policy

Beyond Kyoto

Advancing the international effort against climate change

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PEW CENTER ON Global CLIMATE CHANGE

Contents

A long-term target

Framing the climate effort

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I. Introduction

More than most other environmental concerns, climate change is inherently a long-term challenge: its full impacts will not become obvious for decades or centuries, and an effective strategy to avert them requires sustained action over decades or longer. These long time horizons, and the scientific uncertainties they present, pose special difficulties for political systems geared to more immediate concerns, and hence, for any effort to mobilize international action against climate change.

There is broad scientific consensus that the planet is warming; that human activity is a principal cause; and that, absent prompt remedial efforts, the world will continue to warm substantially over the next several centuries, with potentially serious consequences for life-sustaining systems. While the risks may be high, most are also quite distant. Yet these far-off impacts can be averted or reduced only if action to reduce greenhouse gas (GHG) emissions begins almost immediately and is sustained over the long term. This requires transforming processes deeply rooted in our socio-economic systems: the way we produce and consume energy, transport ourselves and our goods, and build and use our infrastructure. These are systems with long life cycles, and even small changes will take time. Few governments, however, are well prepared to consider and adopt policies for long-term action to address long-term risk. Mitigating climate change thus clashes with the usual time frame of political action.

A central issue in the climate debate is whether a clear long-term target would be helpful—or perhaps even essential—in framing and motivating effective long-term action. Article 2 of the United Nations Framework Convention on Climate Change (UNFCCC), adopted in 1992, takes a step in this direction by establishing a broad long-term objective:

> *"...stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system..."* [1]

The international community has yet to better define this objective, focusing instead on nearer-term targets. The first of these, also in the Framework Convention, required that advanced industrialized countries "aim" to return their emissions to 1990 levels by 2000. The parties, recognizing that this limited goal was inadequate, soon launched a second negotiation leading to the 1997 Kyoto Protocol. Kyoto would establish new emissions reduction commitments—still short-term (for the period 2008-2012), but legally binding. It also foresees subsequent negotiations toward future commitments. At the time the

Protocol was negotiated, this iterative process was presumed to be a viable framework to address the long-term climate challenge.

With the United States now rejecting the Protocol, and its entry into force uncertain, it appears unlikely that Kyoto will achieve even its initial near-term goals. However, if Kyoto does enter into force, the international community will soon face a new round of climate negotiations: the Protocol requires that negotiations toward a second set of near-term commitments, presumably for the period 2013-2017, begin by 2005. Conversely, if Kyoto founders, parties will be forced to consider alternative approaches. Either scenario would afford an opportunity to revisit the question of a long-term target.

A long-term climate target, while typically understood as a quantitative limit on GHG concentrations in the atmosphere, might take any number of forms. It might, for instance, be cast in terms of mean global temperature or global GHG emissions, rather than atmospheric concentrations. More broadly, a target might be merely notional or aspirational, meaning its achievement is broadly desired but not obligatory; or it might in some way be binding, requiring specific actions or measures to ensure it is met. In either case, a long-term climate target is understood here as a complement to near- or medium-term goals, serving to drive or frame, not supplant, them.

Examples of different approaches to long-term target setting can be found elsewhere in the international arena. In one category are the type of non-binding medium-term goals adopted by United Nations bodies in recent years, such as the Millennium Development Goals[2] and those negotiated at the 2002 World Summit on Sustainable Development. These include, for instance, halving the population iving in poverty or without access to safe drinking water by 2015. Clearer examples of long-term environmental targets are those established by the Montreal Protocol on Substances that Deplete the Ozone Layer and the Stockholm Convention on Persistent Organic Pollutants (POPS). The POPS agreement takes an approach similar to the climate convention, setting a broad long-term objective of "protecting human health and the environment from persistent organic pollutants,"[3] followed by specific restrictions on the production and use of certain compounds. The Montreal Protocol set a harder, more explicit objective—phasing out ozone-depleting substances—which was then the basis for corresponding near-term obligations. Unlike the UNFCCC, neither treaty sets a goal based on larger physical systems (e.g., for ozone, "restoring the stratospheric ozone layer").

