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EUROPE'S LONG TERM CLIMATE TARGET: A CRITICAL EVALUATION

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Abstract

The European Commission and a number of its Member States have adopted a stringent long-term target for climate policy, namely that the global mean temperature should not rise more than 2°C above pre-industrial times. This target is supported by rather thin arguments, based on inadequate methods, sloppy reasoning, and selective citation. In the scientific literature on "dangerous interference with the climate system", most studies discuss either methodological issues, or carefully lay out the arguments for or against a particular target. These studies do not make specific recommendations, with the exception of cost-benefit analyses which argue for less stringent policy targets. However, there are also a few studies that recommend a target without the supporting argumentation. Overall, the 2°C target of the EU seems unfounded.

Keywords

Climate policy, Article 2, dangerous interference, European Union

David Pearce promised to give comments on an earlier version of this paper, but time did not allow him to do this. David taught me how to apply economic analysis to political issues, and the importance of intellectual honesty above all else. This paper is dedicated to his memory.

1. Introduction

The European Union and some of its Member States have adopted a long-term target for international climate policy, which is that the world should not warm more than 2°C above pre-industrial temperatures.[1] This is an ambitious target. Given the current uncertainties, it

[1] The June 25, 1996, Council Meeting stated that it "believes that global average temperatures should not exceed 2°C above pre-industrial level" (CEU, 1996). In the provisional minutes of its meeting of December 20, 2004, the Environment Council "REAFFIRMS that […] overall global annual mean surface temperature increase should not exceed 2°C above pre-industrial levels" (CEU, 2004).

would imply that the atmospheric concentration of carbon dioxide could not rise much above 400 ppm (Meinshausen, 2005), only some 20 ppm above today's concentration; if recent trends continue, the 400 ppm level would be reached by 2020 (after Keeling and Whorf, 2005). This paper reviews the reasons for adopting this target.

Previously, another target was circulated, namely that the rate of warming should not exceed 0.1°C per decade. Although this target was frequently mentioned (e.g., Swart *et al.*, 1989, 1991), the main defence was always a reference to a previous paper. The 0.1°C/decade target can be traced to the late 1980s, but then the trace vanishes. Apocryphal evidence[2] holds that the 0.1°C/decade target is appropriate for a plant species on the shores of a lake in North America. This study was never published, but mentioned at dinner during an early climate conference. Someone else repeated the information the next day in plenary, and an urban legend was born. As the 0.1°C/decade target has vanished from policy discussions – perhaps because natural variability is greater[3] – it need not concern us any further. However, it is important to know whether the 2°C is valid or similarly based on bogus science.

The 2°C target is already almost 10 years old. It was first raised in WBGU (1995), and adopted in CEU (1996). It was little prominent for a while, but recently it has surfaced again (e.g., CEU, 2004) as the preparations for climate policy in the period after 2012 (the end of the first commitment period under the Kyoto Protocol) are starting. As the EU is one of the main players in international climate policy, its long-term target requires serious discussion.

The paper is structured as follows. Section 2 reviews the official documents that present the 2°C target. The focus is on the European Union, Germany, the Netherlands and the United Kingdom. These three countries are at the forefront of European climate policy, and the author happens to be able to read their languages. Section 3 reviews the scientific literature that may substantiate, perhaps even justify a 2°C target. Section 4 concludes.

2. A review of official documents

CEC (2005a) repeats the earlier EU position that it "believes that global average temperatures should not exceed 2°C above pre-industrial level". The aim of CEC (2005a) is to conduct "a cost benefit analysis which takes account both of environmental and competitiveness considerations". CEC (2005a) concludes that "[t]here is increasing scientific evidence that the benefits of limiting the global average temperature increase to 2°C outweigh the costs of abatement policies". It is always convenient when a cost benefit analysis justifies the policy agreed on beforehand.

The actual cost benefit analysis is placed in the annexes to CEC (2005a). Annex I is a haphazard selection of fact and speculation on the effects of unmitigated climate change. The title of Annex II is "the benefits and costs of limiting climate change". It quotes the IPCC Second Assessment Report (Pearce *et al.*, 1996), stating that "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, with significant regional variations". No indication is given of how much of that damage would be avoided by emission reduction. In fact, Annex II admits that "comprehensive, quantitative estimates of the benefits of stabilization at various levels of atmospheric concentrations of

[2] The main source of the following is a conversation with Rik Leemans, who has been in climate change research much longer than I have, and who is a known advocate of stringent emission reduction.
[3] The standard deviation of the linearly detrended decadal averages of the global mean temperature (Jones *et al.*, 2005) is 0.11°C. I am grateful to Michael Schlesinger for alerting me to this.

greenhouse gases do not yet exist".[4] Annex II ignores that much has changed in the climate impacts literature since the mid-1990s (e.g., Smith *et al.*, 2001; Tol, 2005a).

Annex II also considers "the possible costs of cutting world emissions consistent with stabilising greenhouse gas concentrations in the atmosphere at 550 ppmv in the long-term." Earlier, the document states "that a level of 550 ppmv (CO_2 equivalents) offers at most a one in six chance of respecting the 2°C target".[5] The emission reduction policy "would reduce GDP in 2025 by about 0.5%". No source is given. Costs beyond 2025 are ignored, even though emission abatement may not seriously begin until 2030 (Wigley *et al.*, 1996).

Ergo, although CEC (2005a) sets out to do a "cost benefit analysis" of greenhouse gas emission abatement, in fact it does nothing of the sort.[6] Its claimed justification of the 2°C target is void.

In a recent letter to parliament, the Junior Minister for the Environment reaffirms the commitment of the Government of the Netherlands to the 2°C target of the European Union (Van Geel, 2005). He states that it is difficult to do a quantitative cost benefit analysis of climate policy, and continues that a communication of the European Commission on this matter is expected soon.[7] He does refer to a report commissioned by the Government of the Netherlands, Rooijers *et al.* (2004).

