

Three Views of Two Degrees

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Abstract

Limiting global warming to 2° Celsius above global mean temperature in pre-industrial times has become a widely debated possible goal for climate policy. It has been supported by many scientists, the European Union, the G8 and a whole series of national governments. However, some claim that it is way too stringent, others that it is not sufficient to avoid major climate risks. We show how the limit emerged out of a marginal remark in an early paper about climate policy and distinguish three possible views of it. The catastrophe view sees it as the threshold separating a domain of safety from a domain of catastrophe. The cost-benefit view sees it as a strategy to optimize the relation between costs and benefits of limiting greenhouse gas emissions. And the focal point view sees it as a solution to a complex coordination problem. We discuss these three views, including a philosophical reflection on some conceptual confusion concerning value judgments, and conclude that the focal point view is the most appropriate. It leads to an emphasis on implementing effective steps towards a near-zero emissions economy and to accept that in the course of time the focal point may be redefined on the basis of practical experiences.

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Introduction

In July 2009, The Economist reported: "The United States, Canada, Japan and Russia for the first time have put their names to a G8 declaration endorsing a position on the climate already taken by the European Union. This sets out that global temperatures, which already rose by 0.7°C in the 20th century, should not be allowed to rise by more than 2°C compared with pre-industrial levels" (The Economist 2009).

Similar media messages were published all over the world. They refer to §65 of the G8 declaration „Responsible Leadership for a Sustainable Future“: „We reaffirm the importance of the work of the Intergovernmental Panel on Climate Change (IPCC) and notably of its Fourth Assessment Report, which constitutes the most comprehensive assessment of the science. We recognise the broad scientific view that the increase in global average temperature above pre-industrial levels ought not to exceed 2°C” (G8 2009). An analogous endorsement of the 2° target was declared by the leaders of the major economies forum, representing 16 countries and the European Union (Major Economies Forum 2009).

Although these are by no means legally binding statements, they strengthen an important argument about how to interpret a text that is legally binding: §2 of the UN Framework Convention on Climate Change. That well-known paragraph states that the convention has the “ultimate objective to prevent dangerous anthropogenic interference with the climate system“ (UNFCCC 1992). The convention has been ratified by countries all over the world, not only those that have ratified the Kyoto protocol. It is valid international law. And while the force of international law is much less obvious than the one of national law, the old Roman saying “pacta sunt servanda” – agreements must be kept – is a rule on which the society of nations can and does rely most of the time, despite quite a few exceptions. How to interpret the phrase “dangerous anthropogenic interference with the climate system”, then, is by no means trivial. And the G8 statement lends force to the claim it should be understood as anthropogenic global warming of more than 2° Celsius above pre-industrial levels.

How to interpret the phrase on dangerous interference has been the subject of intense debate (Dessai et al. 2004, Hare 2003, Oppenheimer and Alley 2005, Schellnhuber et al. 2006, Schneider 2001). While it is unclear whether a canonical interpretation will ever be established, the 2° approach has emerged as the most visible one in the debate.

We discuss this emergent property of the climate debate as follows. The 2° limit was first introduced by a marginal remark in one of the early papers on climate risks. It was then taken up in a perspective of catastrophe theory as a possibility to delimit a domain of safety in order to avoid climate catastrophes. We call this the catastrophe view, in contrast to the cost-benefit view. The latter justifies the limit by comparing benefits of avoiding climate damages – expressed as percentage points of GDP – with costs of reducing economic growth. We argue that while both views contribute important insights, none of them provides a clear rationale for why the 2° limit should be more appropriate than a series of conceivable alternatives. We then claim that the debate about the 2° limit suffers from a conceptual confusion that can be overcome with the help of recent advances in philosophy: the distinction between descriptive and normative uses of words is often confused with a misleading dichotomy between facts and values. With that background, we propose a view of the 2° limit as a possible focal point in a coordination game, and argue that it is good enough for that purpose. The debate should now focus on how to reach a new coordination equilibrium of the world economy characterized by near-zero emissions.

A First Intuition

Surprisingly, perhaps, the first suggestion to use 2° Celsius as a critical limit was made by an economist, W.D. Nordhaus, in a graph published in a discussion paper of the prestigious Cowles foundation (figure 1).

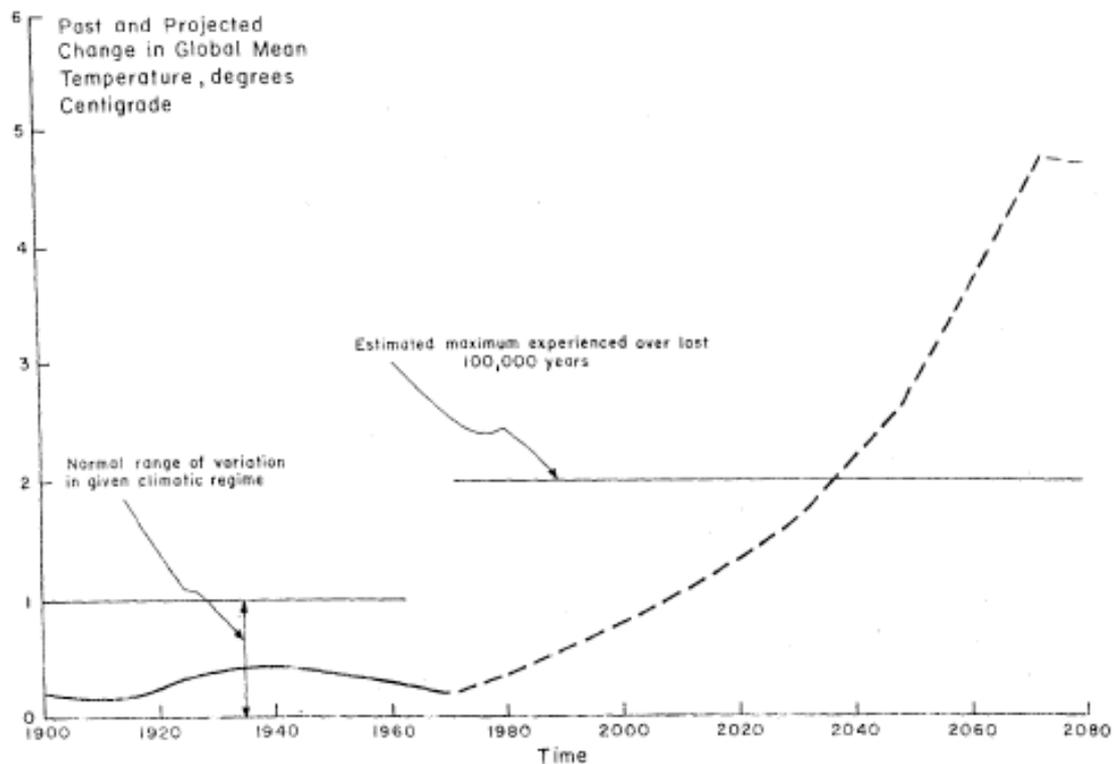


Figure 1. Past and projected global mean temperature, relative to 1880-84 mean. Solid curve up to 1970 is actual temperature. Broken curve from 1970 on is projection using 1970 actual as a base and adding the estimated increase due to uncontrolled buildup of atmospheric carbon dioxide.

Figure 1: The first suggestion of 2° Celsius as a critical limit (Nordhaus, 1977, p.3).

There he claimed: “As a first approximation, it seems reasonable to argue that the climatic effects of carbon dioxide should be kept within the normal range of long-term climatic variation. According to most sources the range of variation between distinct climatic regimes is in the order of $\pm 5^{\circ}\text{C}$, and at the present time the global climate is at the high end of this range. If there were global temperatures more than 2 or 3° above the current average temperature, this would take the climate outside of the range of observations which have been made over the last several hundred thousand years” (Nordhaus 1977, p.39-40; see also Nordhaus 1975, where the same words are to be found, but without the suggestive diagram).

At that time, he thought a 2° limit was roughly equivalent to a limit of doubling pre-industrial CO_2 - concentrations, and took the latter benchmark as a preliminary

standard - as would the vast majority of climate modellers who in the subsequent years fed the IPCC with estimates of climate impacts at double CO₂ concentration. Introducing the 2° limit was by no means a major point in Nordhaus' intentions, but then the image of an invisible hand became a hugely influential metaphor after having been introduced by another economist as a minor remark in his work on the wealth of nations.

