future, climatology can only offer array of possible pathways whose details are random. Climate is by definition an average, a trend, a representative but not exact image of a system and its evolution (IPCC 2007, glossary)

able to assess the consistency of actions undertaken or of expected trajectories for a fixed objective. They can also request further explanations if they deem that the choices are inconsistent. Drawing on Bruno Latour (2010), we are not faced with a 'future' (as he well points out, the future is more than threatened if we are to believe the possible consequences of inaction regarding climate change), but with an 'envelope' of continually revised and renegotiated prospects. Scientists, like negotiators, move forward groping in the same fog of uncertainties, probabilities, irreconcilable maybes and prospective visions built on varyingly realistic assumptions that remain unverifiable until they have come to pass.

The issue then is to agree on how these prospects are to be managed and constructed and to make decisions in this relentlessly uncertain environment. 2°C is a vague objective given its degree of flexibility, but it does allow negotiations to continue: perhaps it appears less definite, less reassuring and lacking in detail regarding a chosen pathway – but an abundance of detail is ultimately no better guarantee of realism and strength and no less symbolic than a fixed long-term objective that will be precisely defined concurrently with the path chosen in order to reach this objective.

### 3.2.4. Has 2°C been denatured?

To say this does not challenge the usefulness of a causal chain that helps to structure the milestones of various pathways and the scales of climate systems. Holding to the sole Copenhagen objective obviously cannot suffice: this does not mean that the choices as to the direction the action takes are fewer in number, quite the contrary. Moving forward, it will evidently be necessary to deal with emission reductions, adaptation and global apportionment of efforts, and setting milestones to limit the numerous possible scenarios still permitted by the 2°C objective is an important guarantee of visibility and coordination of the action.

While it is difficult to formulate policy objectives that look ahead to 2050, thinking in terms of pathways is a way of visualising to what extent what is done (or not done) in the near term and the distant target to be reached constrain the possibilities – and, above all, whether both remain compatible. Despite the uncertainties, setting a long-term temperature target makes it possible to disqualify some pathways, and then use the remaining plausible pathways to discount or challenge certain political choices. The debate on concentration stabilisations, peak dates, emissions pathways and whether or not to allow pathways to overshoot is therefore far from over. And if nothing is decided, there is a high risk of seeing the 2°C target denatured, made obsolete and downgraded to the symbolic quasi-decorative status of a safeguard.

According to Geden (2010), it is already almost certain that the 2°C target cannot be respected in the future, and if it is not disqualified as of now, it will be necessary to consider reformulating objectives that are more credible and achievable in order to have a replacement the day that the 2°C target permanently loses its meaning, after being gradually stripped of the detailed parameters that could increase its power of constraint. The emerging approach in the form of a 'carbon budget' (Broecker, 2007), which proposes agreeing on a future emissions stock and then sharing it out, is posing a serious challenge to temperature – filling the void left by the collapse of the pathway calibration parameters abandoned in Copenhagen. Although conceding it a certain theoretical elegance, Geden discounts this approach as politically impractical, as it is much too rigid and at the same time will likely need to be reassessed in each new IPCC report. He proposes instead a paradigm shift that involves setting an objective such as 'climate neutrality',[20] which he considers more flexible than 2°C, with which to assess and calibrate 'bottom-up' initiatives.

However, nothing says that 2°C cannot fulfil this role or that it is useful to replace it with a concept such as climate neutrality. Not exceeding a 2°C rise in temperature, regardless of the benchmark against which we understand it, sooner or later implies climate stabilisation, and hence greenhouse gas concentrations, and hence zero $CO_2$ emissions.[21] More importantly, once rid of the chaining that Copenhagen refused to unwind, the 2°C target lost its strength, leaving plenty of room for the step-by-step negotiation advocated by Geden. It has, however, retained the ability to serve as rappelling rope, to make the connection between impacts and actions, and project long-term responses to short-term decisions. Through its ability to interconnect scales and stakes, which stems partly from the diversity of meaning that it can carry, it has brought the future into negotiations, and with this forward vision underlined irreversibility. The choice of this objective was an explicit affirmation of the need for the long term in order to inform short-term action. Until exceeding the 2°C limit becomes a certainty, it places a (strong, as it is a very

20. Understood as an objective to reduce greenhouse gas emissions to zero.

21. Due to the time that $CO_2$ remains in the climate system, definitive stabilisation of atmospheric $CO_2$ concentrations is possible only if no more is emitted; reducing emissions does not in itself prevent accumulation, although it slows the pace.

ambitious target if taken seriously) constraint on decisions at each moment of the process, thus allowing it to be controlled, precisely because what is done or not done today has inescapable consequences in the long term. Modelling enables these consequences to 'exist' in negotiations, to represent this irreversibility in a concrete form that is all the more striking when models produce images that are easily confused with reality.[22]