Rooijers *et al.* (2004) is a lengthy report, including a review of the climate change impacts literature, with a particular focus on the Netherlands. The authors do not try to estimate the impacts that would be avoided if climate change were to be limited to a warming of 2°C. Nonetheless, in its summary, under the heading of scientific insights, it says "in order to keep these impacts under control, the worldwide temperature increase should not exceed 2°C in the coming century".[8] An important source of this conclusion is a study by Gupta and Van Asselt (2004). In its conclusion, the latter report states that "[b]eyond 2°C global warming in relation to pre-industrial levels, there is consensus that the climatic and ecological system could become unstable and irreversible impacts may become inevitable". This conclusion is too vague to contradict. Interestingly, the main text of the chapter discusses impacts of climate change, but not the impacts avoided by keeping below a 2°C warming. Only for food production, impact estimates are presented for different levels of climate change. Here, Gupta and Van Asselt (2004) simply copy WBGU (2003a), which copies Hare (2003).

The Scientific Advisory Council Global Environmental Change of the (German) Federal Government (WBGU) issued a number of reports on climate change, in which it recommends targets as well. WBGU (1995) is the first in the series. Climate policy targets rest on two principles: (1) safeguarding creation and (2) avoidance of unreasonable costs (WBGU, 1995, p. 7). The first principle is a peculiar one for a *scientific* council of a *secular* government. It is made operational by looking at the temperature variation in recent geological history, in which it was never warmer than 16.1°C. Adding an arbitrary 0.5°C and assuming that the current global annual mean surface air temperature is 15.3°C, this leads to a maximum allowed warming of 1.3°C relative to 1995, which roughly corresponds to 2.0°C relative to

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[4] This is probably true if the attention is limited to *explicit* estimates of avoided damage (Tol, 2005b). However, avoided damages are an *implicit* part of the cost-benefit analysis published by, amongst others, Nordhaus (1991), Peck and Teisberg (1992), Maddison (1995), Manne *et al.* (1995) and Tol (1997). Oddly, CEC (2005a) does not refer to these cost benefit analyses published in the peer-reviewed literature.

[5] No source is given for this conjecture.

[6] The background paper, CEC (2005b), offers no cost benefit analysis either, and not even a systematic review of the climate change impacts literature.

[7] Perhaps, Van Geel (Feb 16, 2005) refers to CEC (Feb 9, 2005a).

[8] "Om deze effecten beheersbaar te houden mag de wereldwijde temperatuurstijging niet meer dan 2°C bedragen in de komende eeuw."

pre-industrial times. The reasoning behind this is thin: WBGU (1995, p. 8) simply states that drastic ecological impacts could be expected if more warming were to happen.

The second principle rests on monetised impact estimates. WBGU (1995, p. 8) states that impacts of 5% of GDP are just tolerable. It quotes the estimates of Pearce *et al.* (1996), who conclude that a doubling of the atmospheric concentration of carbon dioxide would damage global welfare by the equivalent of a loss of 1-2% of GDP. WBGU (1995, p. 8) continues that this is an underestimate as extreme weather events and synergies between impacts are excluded, and arbitrarily increases the impact to 5% of GDP. Although the studies surveyed in Pearce *et al.* (1996)[9] pay scant attention to the rate of climate change, WBGU (1995) concludes from this that the global mean temperature should not exceed 0.2°C per decade.

WBGU (1997) adopts the targets of WBGU (1995). WBGU (2003a) goes a step further. The targets are the same as in WBGU (1995), but the reasoning is different. The 0.2°C is maintained because no new research had come to the attention of the WBGU between 1995 and 2003.[10] The 2°C target is maintained because new evidence would support it. The first line of evidence is ecosystem change. It is largely based on Hare (2003), a study commissioned by the WBGU.[11] Shifts of 20-30% of the areas of biomes should be avoided, as well as the loss of areas of nature reserves and biodiversity hot spots. A 2°C target would see that such changes are avoided. WBGU (2003a) further quotes Parry *et al.* (2001) who conclude that at a 2-3°C warming, global food production would start falling.[12] Water resources are a third line of evidence. Quoting Parry *et al.* (2001), a 2°C warming would put 2 billion people under water stress, up from 0.6 billion people for a 1.5°C warming; these numbers derive from the work of Arnell (1999), which is flawed as it omits adaptation (see below). Implicitly, WBGU (2003a) argues that 2 billion people with water stress is tolerable, but more is not. WBGU (1995) heavily relies on Pearce *et al.* (1995), but WBGU (2003a) only selectively quotes Smith *et al.* (2001). It mentions damage estimates for some countries, but not Germany or Western Europe, nor for the world (as in WBGU, 1995). A fifth line of evidence is human health. WBGU (2003a) here relies on Campbell-Lendrum *et al.* (2003), even though this study does not estimate health impacts for alternative stabilisation levels (see below). Finally, WBGU (2003a) argues that a 2°C target would limit the probabilities of a thermohaline circulation collapse, a runaway greenhouse effect, a shift in the monsoon, a collapse of the West-Antarctic Ice Sheet and a melting of the ice of Greenland. WBGU (2003b) argues along the same lines.

The (British) Royal Commission on Environmental Pollution argues for a target of 550 ppm for the atmospheric concentration of carbon dioxide (RCEP, 2000, p. 53). CEU (1996) equates this with a 2°C global mean warming, but CEU (2004) realises that this is overly optimistic. RCEP (2000, p. 31) gives two concrete reasons for adopting this target. People subject to coastal flooding would fall from 94 million per year (unabated climate change) to 19 million per year (550 ppm), and people affected by water shortages from 3 billion to 1 billion per year. The latter argument is presumably more important. It is based on the study of Arnell (1999), which is methodologically flawed as it omits adaptation (see below).

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[9] Note that the current author is one of the *alii*.

[10] Fortunately, the IPCC is more careful in its literature review. A comparison of Pearce *et al.* (1995) and Smith *et al.* (2001) shows that a number of economic impact studies were published in this period, and that estimates had shifted.