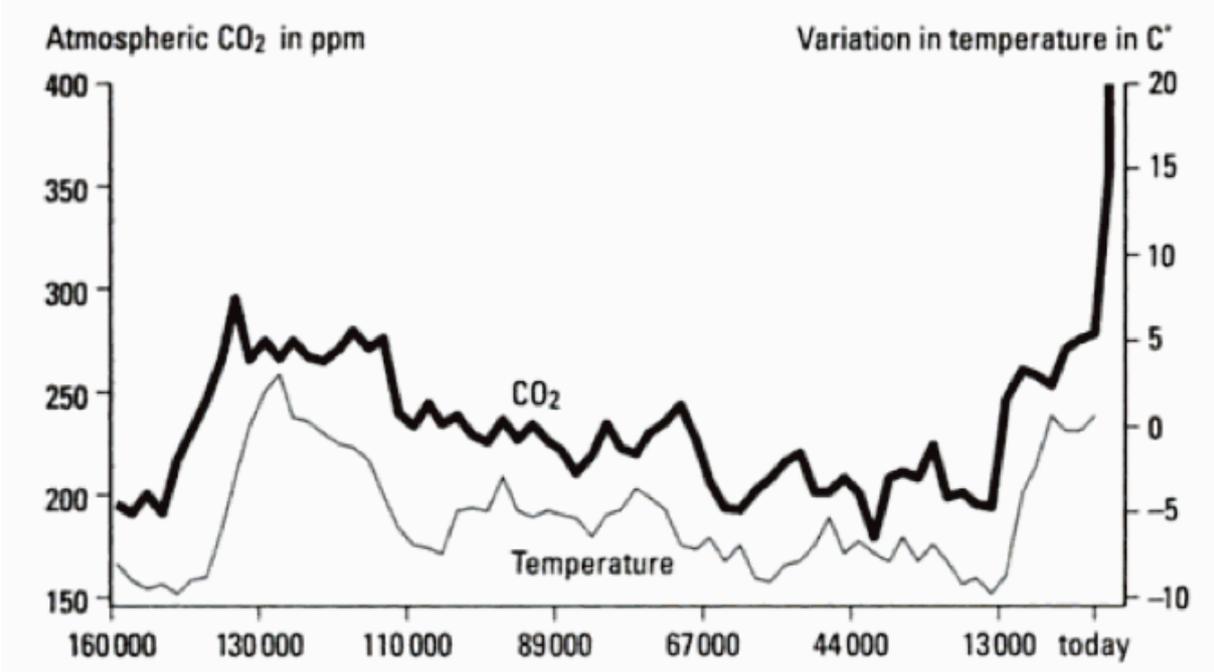


Figure 2: Estimates of past temperature and CO₂ concentration (von Weizsäcker et al. 1998, p.226, based on Jouzel 1987).

Nordhaus just expressed a preliminary intuition and did not support his claims by data or references. He admitted freely “that the process of setting standards used in this section is deeply unsatisfactory” (Nordhaus 1977, p.41). A decade later, however, data from the Vostok ice core made better estimates of past temperatures possible (figure 2). And the newer data did support the claim that global mean temperatures more than 2° higher than those around 1800 were hardly ever experienced during the last 100,000 years, and probably much longer.

The Catastrophe View

For over a decade, Nordhaus' first intuition plaid no significant role in the climate policy debate. The 2° limit, however, reemerged as an important issue in 1990, the year when IPCC published its first assessment report. Remarkably, perhaps, the 2° limit was not discussed there, and it has never been since then in any IPCC document. Rather, the 2° limit was forcefully introduced into the climate debate by the influential report of the so-called AGGG, the WMO/ICSU/UNEP Advisory Group on Greenhouse Gases " (Rijsberman, Swart, 1990).

However, while Nordhaus had argued for a 2° Celsius limit with the argument of a natural range – which also entails an ice-covered Europe, sea level variations of over 100 m or temperature changes over Greenland of up to 16° Celsius within decades (Lang et al. 1999) – the new proponents had different arguments for the same number. The AGGG report stated that a 2° Celsius increase was “an upper limit beyond which the risks of grave damage to ecosystems, and of non-linear responses, are expected to increase rapidly” (Rijsberman, Swart, 1990).

Clearly, the two arguments do not exclude each other, and the German Advisory Council on Global Change supported both lines of thinking in 1995. It considered the late Quaternary, i.e. the period of the last 800,000 or so years, and claimed: “This geological epoch has shaped our present-day environment, with the lowest temperatures occurring in the last ice age (mean minimum around 10.4 °C) and the highest temperatures during the last interglacial period (mean maximum around 16.1 °C). If this temperature range is exceeded in either direction, dramatic changes in the composition and function of today's ecosystems can be expected. If we extend the tolerance range by a further 0.5 °C at either end, then the tolerable temperature window extends from 9.9 °C to 16.6 °C. Today's global mean temperature is around 15.3 °C, which means that the temperature span to the tolerable maximum is currently only 1.3 °C” (WBGU 1995, p. 7). By adding 0.7° C for the increase from pre-industrial levels to 1995, this is equivalent to the 2° limit (as re-iterated in WBGU

1997, p. 13).

In 1996, the Council of the European Union officially adopted the 2° limit as a standard of climate policy: "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 degree above pre-industrial level" (CEU 1996).

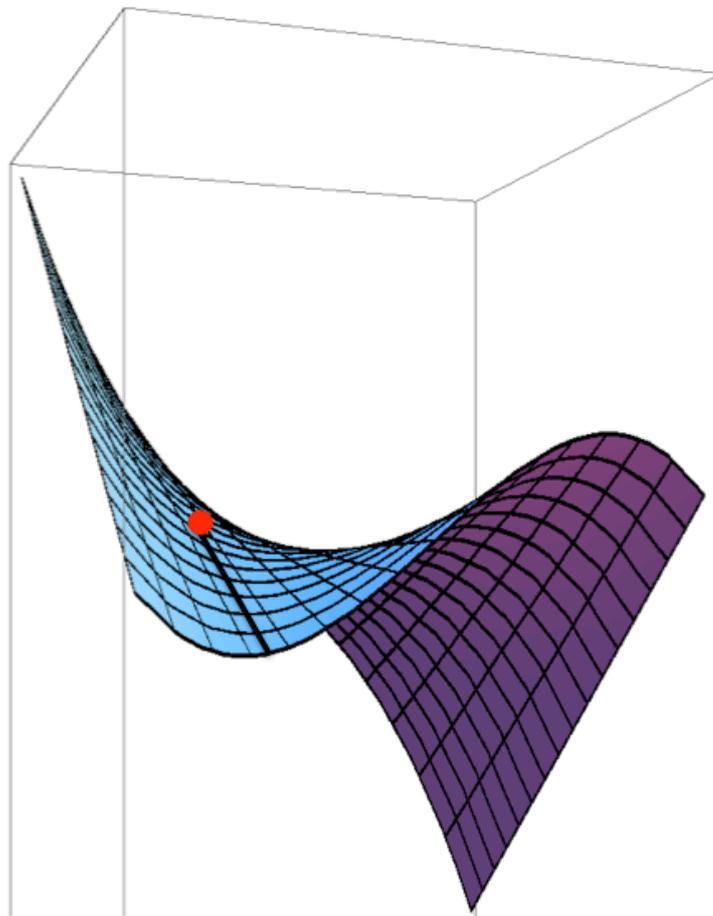


Figure 3: A catastrophe landscape
Black line: stable equilibria; red disk: tipping point

The claim according to which there is a temperature limit beyond which important risks increase rapidly has encouraged talk of a „climate catastrophe“. While the

emotional connotations of this expression are quite clear, there is also an important technical side to it, related to mathematical catastrophe theory (e.g. Castrigiano and Hayes 2004). This theory analyses non-linear dynamical systems for which continuous change of critical parameters can have minor effects on the behavior of the system for a certain parameter range, while leading to abrupt change beyond a well-defined tipping point. Figure 3 illustrates this situation by representing the so-called fold catastrophe: a valley providing a set of stable equilibria – as long as a parameter defining where in the valley the system sits does not exceed the tipping point.