The 2°C target is in danger of becoming a hollow shell only if we consider that 'science' ceases to be involved in the process once 'policy' decisions have been adopted. Viewed from this angle, science and policy are seen as two spheres evolving separately and only occasionally coming to meet, with science injecting its findings into the circle of negotiations for the purpose of enlightenment – all of which would mean that the consensus reached with great difficulty in Copenhagen could in effect have no more than a symbolic value. But as we have attempted to demonstrate, the dynamic of climate negotiations is completely different; knowledge production and policy composition advance arm-in-arm, constantly interacting and co-producing their respective prerogatives. When climate science is there to explain 'the arithmetic of 2°C' (Stern), policy action is then to some degree accountable to this science: policy relies on climatology to assess its action, and scientists play a legitimate role as judge of whether the decisions made in the negotiation process are consistent. As demonstrated by the UNEP in 'The Emission Gap Report' (UNEP, 2010), they can only indicate, with the information at their disposal, that atmospheric $CO_2$ will be at least 5GT over the 2020 limit required to keep the 2°C target on track. The last paragraph of the Copenhagen Accord[23] also implicitly recognises this role, which they instantly seized on – this is evident in the articles and reports estimating the feasibility of 2°C or 1.5°C or assessing the compatibility of short-term commitments with long-term objectives (e.g. Rogelj et al., 2009; Ranger et al., 2010). Finally, we find that policy choices have been integrated into climate model as parameters, but from now on this is in view of assessing the consistency of their choices once they have been adopted, and no longer in order to compare potential implications and influence their choices.

22. On this subject, see Lahsen (2005), who shows that certain climatologists acknowledge that sometimes they consider their models as mirror images of reality.

23. 'We call for an assessment of the implementation of this Accord to be completed by2015, including in light of the Convention's ultimate objective. This would include the consideration ofstrengthening the long-term goal referencing various matters presented by the science, including relation to temperature rises of 1.5 degrees Celsius.'(UNFCCC, 2009)

## 4. CONCLUSION

Faced with an issue such as climate change, which so openly challenges the dichotomy between Science and Politics, Nature and Society, Facts and Values (Latour, *Politiques de la Nature*), it is interesting to propose an analysis that breaks free as far as possible from all preconceptions of the respective roles played by scientists and policymakers. This is what we have attempted to do in this paper, relying on Jasanoff's co-productionist approach and the actor-network theory to retrace the highly non-linear path of the 2°C.

What we see is a rather disorderly emergence, far from the image of a neutral science that informs the policymakers responsible for making decisions. The 2°C value was first used by various actors for heuristic purposes: as it constituted a simple and relevant marker for climate issues, it has been used to calibrate climate, economic and policy models alike. Acquiring a relevance and signification in each field that used it, it gained in strength and became a widespread reference, that increasingly framed the ways of addressing climate change. This is well and truly an example of co-production, as both science and policy seized on it as a basis for their modelling.

There is thus a share of randomness in the choice of the 2°C model, in the sense that it does not directly result from the ascendance of a rational argument that has convinced a majority that it offered the best response: even impact studies, which are the closest thing to this type of model, inevitably produce results that are too imprecise to warrant the claim that a 2°C cap is clearly required for them to be adopted (on this count, it is moreover interesting that the attempts to deduce an objective from a scientific or economic analysis has come down in favour of quantifications expressed in terms of concentrations, which are less directly uncertain). Instead of this, the 2°C target has been put to the test in different contexts at the same time as the negotiating structures authorised by this marker were also being tried and tested. If it has been adopted as a given with no claim of paternity being staked, this would indicate that the results of these experiments, conducted by both the scientific and political circles, have been relatively satisfactory.

While it is certainly imprecise, vague covers several meanings, the '2°C increase in global temperature' still remains a way of describing climate change and bringing it down to a scale that is humanly and politically comprehensible. The different interpretations that can be given to it results in it becoming associated with different constraints, but in any event 'not more than 2°C in 2050 ' estimates a level of ambition. Combining flexibility and stability, the 2°C thus have all the characteristics of a *boundary object* that serves as interface between the issues raised by climate change, between scientific and political discourse and between the Parties to negotiations. It is because it is only partly malleable that their share of ambiguity has been able to translate into a resource.

Beyond the analysis of interlinkages between scientists and political leaders, this study brings to light the irreducible uncertainties operative in the climate arena, uncertainties that transform the way these interlinkages are conceived. Scientific production is no more stabilised than are the directions for action: both are constantly being (re) negotiated, which the 2°C can allow for as it is a versatile link between several still open questions.

From this angle, Copenhagen has made a difference. Before, the 2°C target was the link in a causal chain of regulating the global thermostat, monitoring the quantities of atmospheric greenhouse gases, limiting emissions and minimising adverse impacts, and not a subject of debate in itself. At one point in preparing the Accord, the chain of events that was expected to mechanically unwind once the temperature objective had been decided on, thus resolving in one fell swoop the dizzying and jumbled complexity of climate change, snapped– one could wonder, as does Bruno Latour (Latour, 2010b), whether 'the failure of Copenhagen can be explained by something other than the intolerable character of an injunction that respected neither the uncertainty of research, of that of policy making.' Afterwards, all that remained was the 2°C, all other parameters that accompanied it having fallen, and it thus became directly challengeable (and challenged). From being a scientific indicator translated into policy, it has been turned into an objective (a fully political status but one that needs scientists to continue to be meaningful).

The Cancún Conference, in December 2010, took note of this, taking up the provisions of the Copenhagen Accord by officially integrating them into the corpus of texts adopted by the Convention. With the search for a clearly mapped out trajectory for the next fifty years now disqualified, negotiations have started out on more shifting ground where climate policy remains to be built, on the basis of an objective whose non-linear pathway is itself a recognition of the uncertainties typical of the issue and interdependence of science and policy.

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