[11] Bill Hare is with Greenpeace International. At the time of writing his report, Hare was seconded to PIK (Hare, personal communication, 2005). WBGU (2003a) largely adopts Hare's (2003) results on ecosystems, food production, water resources and monetised impacts.

[12] According to Parry *et al.* (2001), 2-3°C warming is the turning point; the WBGU forgets that between today and that turning point, food production would increase.

In sum, the official documents that justify the 2°C warming target for long term climate policy have severe shortcomings. Methods are inadequate, reasoning sloppy, citations selective, and the overall argumentation rather thin. This does not suffice for responsible governments, answerable to the people, when deciding on a major issue.

3. A review of the scientific literature

Campbell-Lendrum *et al.* (2003) is often quoted on the impacts of climate change on human health. This study does not recommend any temperature target. Instead, it compares impacts for unmitigated climate change, stabilisation at 750 ppm, and at 550 ppm. Unfortunately, it does this comparison at 2030 only, at which time the three scenarios are hardly distinguishable. The stabilisation scenarios are the so-called "S" scenarios, which are unnecessarily expensive (Wigley *et al.*, 1996), but Campbell-Lendrum *et al.* (2003) ignore the effects of emission reduction on health (Tol and Dowlatabadi, 2001); they look at avoided climate change only. Health impacts include malnutrition; floods; cardiovascular disease; diarrhoea; and malaria. For malnutrition, a single model is used (Rosenzweig and Parry, 1994), that happens to be more pessimistic than other models on the impact of climate change on agriculture (Tol, 2002). The model assumes that malnutrition is driven by availability of food, rather than by access to food (Sen, 1981). Campbell-Lendrum *et al.* (2003) acknowledge that vulnerability to climate change will be different in the future (e.g., malaria, diarrhoea and malnutrition would be less prevalent in a richer future, while cardiovascular diseases would be more prevalent in a richer and older future), but they ignore this in their estimates. Campbell-Lendrum *et al.* (2003) is a useful methodological study, but it cannot be used for policy advice; note that they do not claim otherwise.

Green *et al.* (2003) is a workshop report, focusing on climate change and biodiversity. In the "synthesis and outlook" section, it reads: "If we manage to contain global warming to 2°C, there will be some species loss but there are conceivable management options for the conservation of global biodiversity. At 4°C global average temperature rise, there will be many species loss, few management options and enormous financial cost. At the uppermost predictions of around 6°C temperature rise, the outlook is dire. It is, therefore, imperative that global warming is contained to 2°C by the end of this century. […] We must constrain global warming to 2°C." (Green *et al.*, 2003, p. 34, 35). This conclusion is clear. However, of the 17 presentations contained in this volume, only one (on arctic vegetation) quantifies a temperature threshold, in the following words: "Although the threshold for this effect is *unknown*, it is considered likely to be within about 2°C warming compared *to the present*" (Green *et al.*, 2003, p. 20; emphasis added). In fact, the report admits that "[r]esearch into the impacts of a wider range of climate change scenarios is required, as well as an assessment of the effect of reducing the increase in global mean temperature (from, say, 4°C to 2°C) upon biodiversity" (Green *et al.*, 2003, p. 33). The conclusions of Green *et al.* (2003) do not follow from their analysis. Note that the WBGU (2003a) argues, based on Green *et al.* (2003), for limiting warming to 2°C relative to *pre-industrial* times.

Parry *et al.* (1996) ask the question "What is dangerous climate change?" They write that it is not the task of science to define this, as that would depend on economic, social and political objectives. Instead, they confine themselves to "identify the means by which such a definition could be made".[13] They continue to define a critical level of impact as the one that "demarcates the boundary between a level of climate change that induces a response which can be accommodated by a system and one that cannot". They continue to discuss types of thresholds, methods of finding thresholds, and methods to translate impact thresholds into

[13] Note that, despite this caution, the journal published this paper as a "viewpoint" rather than an "article".

emission targets. Their discussion avoids the issue of scale, and what should be seen as a "system". Although they define "forest dieback" as critical, the size of the forest is not stated. A loss of long-term food self-sufficiency is also seen as critical, but they probably do not worry too much about Singapore. Note that Parry *et al.* (1996) do not (attempt to) define what would constitute "dangerous climate change".

Dessai *et al.* (2004) distinguish between external definitions of danger (as set by teams of experts), and internal ones (as perceived by people); and argue for the combination of the two. They do not define what is dangerous.[14] Schneider (2001)[15] chooses "arbitrarily a temperature increase of 3.5˚C", attributing this choice to the IPCC (Smith *et al.*, 2001), who in fact are silent on this.[16]

Azar and Rodhe (1997) argue that "the concept of dangerous interference is ultimately a question of value judgments that can only be settled in the political arena". Although they admit to substantial uncertainty, Azar and Rodhe (1997) argue that future climate change should not exceed twice the natural climate fluctuations of the past millennium; the latter is estimated at 1˚C, so the target is to avoid warming greater than 2˚C compared to pre-industrial times. Azar and Rodhe (1997) defend this using a precautionary argument: until it is proven safe to exceed this limit, it should not be crossed. The problem with precautionary arguments is that they are one-sided. Emission reduction is not costless, and stringent climate policy bears substantial risks too, e.g., to the coal and oil industry and the people it employs.

Parry *et al.* (2001) refrain from defining "dangerous interference".[17] They do, however, estimate the number of people "at risk" from climate change, through coastal flooding, hunger, malaria and water shortages (in order of increasing importance); as well as how these numbers vary with different concentrations of atmospheric carbon dioxide. Although the numbers are impressive – stabilisation at 450 ppm could protect several hundred million people from risk – the analysis leaves much to be desired. Firstly, the impacts for different stabilisations levels are indicative, rather than estimated. Secondly, impacts are assumed to be independent of the costs of mitigation. Thirdly, results are presented for a single scenario, and a single set of models. Fourthly, and most importantly, adaptation is omitted, particularly in the dominant risks malaria and water shortage. The results are therefore not robust and biased upwards.