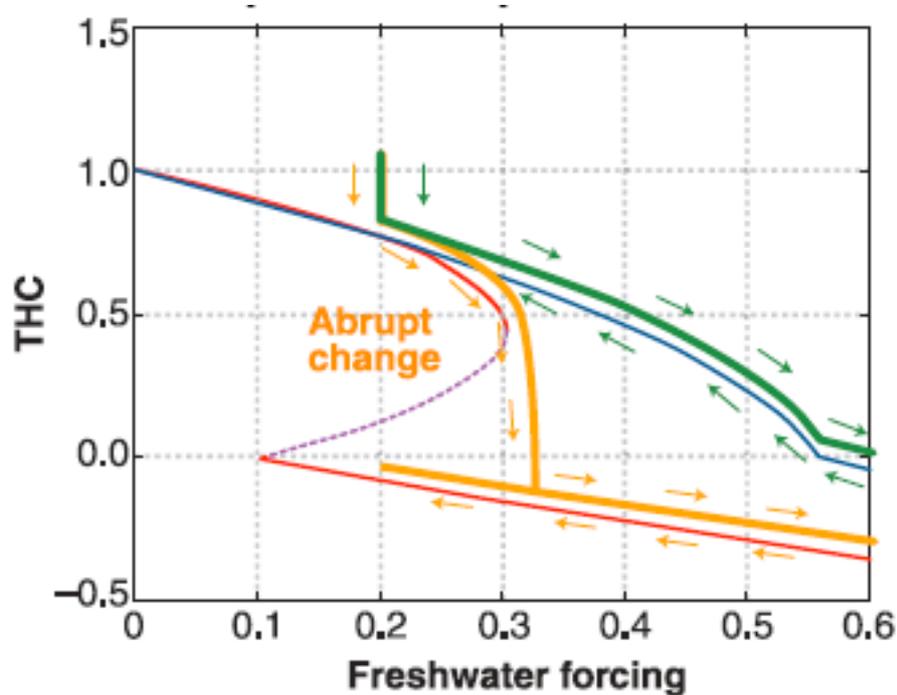


Figure 4: The catastrophe structure of the thermohaline circulation (Alley et al. 2003, p.2007).
 Green / blue: non-catastrophic relation between freshwater forcing and THC;
 Yellow / red: relation in the catastrophic domain

With this background, the concept of abrupt climate change gained prominence in the climate policy debate (Alley et al. 2003). Even more visibility was achieved by the concept of tipping points (Lenton et al. 2008), in part due to the widespread

sociological use of the concept introduced by Gladwell (2000).

A major example of a link between climate change and catastrophe theory is what Thual and McWilliams (1992) have called „the catastrophe structure of thermohaline convection”. Oceanographers have produced a large literature about the possibility that anthropogenic global warming may lead to so much freshwater flowing into the North Atlantic that an important pattern of ocean currents would break down (figure 4). This pattern, known as the Atlantic thermohaline circulation (THC for short) is not identical to the gulf stream, but has a similar warming effect on the surrounding regions – its breakdown could compensate or over-compensate the effects of global warming in those regions.

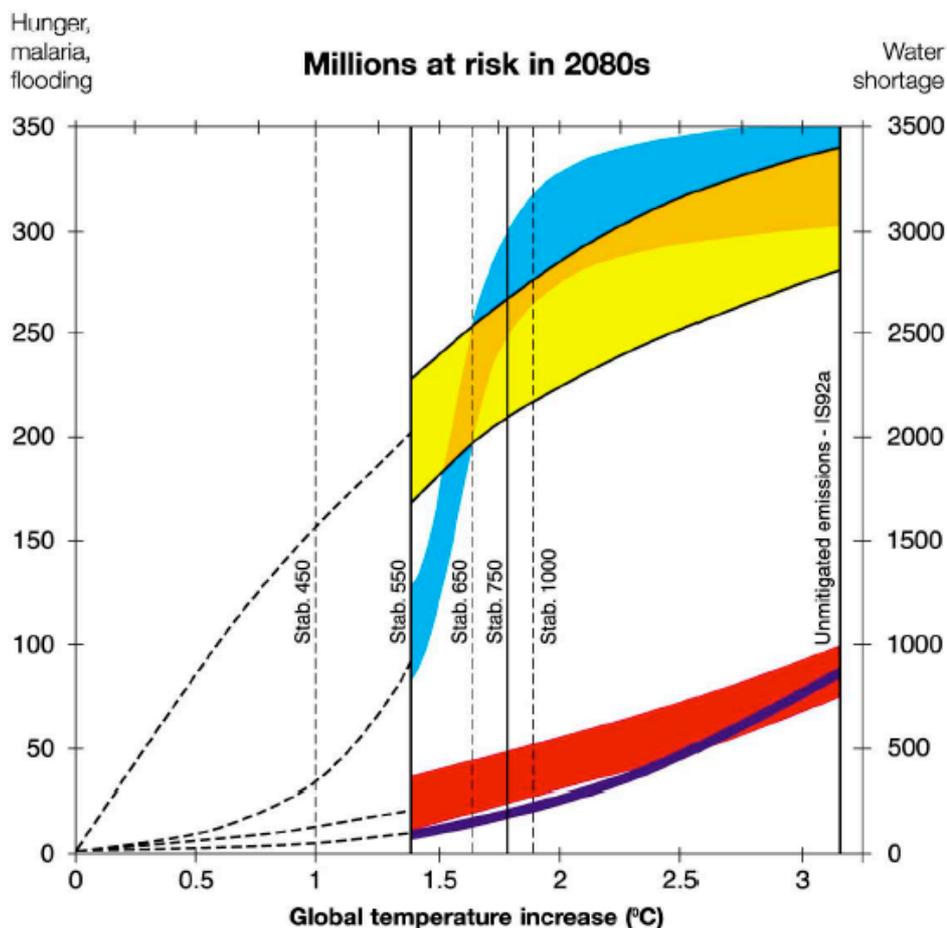


Figure 5: Climate risk assessment according to Parry et al. (2001)
Purple: coastal flooding, red: hunger, yellow: malaria, blue: water shortage.

A less mathematical, but equally influential assessment of the idea that there might be an important non-linear relation between global mean temperature and climate impacts was developed in the study „millions at risk“ (Parry et al. 2001). It provided an estimate of how many people would be exposed to various risks from climate change (figure 5). Although the probabilities involved are less than clear, a claim of a strong non-linear effect is made for water shortages – and it seems to justify a limit not even of 2, but of 1.5° C („seems“: as Tol, 2007, has noticed, the effect is based on a first approximation that squarely neglects the capacity of people to respond to challenges).

Hare (2003) worked in a similar spirit, concluding: “Above 2° C the risks increase very substantially involving potentially large extinctions or even ecosystem collapses, major increases in hunger and water shortage risks as well as socio-economic damages, particularly in developing countries” (p.89). The German Advisory Council on Global Change (WBGU 2003) combined its earlier arguments (WBGU 1995 and 1997) with those of Parry (2001) and Hare (2003) to reinforce its support of the 2° limit.

In 2005, a worldwide effort to bring together decision makers and scholars led to the so-called International Climate Change Taskforce recommending that a “long-term objective be established to prevent global average temperature from rising more than 2° C (3.6° F) above the pre-industrial level” (ICCF, 2005) on the basis of the arguments advanced by Parry et al (2001) and WBGU (2003).

The Cost-Benefit View

In 1996, Nobel prize winner Ken Arrow and an eminent group of economists and policy analysts published a paper in Science magazine (Arrow et al. 1996) arguing that sound environmental policy – and sound risk management in other fields as well – should systematically rely on cost-benefit analysis (CBA). This line of thinking

assumes that different policy options can be evaluated by associating monetary measures of aggregate costs and aggregate benefits to policy variables, and it requires policy to maximize the difference that results if one subtracts the cost number from the benefits number. One of the most fundamental results of contemporary economics then shows that a necessary condition of optimal decisions is that its marginal costs must be equivalent to its marginal benefits. CBA starts with monetary effects, translates non-monetary effects (including uncertainties) into monetary ones so that the two can be added and subtracted, somehow forms a weighted average of the different preferences held by different people, and finally assumes that there is only one optimal policy.