While these examples may suggest lessons for addressing climate, the climate challenge is of an entirely different order, implicating a much broader range of human activities. This paper explores the rationale for—and practicality of—negotiating and adopting some form of long-term climate target. It begins, in section II, by setting out the case for establishing a long-term target.[4] Section III reviews the climate cycle—from human activity, through emissions, to concentrations and ultimately to climate impacts—and considers the prospects of adopting a long-term target at each of these stages. In light of this review, section IV reassesses the case for adopting a specific long-term target. It concludes that negotiating a target may not be politically viable, and attempting to could even be counterproductive, but that if pursued, the most promising approach may be an "activity-based" target more immediately related to the concrete challenges to be met. Section V explores alternative approaches that could deliver some of the benefits of a quantified long-term target, including a hedging strategy that seeks to keep options open.

Underpinning this analysis is the strong view that the ultimate objective of the Framework Convention can be achieved only if net GHG emissions (emissions minus removals by sequestration) eventually reach zero. Implicitly or explicitly, then, a fundamental issue in considering a long-term target is whether it can motivate the actions necessary to achieve that—and, if so, by when.

II. The Case for Setting a Long-Term Target

Attaining a long-term climate target would require action across the globe. Nevertheless, individual countries and groups of countries have begun adopting targets of their own. Recent examples include: the European Union, which aims to stabilize carbon dioxide (CO_2) concentrations at no more than 550 parts per million (ppm) and limit global temperature rise to 2 degrees Celsius above pre-industrial levels; the United Kingdom, where a recommendation by the Royal Commission on Environmental Pollution to reduce CO_2 emissions 60 percent by 2050 and stabilize concentrations at 550 ppm has been endorsed by Prime Minister Tony Blair; and Sweden, which has a stabilization target of 550 ppm, but for all six GHGs covered by the Kyoto Protocol (essentially, a CO_2 target of 500 ppm).[5] None of these targets is in any sense binding.

Advocates of an internationally agreed long-term target say it is an essential functional component of the climate regime.[6] A variety of rationales have been put forth. They include:

Providing a concrete goal for current and future climate efforts A long-term target would provide the international community with a clear statement of the goal to which near- and medium-term efforts must be geared. It has been said, metaphorically, that when starting a journey it makes sense to know where you are going. A long-term target may provide a more concrete answer to the legitimate question raised by any stakeholder asked to make a sacrifice: to what end?

Increasing awareness of the long-term consequences of our actions Current emissions and concentrations trajectories represent, by default, implicit "targets." Defining a long-term target may help make those trends explicit and amenable to control.

Calibrating short-term measures and measuring progress A long-term target provides a metric to guide nearer-term measures and to gauge progress over time. At any given moment, "being on track" can only be determined if the final destination is known. A fixed endpoint also allows a determination of the total effort required, possible pathways to the objective, and the adequacy of individual steps.

Inducing technological change Effectively addressing climate change will require deep technological change. A long-term target, particularly if coupled with convincing near-term signals, could help drive the necessary research effort and investment flows. Markets would receive a stable signal as to where they should be heading, irrespective of the ups and downs of negotiations over short-term issues. In addition, a long-term signal could favor investment in technologies that can be developed and fully deployed only over a period of decades.

Limiting future risks derived from climate change An adequate long-term target may provide some assurance that specific undesirable outcomes will *not* take place; it might be an effective way of managing global risks. Furthermore, by implicitly providing information on the level of risks that are acceptable, a target can push the international community to come to terms with how it will cope with those that are not.

Mobilizing society A long-term target resulting from a multilateral negotiation would provide a degree of legitimacy to the climate mitigation effort. It could thus help mobilize society, including the private sector, individuals, and NGOs.[7] Just as many local communities build a "thermometer" to publicly track contributions toward an initiative, the international community may be sensitized with respect to climate change, keep track of advances, and step up collective efforts by monitoring progress toward a long-term target.