Van Lieshout *et al.* (2004) is a recent paper on the malaria model used by Parry *et al.* (2001).[18] The abstract states that "[t]he outcomes of the model are sensitive to [climate change] and population growth". This is fine. However, it has been amply demonstrated that socio-economic development (beyond population growth) also affects malaria. Tol and Dowlatabadi (2001) show how misleading it can be to ignore economic growth in projecting climate change impacts on malaria. Van Lieshout *et al.* (2004) acknowledge the importance of economic development, even classify countries with regard to their adaptive capacity. Yet, curiously, they hold adaptive capacity constant over time.

Arnell (2004) is a recent paper on the water resources model used by Parry *et al.* (2001); an earlier version is described in Arnell (1999). The model suffers from the same drawbacks as does the model of Van Lieshout *et al.* (2004): Climate change impacts are determined by climate change and population size. No attempt to model adaptation or adaptive capacity is included. It is well known that without adaptation, climate change impacts are drastically overestimates, and estimates may even have the wrong sign (cf. Smit *et al.*, 2001). Adaptation

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[14] This paper was classified by the journal as an "editorial essay".
[15] This paper was classified by the journal as a "commentary".
[16] Note that the current author is one of the *alii*.
[17] Again, the paper was published as a "viewpoint".
[18] The model goes back to Martens *et al.* (1995, 1997).

to climate change impacts on water resources has been amply studied (Cohen *et al.*, 2000; Frederick, 1997; Major and Frederick, 1997; Miller *et al*., 1997; Smith, 1996; Tol *et al.*, 2003), even modelled (Hurd *et al.*, 1999; Mendelsohn, 2000; Mendelsohn and Bennett, 1997; Yates and Strzepek, 1998). Yet, Arnell (2004) omits adaptation.

Mastandrea and Schneider (2004) use the "reasons for concern" defined by Smith *et al.* (2001) to define "dangerous anthropogenic interference". It should be noted that Smith *et al.* (2001) avoid this interpretation, and that their transition from yellow to red does not imply a threshold crossing in anything but a numerical sense.[19] Smith *et al.* (2001) distinguish *four* reasons for concern, while Mastandrea and Schneider (2004) distinguish *five*. The reasons of concern, as defined by Smith *et al.* (2001), reflect alternative, mutually incompatible world-views, but Mastandrea and Schneider (2004) combine them to a single density function of "dangerous interference", giving each reason equal weight.[20] Mastandrea and Schneider (2004) do not recommend any particular concentration target or carbon tax. Instead, they compute the probability of dangerous interference as a function of the carbon tax (in 2050) and the pure rate of time preference (which determines the acceleration of the carbon tax over time).

Leemans and van Vliet (2005) focus on only one of the reasons of concern, namely impacts on species and ecosystems. They argue that Smith *et al.* (2001) were wrong to put the threshold at 2.0˚C above pre-industrial times,[21] opting for a 1.5˚C target instead. In support of this, they quote a number of studies that show that species and ecosystems have responded to past warming, implicitly assuming that all change is bad. Based on a similar line of thinking, Lanchbery (2005) concludes that "atmospheric concentrations of greenhouse gases are already too high".

O'Neill and Oppenheimer (2002) also focus on the "reasons for concern" of Smith *et al.* (2001), but limit themselves to coral reefs, the West-Antarctic Ice-Sheet and the Thermohaline Circulation. (Keller *et al.*, forthcoming, adopt the same targets for coral reefs and WAIS.) For coral reefs, they quote Hoegh-Guldberg who claims that a 1˚C warming (above 1990) would do severe damage. They quote Oppenheimer (1998), who claims that a 2˚C (above 1990) would endanger the stability of the WAIS. See below. For the THC, a 3˚C (above 1990) is considered safe, based on Stocker and Schmittner (1997). Gregory *et al.* (2005) show that more complex, perhaps more realistic models of the THC than the one used by Stocker and Schmittner (1997) do not show a rapid or complete collapse. Link and Tol (2004) show that, even if the THC collapses, impacts would be small (and positive) as the cooling of a THC collapse does not offset the warming due to the enhanced greenhouse effect, at least not over densely populated areas.

Oppenheimer and Alley (2005)[22] argue that disintegration of the Greenland and West-Antarctic Ice Sheets may provide "plausible example[s] of dangerous anthropogenic interference." They stress the uncertainties about the interactions between atmosphere, ocean and ice sheets. Interestingly, they are silent about the potential impacts of the resulting sea level rise. Oppenheimer and Alley (2004)[23] estimate that the WAIS may collapse if the world warms by 2˚C compared to today; they emphasize that the science is uncertain, and that their estimate is inspired by precaution. Oppenheimer (1998) is even more cautious, also emphasizing the uncertainty in the projected temperature and precipitation changes over Antarctica.

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[19] Note that the current author is one of the *alii*.
[20] Mastandrea and Schneider (2005) backtrack, separately considering the reasons for concern.
[21] Note that Smith *et al.* (2001) did no such thing, although Leemans is one of the *alii*.
[22] This paper is classified by the journal as an "editorial essay".
[23] This paper is classified by the journal as an "editorial comment".

Hare *et al.* (2004) conclude that "the climate system is likely to face several critical limits in its key subsystems if global mean temperature increases to 2˚C to 3˚C above preindustrial levels; however, even global temperature[s] rises below 2˚C cannot be considered 'safe', given the large uncertainty in some of the thresholds. Long-term sea level rise, and increases in frequency and strength of extreme events are likely to adversely affect particular regions and ecosystems already for moderate warming levels below 2˚C." This conclusion is based on a workshop with some 50 participants, only a minority of whom have a track record in climate change impacts research, and a limited literature review; in fact, the report contains a large number of unsubstantiated conjectures.

The scientific literature on "dangerous interference" comes in four types. There are studies that do not define dangerous interference, but are interpreted by others as doing so. There are studies that adopt a target from another study, and analyse the implications for policy strategies. There are also studies that discuss the methodology for assessing dangerous interference. Finally, there are studies that define dangerous. Some of these studies are couched in careful terms, with solid arguments and all necessary caveats. One can accept the argument, but one need not. Other studies make unfounded claims, based on faulty or incomplete analyses, and sometimes based on nothing at all. It is surprising that such studies are published and used.