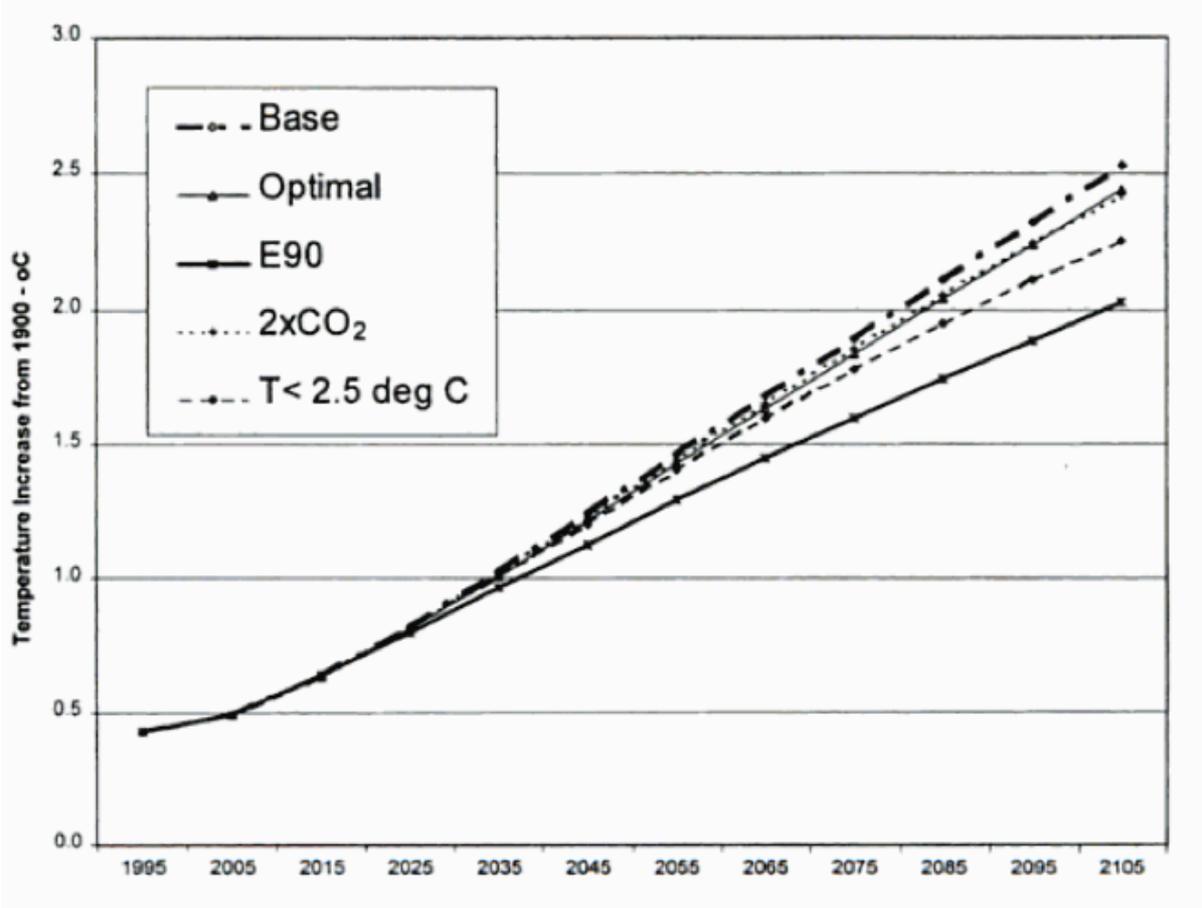


Figure 6: Searching for optimal climate change (Nordhaus and Boyer 2000, p.140)

In the case of climate policy, this requires an analysis of how much a small change of policy changes the aggregate costs and benefits one associates with them. This is what Nordhaus had in his mind all the time, and therefore he moved from his first intuition of a critical limit towards the study of optimal temperature trajectories. As figure 6 shows, this led him to consider a trajectory as optimal that would go beyond 2° towards the end of the 21th century – and would keep increasing thereafter.

Although several arguments have been advanced against the use of CBA for climate policy (e.g. Baer and Spash, 2008), and Arrow himself had once proved a major theorem according to which no meaningful aggregation of given preferences is possible in many cases (Arrow 1950), the cost-benefit approach profoundly changed the climate policy debate.

Some proponents of the 2° limit reacted by suggesting that this limit did in fact meet the criterion of cost-benefit analysis. In 2005, the Council of the European Union reiterated its previous decision: “On the basis of the 2nd Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) the EU Council of Ministers stated in 1996 that it ‘believes that global average temperatures should not exceed 2 °C above pre-industrial level’ ” (CEU 2005, p. 3). It then went on to claim: “There is increasing scientific evidence that the benefits of limiting the global average temperature increase to 2 °C outweigh the costs of abatement policies (for detailed summaries see Annexes 1 and 2). If temperatures continue to rise beyond 2 °C a more rapid and unexpected response of the climate becomes more likely and irreversible catastrophic events may occur” (CEU 2005, p.4).

Quoting the relevant chapter of the IPCC Second Assessment Report (Pearce et al. 1996) the Council addressed the benefits of its proposed policy by assessing the order of magnitude of the damages that can be avoided by climate policy: „a 2.5°C rise in global temperature could cost as much as 1.5 to 2.0 % of global GDP in terms of future damage“ (CEU 2005, p.14). It addressed the costs of the policy by quoting relevant material from the more recent IPCC Third Assessment Report (Pachauri et al. 2001, p.61) trying to assess a whole range of mitigation policies: „on average, over the period 1990 to 2100, world GDP growth would be slowed by 0.003% per

year; the maximum reduction (to reach a very ambitious target in a high growth scenario) was 0.06% per year“ (CEU 2005, p. 15).

If a 2.5° C temperature rise leads to a 2% loss of GDP in 2100, then a 2° limit may lead to a 1.5% loss, so that marginal benefits would be 0.5% of GDP in 2100. If on the other hand a 2.5° limit leads to a reduction of annual growth by 0.003%, then a 2° limit may lead to a reduction of annual growth by 0.0006%, and so to marginal costs of 0.07% of GDP in 2100. This, however would imply that a 2° limit is way to loose, and the optimal policy would be to aim for 1 or even 0.5°. Things will look different if one introduces discounting (which CEU 2005 does not) and makes additional assumptions about the temporal distribution of costs and benefits – but then Nordhaus' results become plausible again. The least one can say is that the figures CEU (2005) quotes – somewhat haphazardly, but correctly – from IPCC hardly support the 2° limit it advocates.

The most comprehensive attempt to propose a cost-benefit analysis justifying a temperature trajectory somewhat close to the 2° limit has been the one by Stern (2007). Discussing the huge literature commenting the Stern review lies beyond the scope of this paper (for some related arguments see Jaeger, Schellnhuber and Brovkin, 2008), our concern here is its relation to the 2° limit. The review advocates stabilizing atmospheric concentration of greenhouse gases at about 550ppm of CO₂ equivalent. As mentioned above, there was a time when this was considered to be roughly equivalent to the 2° limit. Meanwhile, however, a series of studies has shown that it implies a considerably higher expected value for temperature (Meinshausen et al. 2009).

As is well known, the Stern Review claims that the benefits of its target are in the range of 5-20% of GDP per year, while the costs are around 1%. What really matters, however, are marginal costs and marginal benefits. Figure 7 illustrates this point. Assume with Stern that a limit of about 3° C would lead to expected costs of about 1% of GDP per year while avoiding anthropogenic climate change would avoid expected benefits of about 15% of GDP per year. Suppose that business as usual would lead to 5° C of warming and that returning to pre-industrial CO₂-concentrations

over a century would cost somewhat more than 10% a year (a conservative estimate compared with the cost estimates for stopping CO₂-emissions and removing CO₂ from the atmosphere suggested e.g. by Keith, Ha-Duong, Stolaroff 2006, and Hansen et al. 2008). Then at any temperature benefits exceed costs, trivially also at the one implied by Stern. There is an optimal limit, though, and in this case it sits at 2.1° C.