4. Discussion and conclusion

I reviewed Europe's 2°C target for international climate policy in the long run. One may of course dismiss this target. Why does Europe decide on a global target? Are the days of colonialism not long past? One may also dismiss Europe's target as just another grand plan, bound to suffer the same fate as the Stability and Growth Pact and the Lisbon Agenda, to name two recent grand plans by European governments that were abandoned at the first confrontation with reality. Such cynicism, however justified it might be, does not forward the debate on long-term targets for international climate policy. As emission abatement could cost many billion of dollars, the 2°C target deserves serious discussion.

Unfortunately, the governments that support the 2°C target are not prepared for such a discussion. Although weighty reports seemingly justify the 2°C target, closer inspection shows that the justification is inadequate. The European Commission claims to have done a cost-benefit analysis of emission control policy, but this is simply not true. The governments of Germany, the Netherlands and the UK rely on a handful, unrepresentative studies – which may not estimate the required indicators, which may be methodologically unsound, or which may be written by environmental NGOs – ignoring many other studies that may have contradictory results.

This lackadaisical attitude to setting targets is surprising, as stringent greenhouse gas emission reduction policy may well be very expensive. One explanation may be that European governments do not believe that abatement is costly. The House of Lords (2005, p. 70) argues that the climate policy debate has been one-sided: "we believe that the Chancellor needs to broaden the scope of the Government's interests, and the Treasury's interests in particular, in aspects of the climate change debate that we feel have not yet been given sufficient emphasis." Another explanation is that 2°C is not a target that has to be met, but rather an aspiration that should be strived for; the role of the government is not to lead, but to entertain; targets are there to make the public feel good about their government. A further interpretation is that the 2°C target is a negotiation target, an opening bid for international climate policy. However, an opening bid needs to induce negotiations, while the EU's position may to be too strong for other countries to engage in a dialogue over.

The current European approach to target-setting cannot be explained by a lack of knowledge or technical expertise. There is a range of climate and climate impact models around, that could well have been used to estimate the impacts of climate change under various policy scenario (including a scenario without emission reduction). Exercises like this have not been published much in the learned literature – Nicholls and Lowe (2004) and Tol (2005b) being the only exceptions – but that may be because this is not exciting science. There is no reason why such work could not have been commissioned as input to policy. Although it would be good to include the costs of emission reduction in this – particularly, the effect of emission reduction on vulnerability and adaptation – and monetise the (avoided) climate change impacts – for reasons of comparability to emission abatement costs – it is not necessary to include these controversial steps to get a reasonable estimate of the benefits of emission reduction. Currently, policy is not informed by any estimate of the benefits.

Note that a number of "cost-benefit analyses" of greenhouse gas emission abatement have been published. The technically sound amongst these studies (Nordhaus, 1991; Peck and Teisberg, 1992; Maddison, 1995; Manne *et al.*, 1995; Tol, 1997) argue that it is not in our collective best interest to stabilise concentrations (unless there happens to a cheap, carbon-free energy source). Lomborg (2004) take a more informal approach, but climate change does not rank high on their list of global problems. Remarkably, policy makers have decided to ignore this literature, including the papers published in the best journals.

The scientific literature on what constitutes "dangerous anthropogenic interference with the climate system" suffers from the fact that this question cannot be solved without making value judgements. The editors of the journals that publish such papers therefore typically classify these as opinion pieces, rather than learned papers.[24] Many of these papers do not set a target at all, but the main thrust of the serious papers that do, is that the science of climate change and its impacts is too uncertain to set any firm and uncontroversial target.

This result may disappoint. However, although the long-term aims of climate policy are shrouded in clouds, the direction of short-term policy is not. The growth of greenhouse emissions has to be slowed if not reversed. Deep cuts in emissions will only be achieved if alternative energy technologies become available at reasonable prices. Some governments want to move faster down this path than do others. Although provisional long-term targets are helpful in formulating short-term policy, they are no substitute for action. A controversial and badly justified target, however, may slow down policy making and implementation, even lead to a backlash. I think that the EU's 2°C target is of this kind.

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References

Arnell, N. W. (1999), 'Climate change and global water resources', *Global Environmental Change*, **9**, 531-549.

[24] Economic journals, publishing cost-benefit analyses of climate change, do not follow this habit. This is probably because part of the value judgements are measured (rather than imputed), while the remaining value judgements (particularly, aggregation over space and time) are based on transparent and well-understood methods.

Arnell, N. W. (2004), 'Climate change and global water resources: SRES emissions and socio-economic scenarios', *Global Environmental Change*, **14**, 31-52.

Azar, C. and Rodhe, H. (1997), 'Targets for Stabilization of Atmospheric CO_2', *Science*, **276**, 1818-1819.

Campbell-Lendrum, D.J., C.F. Corvalan and A. Prüss-Ustün (2003), 'How Much Disease Could Climate Change Cause?' in A.J. McMichael, D.H. Campbell-Lendrum, C.F. Corvalan, K.L. Ebi, A. Githeko, J.D. Scheraga and A. Woodward (eds.), *Climate Change and Human Health – Risks and Responses*, World Health Organisation, Geneva.

CEC (2005a), *Winning the Battle against Global Climate Change*, Communication from the Commission to the Council, the European Parliament, the European Economics and Social Committee and the Committee of the Regions **COM(2005) 35 final**, Commission of the European Communities, Brussels.

CEC (2005b), *Winning the Battle against Global Climate Change – Background Paper*, Commission Staff Working Paper, Commission of the European Communities, Brussels.

CEU – Council of the European Union (1996), *1939th Council Meeting, Luxembourg, 25 June 1996*.

CEU – Council of the European Union (2004), *2632nd Council Meeting, Brussels, 20 December 2004*.