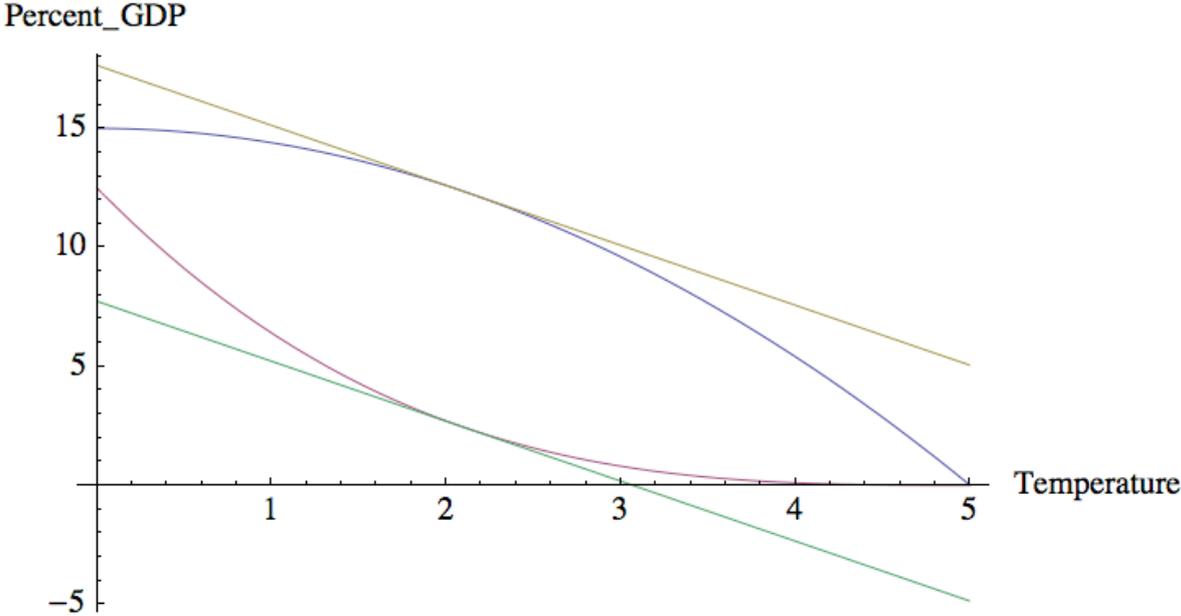


Figure 7: The relevance of marginal costs and benefits.
 Percent_GDP means average GDP loss (purple) or gain (blue) per year
 blue: benefits; purple: costs; tangents: marginal costs and benefits

Even if one accepts all of Stern’s numbers, however, functions for costs and benefits are not defined, and so no optimal target for climate policy can be derived from his review. His achievement is to have helped convince opinion leaders and decision makers worldwide that rapid action on climate change would be a good thing – not to have provided a cost-benefit analysis for a particular stabilization goal.

A Descent into the Maelström

In order to develop the focal point view to be discussed below, it is important to reflect on the image of a climate catastrophe. In his story about surviving the horror of the maelström, Edgar Allan Poe praises the willingness to observe and analyse what looks like the ultimate disaster. With regard to the risk of a thermohaline catastrophe, this has been tried by Kuhlbrodt et al. (2009). Two findings stand out.

First, experts that were asked to provide their subjective probability of a THC breakdown this century provided numbers between 0 and 80%, and computer simulations suggest that a breakdown can be avoided if global mean temperature does not increase by more than 2.5° Celsius. For larger increases, it would be unreasonable to rule out a breakdown.

Second, socio-economic impacts of a THC breakdown seem to be much smaller than suggested by the word catastrophe.

- About fishery, where the impact would be greatest: „Since fishery accounts for about 2% of the Norwegian gross national product and 6% of the exports, economic losses from unprofitable cod fishery are within the usual macro-economical fluctuations and hence do not appear to be serious“ (no page numbers given in online first publication).
- Agriculture: „Overall, according to our simulations, the effect of reduced global warming and additional precipitation in some parts of Europe due to a THC breakdown could be positive because of the increased potential profits from agriculture.“
- Sea level rise (to be expected from a THC breakdown): „an additional SLR of 50 cm by the 2080s would cause costs of 670 millionUSD/year for Europe as a whole (in prices of 1995). These costs are small in terms of the gross national product.“
- Conceivable effects of a THC breakdown on weathern patterns in the Southern hemisphere are mentioned, but not analysed by Kuhlbrodt et al. (2009). As for non-monetary impacts like the threats posed by climatic change to the beauty of coral reefs, in the case of a THC breakdown they are hardly

prominent.

This assessment suggests that catastrophe theory is useful to study THC dynamics, but that this dynamics does not provide the kind of tipping point that might justify the 2° limit.

Hansen et al. (2008), however, claim that a significantly lower limit is in fact warranted because of a different kind of catastrophe: „Continued growth of greenhouse gas emissions, for just another decade, practically eliminates the possibility of near-term return of atmospheric composition beneath the tipping level for catastrophic effects“ (p.17 in open access preprint).

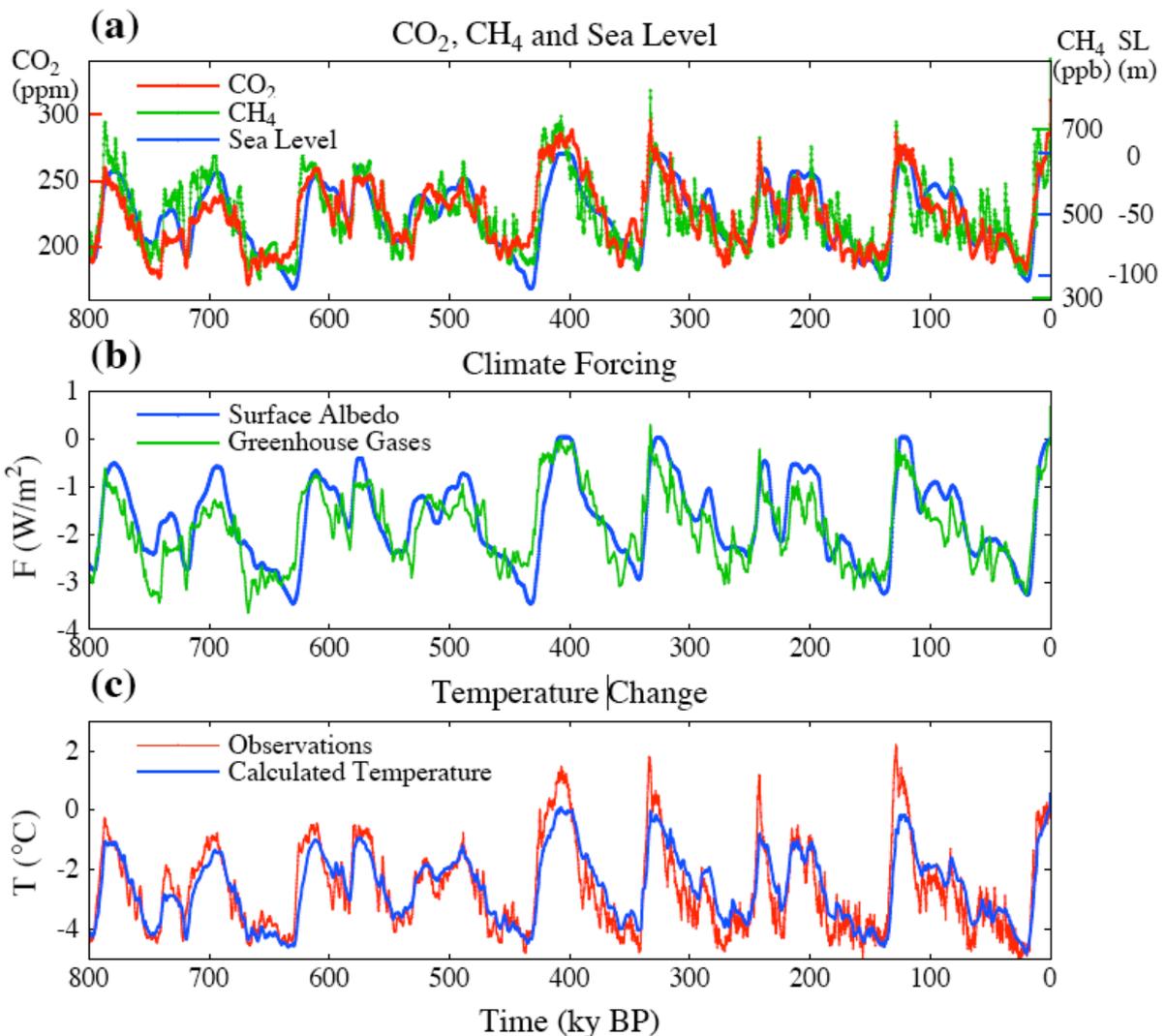


Figure 8: Long-term estimates of the variation of temperature, sea level, and further variables (Hansen et al. 2008, Supplementary Material, p. xvi)

Several findings deserve special attention (see figure 8 and Hansen et al. 2008):

- During the past 800.000 years, global mean temperature has never been more than 3° warmer than today, and it has nearly always been considerably lower – up to 5° less than today. Over the same period, CO₂-concentration has never been higher than 300ppm.
- Sea level has fluctuated with temperature at a rate of about 20m per degree Celsius. Changes of about hundred meters have happened several times in a time-span of less than ten thousand years.
- 2° of global warming may lead to sea level rise of more than 30m over the next millennia.

Before this background, Hansen et al. (2008) claim: „If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, paleoclimate evidence and ongoing climate change suggest that CO₂ will need to be reduced from its current 385 ppm to at most 350 ppm, but likely less than that“ (p.1 in open access preprint). Tällberg Foundation (2009) has provided support for that claim by a range of researchers, policy makers and environmentalists.

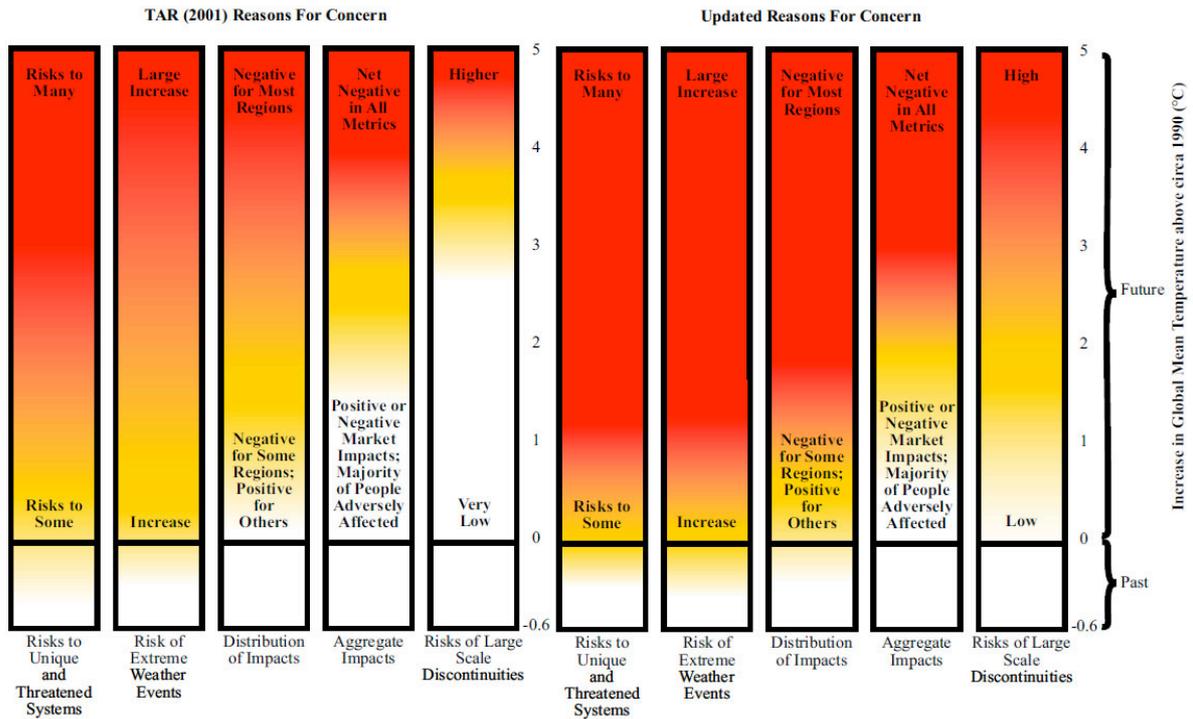


Figure 9: Impacts of global warming – an attempt at synthesis
 Smith et al. (2009) p. 4134

That statement needs to be seen in the context of Rohling et al. (2009), who claim: „Our results imply that even stabilization at today’s CO₂ levels may cause sea-level rise over several millennia that by far exceeds existing long-term projections“ (p. 500). More specifically, they argue that current greenhouse gas concentrations already imply a sea-level rise of about 25m. Taken at face value, the Hansen-Tällberg argument does not justify 350, but 280ppm.

Compared with these stern warnings, the famous „burning embers“ graph (figure 9) looks like an innocuous exercise. Still, three key facts must not be overlooked. First, science as we know it is an on-going process of inquiry – in a decade or a century the claims by Hansen or Rohling may be superseded by other insights. Second, the processes they discuss happen on time scales of centuries and millennia, not decades and years. And third, it is impossible to know what technological and social skills relevant for climate policy humans will have a few centuries from now.

Investigating the maelström of oceanic catastrophes does not settle the debate about

the 2° limit. The THC assessment suggests a higher limit, the sea-level argument a lower one. Again, the burning embers give a whole menu of more or less plausible limits. Nor does cost-benefit analysis provide a convincing closure to the debate, as we have seen. So what are we to make of the „scientific view“ recognized by the EU in 1995 and by the G8 in summer 2009?

Perhaps we should ponder Schellnhuber's (2008) description of the „burning embers diagram“ as providing „a direct scientific way to gauge the *political* target of limiting global mean temperature (GMT) rise to less than 2°C“ (p. 14239, his emphasis). It seems that for decades European politicians – and more recently many of their partners from all over the world – have tried to orient their decisions on a guideline they perceived as expressing a scientific view, while scientists – who did introduce the 2° limit into the climate debate – treat that guideline as a political issue.

The Art of Inquiry

It is surprising how well a statement Wittgenstein (1953) made long ago about the psychological research of his times fits important aspects of contemporary research on climate change: „there are experimental methods and conceptual confusion [...] The existence of the experimental method makes us think we have the means of solving the problems which trouble us; though problem and method pass one another by“ (p. 232).

So where might we have entangled ourselves in conceptual confusion? A good point to start looking for an answer is one of the most famous paragraphs in the “Treatise of Human Nature”, offered to the public in 1740 by David Hume. He there distinguishes between “is-sentences” and “ought-sentences” and criticizes lines of argument that start with the former only and end with the latter only: “In every system of morality, which I have hitherto met with, I have always remark'd, that the author proceeds for some time in the ordinary ways of reasoning, and establishes the being of a God, or makes observations concerning human affairs; when of a sudden I am surpriz'd to find, that instead of the usual copulations of propositions, is, and is not, I

meet with no proposition that is not connected with an ought, or an ought not. This change is imperceptible; but is however, of the last consequence. For as this ought, or ought not, expresses some new relation or affirmation, 'tis necessary that it should be observ'd and explain'd; and at the same time that a reason should be given; for what seems altogether inconceivable, how this new relation can be a deduction from others, which are entirely different from it." (Hume, 3.1.1.27)

This paragraph has been used again and again to form an image of science as studying facts, not values. In the words of a philosopher who helped shaping that image like few others: "The grounds on which scientific hypotheses are accepted or rejected are provided by empirical evidence, which may include observational findings as well as previously established laws and theories, but surely no value judgments" (Hempel 1965, 91).

It is this image that leads Michael Oppenheimer in his thoughtful investigation about "Defining dangerous anthropogenic interference: the role of science, the limits of science" to ask: "Where does science end and value judgment begin?" (Oppenheimer 2005, p. 1400.) Or, as Schneider and Lane (2006, p.14, their emphasis) put it: „it is a common view of most natural and social scientists that it is not the direct role of the scientific community to define what ‚dangerous‘ means. Rather, it is ultimately a political question because it depends on *value judgments*“. And it is the same image that Moss (1995) presupposes in his comment on a workshop in which IPCC tried to address the question of what might constitute dangerous interference with the climate system. That comment was entitled: „Avoiding ‘dangerous’ interference in the climate system: The roles of values, science and policy“, and the image is clear: science deals with facts, values are for policy.