Cohen, S. J., Miller, K. A., Hamlet, A. F., and Avis, W. (2000), 'Climate Change and Resource Management in the Columbia River Basin', *Water International*, **25** (2), 253-272.

Dessai, S., Adger, W. N., Hulme, M., Turnpenny, J., Köhler, J., and Warren, R. (2004), 'Defining and Experiencing Dangerous Climate Change', *Climatic Change*, **64**, 11-25.

Frederick, K. D. (1997), 'Adapting to Climate Impacts on the Supply and Demand for Water', *Climatic Change*, **37**, 141-156.

Green, R.E., Harley, M., Miles, L., Scharlemann, J., Watkinson, A. and Watts, O. (eds), (2003), *Global Change and Biodiversity*, Royal Society for the Protection of Birds, Sandy. (http://www.unep-wcmc.org/information_services/publications/GCCB2003.pdf)

Gregory, J. M., Dixon, K. W., Stouffer, R. J., Weaver, A. J., Driesschaert, E., Eby, M., Fichefet, T., Hasumi, H., Hu, A., Jungclaus, J. H., Kamenkovich, I. V., Levermann, A., Montoya, M., Murakami, S., Nawrath, S., Oka, A., Sokolov, A. P., and Thorpe, R. B. (2005), 'A model intercomparison of changes in the Atlantic thermohaline circulation in response to increasing atmospheric CO_2 concentration', *Geophysical Research Letters*, **32** (L12703), 1-5.

Gupta, J. and H. van Asselt (eds.) (2004), *Re-evaluation of the Netherlands Long-Term Climate Targets*, Institute for Environmental Studies, Vrije Universiteit, Amsterdam.

Hare, W. (2003), *Assessment of Knowledge on Impacts of Climate Change – Contribution to the Specification of Art. 2 of the UNFCCC,* Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, Berlin (http://www.wbgu.de/wbgu_sn2003_ex01.pdf))

Hare, W., M. Schaeffer and M. Meinshausen (2004), *What is Dangerous Climate Change? Initial Results of a Symposium on Key Vulnerable Regions Climate Change and Article 2 of the UNFCCC*, European Climate Forum and Potsdam Institute for Climate Impact Research, Potsdam.

House of Lords (2005), *The Economics of Climate Change*, HL Paper 12-I, Select Committee on Economic Affairs 2nd Report of Session 2005-06, London.

Hurd, B., Callaway, J. M., Smith, J. B., & Kirshen, P. (1999), "Economic Effects of Climate Change on U.S. Water Resources," in *The Impact of Climate Change on the United States Economy*, R. O. Mendelsohn & J. E. Neumann, eds. (eds.), Cambridge University Press, Cambridge, pp. 133-177.

Jones, P.D., D.E. Parker, T.J. Osborn and K.R. Briffa (2005), 'Global and Hemispheric Temperature Anomalies – Land and Marine Records' in *Trends: A Compendium of Data on Global Change*, Carbon Dioxide Information Centre, Oak Ride National Laboratory, Oak Ridge.

Keeling, D.C. and T.P. Whorf (2005), 'Atmospheric CO_2 Records from Sites in the SIO Air Sampling Network' in *Trends: A Compendium of Data on Global Change*, Carbon Dioxide Information Centre, Oak Ride National Laboratory, Oak Ridge.

Keller, K., M. Hall, S.-R. Kim, D.F. Bradford and M. Oppenheimer (forthcoming), 'Avoiding Dangerous Anthropogenic Interference with the Climate System', *Climatic Change*.

Lanchberry, J. (2005), 'Ecosystem Loss and its Implications for Greenhouse Gas Concentration Stabilisation', *International Symposium on Stabilisation of Greenhouse Gases*, Exeter, February 1-3.

Leemans, R. and A. van Vliet (2005), 'Responses of Species to Changes in Climate Determine Climate Protection Targets', *International Symposium on Stabilisation of Greenhouse Gases*, Exeter, February 1-3.

Link, P.M. and R.S.J. Tol (2004), 'Possible Economic Impacts of a Shutdown of the Thermohaline Circulation: An Application of *FUND*', *Portuguese Economic Journal*, **3**, 99-114.

Lomborg, B. (ed.) (2004), *Global Crises, Global Solutions* Press Syndicate of the University of Cambridge, Cambridge, UK.

Maddison, D. J. (1995), 'A Cost-Benefit Analysis of Slowing Climate Change', *Energy Policy*, **23** (4/5), 337-346.

Major, D. C. and Frederick, K. D. (1997), 'Water Resources Planning and Climate Change Assessment Methods', *Climatic Change*, **37**, 25-40.

Manne, A. S., Mendelsohn, R. O., and Richels, R. G. (1995), 'MERGE - A Model for Evaluating Regional and Global Effects of GHG Reduction Policies', *Energy Policy*, **23** (1), 17-34.

Martens, W. J. M., Jetten, T. H., Rotmans, J., and Niessen, L. W. (1995), 'Climate Change and Vector-Borne Diseases -- A Global Modelling Perspective', *Global Environmental Change*, **5** (3), 195-209.

Martens, W. J. M., Jetten, T. H., and Focks, D. A. (1997), 'Sensitivity of Malaria, Schistosomiasis and Dengue to Global Warming', *Climatic Change*, **35**, 145-156.

Mastandrea, M.D. and S.H. Schneider (2004), 'Probabilistic Assessment of "Dangerous" Climate Change and Emissions Scenarios', *Science*, **304**, 571.

Mastandrea, M.D. and S.H. Schneider (2005), 'Probabilistic Assessment of "Dangerous" Climate Change and Emissions Scenarios', *International Symposium on Stabilisation of Greenhouse Gases*, Exeter, February 1-3.

Meinshausen, M. (2005), 'On the Risk of Overshooting 2°C', *International Symposium on Stabilisation of Greenhouse Gases*, Exeter, February 1-3.

Mendelsohn, R. (2000), 'Efficient adaptation to climate change', *Climatic Change*, **45**, 583-600.

Mendelsohn, R. O. and Bennett, L. L. (1997), 'Global Warming and Water Management: Water Allocation and Project Evaluation', *Climatic Change*, **37**, 271-290.

Miller, K. A., Rhodes, S. L., and MacDonnell, L. J. (1997), 'Water Allocation in a Changing Climate: Institutions and Adaptation', *Climatic Change*, **35**, 157-177.

Nicholls, R. J. and Lowe, J. A. (2004), 'Benefits of mitigation of climate change for coastal areas', *Global Environmental Change*, **14**, 229-244.

Nordhaus, W. D. (1991), 'To Slow or Not to Slow: The Economics of the Greenhouse Effect', *Economic Journal*, **101**, 920-937.

O'Neill, B.C. and M. Oppenheimer (2002), 'Dangerous Climate Impacts and the Kyoto Protocol', *Science*, **296**, 1971-1972.

Oppenheimer, M. (1998), 'Global Warming and the Stability of the West Antarctic Ice Sheet', *Nature*, **393**, 325-332.

Oppenheimer, M. and R.B. Alley (2004), 'The West Antarctic Ice Sheet and Long Term Climate Policy', *Climatic Change*, **64** (1-2), 1-10.

Oppenheimer, M. and R.B. Alley (2005), 'Ice Sheets, Global Warming, and Article 2 of the UNFCCC', *Climatic Change*, **68**, 257-267.

Parry, M., Arnell, N. W., McMichael, T., Nicholls, R., Martens, W. J. M., Kovats, S., Livermore, M., Rosenzweig, C., Iglesias, A., and Fischer, G. (2001), 'Millions at risk: defining critical climate change threats and targets', *Global Environmental Change*, **11**, 181-183.

Parry, M.L., T.R. Carter and M. Hulme (1996), 'What is Dangerous Climate Change?' *Global Environmental Change*, **6** (1), 1-6.

Pearce, D.W., A.N. Achanta, W.R. Cline, S. Fankhauser, R. Pachauri, R.S.J. Tol and P. Vellinga (1996), 'The Social Costs of Climate Change: Greenhouse Damage and the Benefits of Control', in: J.P. Bruce, H. Lee, and E.F. Haites (eds.) *Climate Change 1995: Economic and Social Dimensions of Climate Change -- Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change*, pp. 179-224 (Chapter 6), Cambridge University Press, Cambridge.

Peck, S. C. and Teisberg, T. J. (1992), 'CETA: A Model for Carbon Emissions Trajectory Assessment', *Energy Journal*, **13** (1), 55-77.

RCEP (2000), *Energy – The Changing Climate*, Royal Commission on Environmental Pollution, London (http://www.rcep.org.uk).

Rooijers, F.J., I. de Keizer, S. Slingerland, J. Faber, R.C.N. de Wit, J. Verbeek, R. van Dorland, A.P. van Ulden, R.W.A. Hutjes, P. Kabat and E.C. van Ierland (2005), *Klimaat Verandering Klimaat Beleid: Achtergrondrapport Inzicht in Keuzes voor de Tweede Kamer* (Climate Change Climate Policy: Background Report Insight in Choices for the Lower House of Parliament), Tweede Kamer (3.748.1), The Hague.

Rosenzweig, C. and Parry, M. L. (1994), 'Potential Impact of Climate Change on World Food Supply', *Nature*, **367**, 133-138.

Schneider, S.H. (2001), 'What is Dangerous Climate Change?', *Nature*, **411**, 17-19.

Sen, A. (1981), *Poverty and Famines* Clarendon Press, Oxford.

Smit, B., Pilifosova, O. V., Burton, I., Challenger, B., Huq, S., Klein, R. J. T., & Yohe, G. W. (2001), "Adaptation to Climate Change in the Context of Sustainable Development and Equity," in *Climate Change 2001: Impacts, Adaptation, and Vulnerability*, J. J. McCarthy et al., eds. (eds.), Press Syndicate of the University of Cambridge, Cambridge UK, pp. 877-911.

Smith, J. B. (1996), 'Development of Adaptation Measures for Water Resources', *Water Resources Development*, **12** (2), 151-163.

Smith, J.B., H.-J. Schellnhuber, M.M.Q. Mirza, S. Fankhauser, R. Leemans, E. Lin, L. Ogallo, B. Pittock, R.G. Richels, C. Rosenzweig, R.S.J. Tol, J.P. Weyant and G.W. Yohe (2001), 'Vulnerability to Climate Change and Reasons for Concern: A Synthesis', Chapter 19, pp. 913-967, in J.J. McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White (eds.), *Climate Change 2001: Impacts, Adaptation, and Vulnerability*, Cambridge University Press, Cambridge.

Stocker, T. F. and Schmittner, A. (1997), 'Influence of CO_2 Emission Rates on the Stability of the Thermohaline Circulation', *Nature*, **388**, 362-364.

Swart, R. J. and Hootsmans, M. J. M. (1991), 'A Sound Footing for Controlling Climate Change', *International Environmental Affairs*, **3**, 124-136.

Swart, R. J., de Boois, H., and Rotmans, J. (1989), 'Targetting Climate Change', *International Environmental Affairs*, **1**, 222-234.

Tol, R.S.J. (1997), 'On the Optimal Control of Carbon Dioxide Emissions -- An Application of *FUND*', *Environmental Modelling and Assessment*, **2**, 151-163.

Tol, R.S.J. (2002), 'New Estimates of the Damage Costs of Climate Change, Part I: Benchmark Estimates', *Environmental and Resource Economics*, **21** (1), 47-73.

Tol, R.S.J. (2005a), 'The Marginal Damage Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties', *Energy Policy,* **33** (16), 2064-2074.

Tol, R.S.J. (2005b), *The Benefits of Greenhouse Gas Emission Reduction: An Application of* FUND, Research Unit Sustainability and Global Change **FNU-64**, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg.

Tol, R.S.J. and H. Dowlatabadi (2001), 'Vector-borne Diseases, Climate Change, and Economic Growth', *Integrated Assessment*, **2**, 173-181.