There is wisdom in this image. If scientists give in to the temptation of trying to impose their views on a particular policy question they risk to deprive the decision process of important insights by other people – and to deprive non-scientists of the opportunity to shape their own destiny.

And there is wisdom in the distinction between describing a situation without

suggesting any particular course of action about it and expressing a call for action with regard to some situation. The point of Poe's tale of the maelström is precisely that sometimes it is important not to give in to what seems to be a compelling emotion – shock and panic in the face of the maelström, or even of climate change – but to spend some time trying to describe and understand the situation in order to discover new possibilities for action.

But what could be taken from Hume as a helpful distinction between a description-oriented and an action-oriented use of words has gradually become a harmful dichotomy. In Hume's own words, "This change is imperceptible; but is however, of the last consequence." If we scholars claim that our quest for reliable knowledge is possible only because we restrict ourselves to "pure" facts, leaving value judgments aside, we implicitly suggest that the quest for reliable knowledge about ethical matters is illusory. And by then declaring that value judgments are a matter for policy, we foster the risk that policy becomes a meaningless power struggle, where debates do not generate insights but reproduce endless battles between various forms of fundamentalism and more or less sophisticated forms of cynicism.

As many of us nevertheless do feel that climate change requires action, we tend to come up with presumed facts that do imply the kind of action we deem appropriate. So we use catastrophe talk to share our sense of urgency with decision makers and the wider public, or we optimize cost-benefit differences to share our sense of responsibility with the same audiences. And we are surprised and irritated that even among scholars we cannot reach an agreement about what should be done. No wonder "society" does not do what we think it should be doing – our thoughts are fraught with conceptual confusion that our familiar methods cannot alleviate. "A picture held us captive. And we could not get outside it, for it lay in our language and language seemed to repeat it to us inexorably" (Wittgenstein 1953, p. 115).

Blending the traditions of pragmatist philosophy and logical analysis, philosophers like Putnam (2004) can help us to listen to our language more carefully. So we can notice that our use of words sometimes is mainly descriptive, sometimes mainly normative, but that in general it has both of these aspects, and many more. To say

that a friend is sick describes a situation, but somebody who does not realize what kinds of action are warranted in such a situation does not understand the description. The same is true for the statement that an explanation is misleading, or that an exercise is healthy. The fact/value dichotomy collapses and gives way to a rich landscape of language games, including describing a work of art, criticising a mathematical theorem, guessing future sea level, sharing a sense of gratitude, coordinating a team effort, etc.

Trying to distill a system of purely descriptive sentences out of human language is a futile exercise, as is the attempt to concoct a system of purely normative ones. This insight creates the space for policy to evolve as the – sometimes painful, sometimes exhilarating – process of inquiry of a political community. The long history of the still unwritten British constitution is a case in point, as is the history of race relations in the U.S. In the coming decades, tackling climate change will become an important element in inquiries very different communities are engaged in – nations, churches, academic networks, professional associations, ethnic groups, and more.

Inquiries about a value judgment are not fundamentally different from inquiries about a judgment of fact or about any of the normal judgments with both descriptive and normative connotations: The relevant judgment is expressed in some language, and that language comes with statements nobody has doubts about. Starting from these statements, somebody advances a claim creating bridges of similarity leading towards the judgment under investigation. The bridges may be accepted or contested by others, tentative actions relying on them may be undertaken. If the actions are successful and few doubts are expressed, the bridges become well established, and in the course of time the judgment at their other end gets accepted. In the process, other judgments may be put in doubt, including some that were taken for granted at the beginning. But if everything were put in doubt simultaneously, there would be no language anymore – as would be the case if all questions had been answered.

What then can and should scientists say about the 2° limit?

- First, we can acknowledge that the limit was – sometimes inadvertently, sometimes consciously – introduced into the policy debate not by policy

makers but by some of us.

- Second, we can make it clear that there is nothing wrong with that: making suggestions as to how to address problems we know something about is one of our tasks as researchers. The fact that IPCC as an organization operates under the constraint of being policy neutral does not mean that the language used by IPCC could be sanitized of all normative aspects, or that science as such should be policy neutral. It only means that IPCC is not allowed by the governments financing it to tell those governments what they have to do.
- Third, and here it becomes a bit more difficult, we can make explicit why some of us think the 2° limit is a valuable proposal, and why others disagree in various ways (this is one of the purposes of the present paper).
- Finally, to those that complain because we do not offer a single final truth, we can say that the very variety of suggestions coming from different researchers is a major resource for society at large. And we can say that an answer to the climate challenge that has been elaborated jointly by the plurality of relevant actors is likely to lead to better results than any scheme designed by scientists alone.

The 'Focal Point' View

The plurality of relevant actors not only makes it undesirable to restrict an inquiry about the 2° limit to scientific communities alone. It also offers a clue as to why that particular limit has gradually gained acceptance and why this may be useful.

Consider the following problem: some twenty people from all over the world who do not know each other are told that next Saturday they will all be flown to Paris. If they manage to meet Sunday at noon, each one of them gets a million dollars and a business ticket back; if not, they get nothing and must find their own way home. What would you do in that situation?

The chances that the group will meet under the Eiffel tower are remarkably high. In Paris, the Eiffel tower is what game theorists (following Schelling, 1960) call a focal

point. The problem itself is known as a coordination game, its solution as a coordination equilibrium. Without a focal point, the problem is hard to solve because it has many possible coordination equilibria and the players do not have a plausible strategy to select one of them.

As a less fanciful coordination game consider speed limits in car traffic, e.g. the 50 km/h limit in many European cities. Why is it 50 and not 47 or 53? The reason is obvious: 50 is a focal point. And why is there a uniform limit and not several limits differentiated by the skills of drivers, the power of cars, etc.? Again the reason is obvious: with a uniform limit, there will be less accidents. And why is the limit 50 and not 10 or 100? The lower number would make car traffic meaningless, the upper one would make it too dangerous. But there is no need to decide about upper and lower bounds for speed limits, it is sufficient to pick one such limit, implement it, and if the need arises learn from experiences with it. Finally, what is the role of scientists in decisions about speed limits? They may produce statistics of different kinds of accidents with different speed limits, develop theories about how various features of traffic change with various limits and other circumstances, they may sit on committees proposing speed limits, and their voices may be heard in debates about them.

Through several decades of intuitions, criticism, struggles, insights, and guesses, the 2° limit has become a focal point of the climate debate. The reasoning that it marks the upper range of climatological conditions humankind has ever experienced in its history gives salience to the number 2. And 2 is a much better focal point than, say, 1.5, or than a combination with temperature increase per decade or further indicators. Moreover, temperature has much stronger intuitive appeal than, say, ppm of some molecule equivalents. Finally, and this may be the most important point at the present time, the 2° limit is a strong call for action, and it is understood as such.

None of this is a compelling reason that would lead to the 2° limit as the only possible focal point. 3 or 2° Fahrenheit might have worked as well, and 2° may still be superseded by some other focal point. But for the time being, the key question is whether or not there is a focal point motivating action on climate change now.

Granted, the 2° limit does not describe individual actions the way a speed limit does. But it implies a collective narrative involving much more effective actions than the world has witnessed so far. The many declarations of intent abounding in climate policy can remind one of the “old joke about a music lover who would do anything to play the violin—except practice” (The Economist, 2009). The 2° limit provides a focus that can motivate and structure practical steps by a multitude of agents, including governments, but by no means limited to governments. It may well take a whole century of great creativity and perseverance to secure a 2° limit. The only way to do so will be to reach near-zero emissions. Otherwise concentrations will keep increasing for millennia until the oceans will have absorbed the bulk of man-made CO₂ (Matthews and Caldeira 2008).

This also means that if greenhouse gas emissions should not be reduced fast enough to stay below the 2° limit, it will be necessary to remove CO₂ from the air artificially. Hansen et al. (2008) discuss various possibilities to do so, e.g. producing biochar in agriculture and forestry (Gaunt and Lehmann 2008) or burning biofuels from marginal land in power plants and capturing the CO₂. They estimate a cost of no more than 40 Euro to remove a ton of CO₂. In any case, the fact that we may well overshoot the 2° limit – emphasised e.g. by Victor (2009) – is no argument against that limit, just as the possibility of driving faster than a given speed limit is no argument against the latter.

It is useful to have an estimate for the shortest time that may be necessary to reach a state of near-zero emissions starting from today’s emission level of about 8 gt of carbon. As a preliminary illustration – not a proposal – consider the possibility of capturing CO₂ from power plants. A high-end estimate of the pure investment costs required for that purpose is about 600.000 Euro per MW of electricity produced (Kuuskraa 2007, p.17). This is net production, i.e. without the energy needed for the CCS operation itself. Operating costs are not included, because maximum deployment speed depends essentially on investment constraints. Total energy use by humankind is currently in the order of 10.000 GW. To produce half of it from fossil fuels with carbon captured would require investing about 3 trillion Euro. Spread over

10 years, this leads to annual investment of about 0.3 trillion Euro.

The point of this computation is not to advocate the technology considered, but to get a benchmark on the time required for drastic emissions reductions. For this, the required investment must be seen in relation to overall investments. Global GDP is currently in the order of 50 trillion Euro, the global capital stock is about 150 trillion, global gross investment about 10 trillion, military expenditure a bit more than 1 trillion. Under these conditions, increasing gross investment by 10% is not economically prohibitive. A benchmark for phasing out coal and a sizeable fraction of oil and gas, then, is just about a decade. 0.3 trillion per year to eliminate CO₂-emissions from fossil fuel use in power plants then would still leave 0.7 trillion to expand renewables, increase energy efficiency and develop electric cars and other transport systems. In ten years this amount of investment could bring down emissions by at least 70%. The task grows the later it starts, however the economic and technological resources available for the task grow as well. Two decades then are a reasonable benchmark for bringing down emissions to near zero levels.

A benchmark, however, is not a policy proposal. To say that it would be technically and economically feasible to dismantle all nuclear weapons on Earth in about a decade is probably true, but this does not mean that there is the slightest chance of a nuclear weapons free world being reality by 2020. Still, such benchmarks are important in order to understand where the real inertias come from.

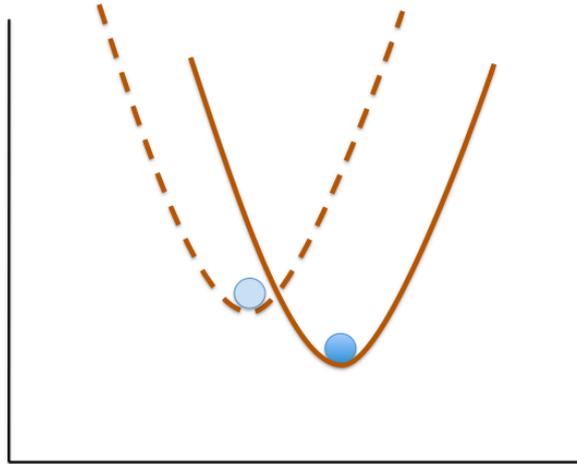


Figure 10: A one-equilibrium system

The capacity of the market economy to absorb shocks and meet challenges is often underestimated. An instructive historical analogue is given by the switch of the Detroit car factories from regular car production to the production of tanks, jeeps, etc. during World War II. That switch was successfully completed within less than a year, and without either reducing economic growth or accelerating inflation to dangerous levels (Clive 1979).

Nowadays, there are about 4 billion people on Earth with the ability to perform economically productive work in the setting of the global economy. Of these, no more than 2 billion are actually engaged in doing so. This means that the world economy has enormous spare capacity that can be tapped. The real problem is how to do so.

The widespread view of the economy as a one-equilibrium system (figure 10) is quite misleading here. This picture leads to the idea that addressing the climate challenge requires a global authority that will move the incentive structure of the world economy in such a way that it reaches the optimal path of greenhouse gas emissions (figures 6 and 7). In figure (10) this is represented by the dashed line. The larger the emissions cut, the larger the expected costs. And in order for the economy to incur these costs, a high carbon price must be established and maintained.

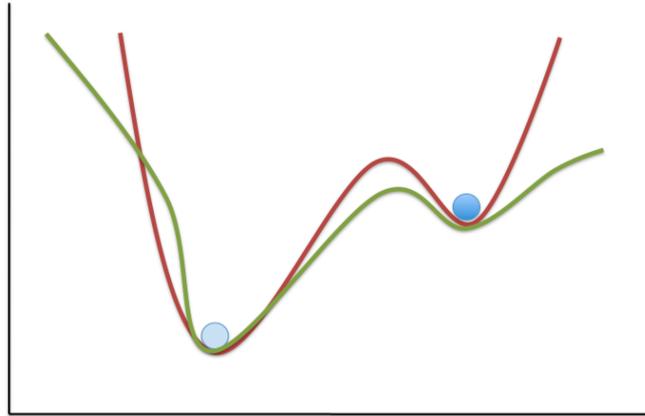


Figure 11: A multi-equilibrium system

But this picture only arises because of completely unwarranted assumptions that do not become less misleading by being widespread. The Sonnenschein-Mantel-Debreu theorem well-known to mathematical economists (Saari 1995) shows how even a model fulfilling all the far-fetched assumptions of general equilibrium theory – convexity of preferences and production sets, perfect competition, futures markets for all goods and services – can have any number of equilibria.

So we should rather think in terms of a picture like figure (11), with some equilibria having high emissions and other ones having low emissions. To move from a high-emissions to a low-emission equilibrium rising carbon prices may be necessary or at least helpful, after the transition their level may be higher or lower than before. The basic pattern is that of a coordination game, and this is why the existence of a focal point is so important. And the 2° limit is a focal point that can drive the search process for a near-zero emissions equilibrium.

Once the world economy will move on a near-zero emissions path, further experience may show whether there is a need to look for another focal point. Perhaps data and improved understanding will suggest that a still lower limit will be appropriate in order to avoid major sea level rise in the centuries to come, or perhaps they will indicate

that there are good reasons to set a less stringent limit. But in order to gather such data and understanding, decades of experience with effective climate policies will be necessary.

In the short run, even more important than experiences with the impacts of climate change on glaciers, oceans, and living beings will be experiences with the impacts of climate policies on national economies. In the present world, no major economy can be expected or for that matter forced to seriously curb emissions if it fears that this will disrupt its economy. And it is simply naïve to imagine that a coalition of nations would be willing to take that risk just because everybody expects others to disrupt their economies, too. Fortunately, the multiple equilibria structure of actual economies means that at least some nations can successfully reduce emissions even if their competitors do not do the same (Jochem et al., 2008, have shown this with a detailed analysis for the German case). Only if some nations successfully assume that leadership role can the inertia that keeps the global economy on its current high-emissions path be overcome.

Azar (2007) has made the important point that the abolition of slavery may be a useful analogue for global climate policy. There, a combination of religious and moral sensibilities (like those of the Quakers) with slave rebellions (like the one of 1791 in Haiti) lead to partial steps towards the abolition of slavery being undertaken in a haphazard way in various places. As the fear that this would undermine the competitiveness of the leading regions and nations proved to be unfounded, the abolitionist movement could succeed.

The abolition of slavery also highlights the risks that even the most well-intentioned efforts can generate. A social catastrophe like the American civil war is nothing one should take lightly, even in the name of a great ideal like the abolition of slavery. Reaching near-zero global emissions is certainly possible, but the risk that the corresponding reconfiguration of the global economy will involve violent social conflicts deserves more attention than it currently receives. The 2° limit, then, is not only a focal point that can help trigger the transition to a low-emissions equilibrium. It is also a call for responsible action in a world where the impacts of a changing

climate are by no means the only risks.

Conclusion

The 2° limit has emerged nearly by chance, and it has evolved in a somewhat contradictory fashion: policy makers have treated it as a scientific result, scientists as a political issue. It has been presented as a threshold separating a domain of safety from one of catastrophe, and as an optimal strategy balancing costs and benefits. We propose to use it as a focal point in a coordination game, where a multitude of actors need to find a new coordination equilibrium in the face of climate risks.

The key challenge then is to start showing by pioneering examples that nations can reduce emissions without disrupting their economies, and to let a global regime leading to near-zero emissions evolve as a complex, multi-level system combining global agreements with regional and local initiatives. In the course of time, the focal point may then be redefined on the basis of experience. But to gather the necessary experience, working towards a 2° limit provides as good a focus as is currently needed.