Tol, R.S.J., N.M. van der Grijp, A.A. Olsthoorn and P.E. van der Werff (2003), 'Adapting to Climate Change: A Case Study of Riverine Flood Risks in the Netherlands', *Risk Analysis*, **23** (3), 575-583.

Van Geel, P.L.B.A. (2005), *Onderzoek Klimaatverandering* (Research Climate Change), Tweede Kamer (vergaderjaar 2004-2005, 29 465, nr. 3), The Hague

van Lieshout, M., Kovats, R. S., Livermore, M. T. J., and Martens, P. (2004), 'Climate change and malaria: analysis of the SRES climate and socio-economic scenarios', *Global Environmental Change*, **14**, 87-99.

WBGU (1995), *Scenario zur Ableitung CO2-Reduktionsziele und Umsetzungsstrategien – Stellungnahme zur ersten Vertragsstaatenkonferenz der Klimarahmenkonvention in Berlin* (Scenario to Deduct CO2 Reduction Targets und Implementation Strategies – Position for the First Conference of the Parties of the Framework Convention on Climate in Berlin), Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, Dortmund.

WBGU (1997), *Ziele für den Klimaschutz 1997 – Stellungnahme zur dritten Vertragsstaatenkonferenz der Klimarahmenkonvention in Kyoto* (Targets for Climate Protection 1997 – Position for the Third Conference of the Parties of the Framework Convention on Climate in Kyoto), Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, Bremerhafen.

WBGU (2003a), *Über Kioto hinaus denken – Klimaschutzstrategien für das 21. Jahrhundert* (Thinking beyond Kyoto – Climate Protection Strategies for the 21st Century), Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, Berlin.

WBGU (2003b), *Welt im Wandel – Energiewende zur Nachhaltigkeit* (Changing World – Energy Turnaround for Sustainability), Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, Berlin.

Wigley, T. M. L., Richels, R. G., and Edmonds, J. A. (1996), 'Economic and Environmental Choices in the Stabilization of Atmospheric CO_2 Concentrations', *Nature*, **379**, 240-243.

Yates, D. N. and Strzepek, K. M. (1998), 'An Assessment of Integrated Climate Change Impacts on the Agricultural Economy of Egypt', *Climatic Change*, **38**, 261-287.

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Bigano, A., J.M. Hamilton and R.S.J. Tol (2004), *The impact of climate on holiday destination choice*, **FNU-55** (forthcoming, *Climatic Change*)

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Lee, H.C., B.A. McCarl, U.A. Schneider, and C.C. Chen (2003), *Leakage and Comparative Advantage Implications of Agricultural Participation in Greenhouse Gas Emission Mitigation*, **FNU-18** (submitted).

Schneider, U.A. and B.A. McCarl (2003), *Implications of a Carbon Based Energy Tax for U.S. Agriculture*, **FNU-17** (submitted).

Tol, R.S.J. (2002), *Climate, Development, and Malaria: An Application of* FUND, **FNU-16** (forthcoming, *Climatic Change*).

Hamilton, J.M. (2003), *Climate and the Destination Choice of German Tourists,* **FNU-15** (revised and submitted).

Tol, R.S.J. (2002), *Technology Protocols for Climate Change: An Application of* FUND, **FNU-14** (*Climate Policy,* **4**, 269-287).

Rehdanz, K (2002), *Hedonic Pricing of Climate Change Impacts to Households in Great Britain*, **FNU-13** (forthcoming, *Climatic Change*).

Tol, R.S.J. (2002), *Emission Abatement Versus Development As Strategies To Reduce Vulnerability To Climate Change: An Application Of* FUND, **FNU-12** (forthcoming, *Environment and Development Economics*).

Rehdanz, K. and Tol, R.S.J. (2002), *On National and International Trade in Greenhouse Gas Emission Permits*, **FNU-11** (forthcoming, *Ecological Economics*).

Fankhauser, S. and Tol, R.S.J. (2001), *On Climate Change and Growth*, **FNU-10** (*Resource and Energy Economics*, **27**, 1-17).

Tol, R.S.J.and Verheyen, R. (2001), *Liability and Compensation for Climate Change Damages – A Legal and Economic Assessment*, **FNU-9** (*Energy Policy*, **32** (9), 1109-1130).

Yohe, G. and R.S.J. Tol (2001), *Indicators for Social and Economic Coping Capacity – Moving Toward a Working Definition of Adaptive Capacity*, **FNU-8** (*Global Environmental Change*, **12** (1), 25-40).

Kemfert, C., W. Lise and R.S.J. Tol (2001), *Games of Climate Change with International Trade*, **FNU-7** (*Environmental and Resource Economics*, **28**, 209-232).

Tol, R.S.J., W. Lise, B. Morel and B.C.C. van der Zwaan (2001), *Technology Development and Diffusion and Incentives to Abate Greenhouse Gas Emissions*, **FNU-6** (submitted).

Kemfert, C. and R.S.J. Tol (2001), *Equity, International Trade and Climate Policy*, **FNU-5** (*International Environmental Agreements*, **2**, 23-48).

Tol, R.S.J., Downing T.E., Fankhauser S., Richels R.G. and Smith J.B. (2001), *Progress in Estimating the Marginal Costs of Greenhouse Gas Emissions*, **FNU-4**. (*Pollution Atmosphérique – Numéro Spécial: Combien Vaut l'Air Propre?*, 155-179).

Tol, R.S.J. (2000), *How Large is the Uncertainty about Climate Change?*, **FNU-3** (*Climatic Change*, **56** (3), 265-289).

Tol, R.S.J., S. Fankhauser, R.G. Richels and J.B. Smith (2000), *How Much Damage Will Climate Change Do? Recent Estimates*, **FNU-2** (*World Economics,* **1** (4), 179-206)

Lise, W. and R.S.J. Tol (2000), *Impact of Climate on Tourism Demand*, **FNU-1** (*Climatic Change*, **55** (4), 429-449).