Promoting global participation Stabilizing GHG concentrations at any level within any reasonable timeframe is impossible without the participation of all major emitters. While at any interim step it may be argued that only the industrialized countries should act, no such latitude is available if a stringent longer-term objective is set: it is impossible to substantially reduce global emissions, atmospheric concentrations, or climate damages without global action. Broadening participation, however, will only be possible if countries can agree on equity issues.

In assessing the different forms that a long-term climate target might take, it will be important to consider how well they match these various rationales. First, however, it is helpful to introduce the key stages of the climate change cycle.

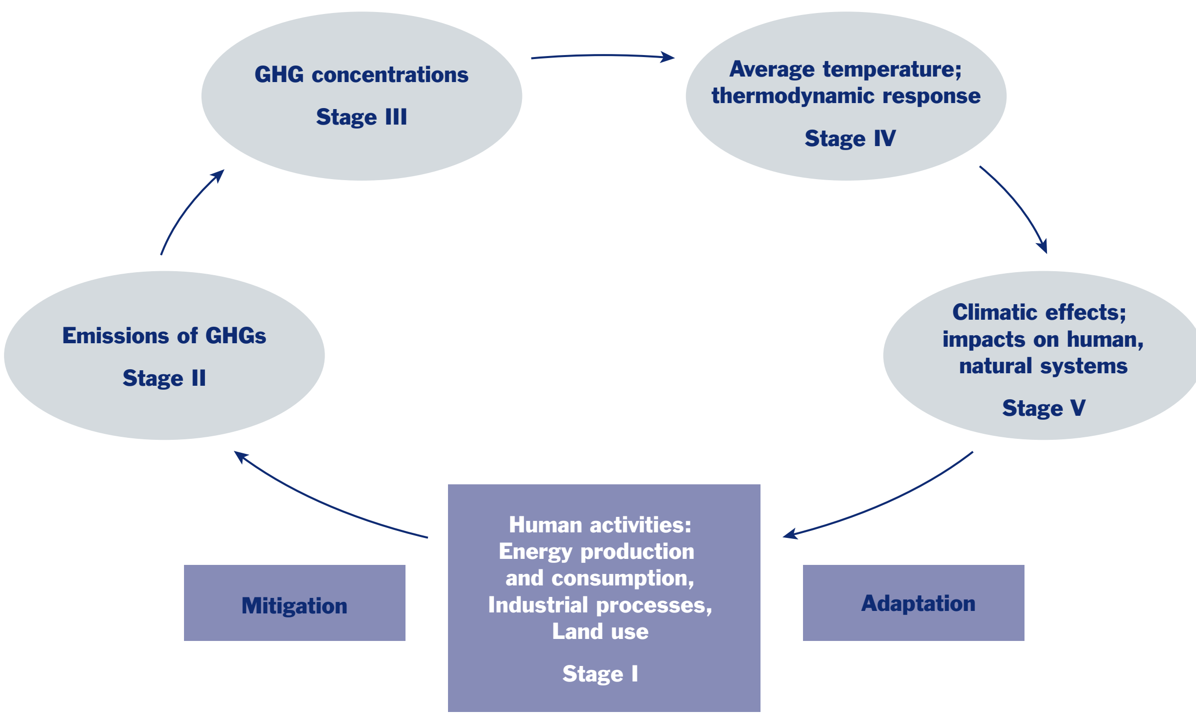
III. Human and Climate Systems

Climate change processes encompass both human affairs and the climate system in a complex interplay on time scales ranging from the instantaneous to millennia. Figure 1 represents, in simplified form, the physical processes and causal links in the climate change cycle. The cycle has five stages, beginning with human activities, then moving clockwise to emissions, to GHG concentrations, to temperature, and finally to climate impacts. Each stage has its own time frame and its own range of uncertainties.

Most *human activities* emit greenhouse gases, either directly or indirectly (stage I).[8] The principal sources of GHG emissions are fossil fuel combustion, deforestation and other land use activities, and industrial processes. The predominant, though not most potent, of the human-induced GHGs is CO_2. Others include methane (CH_4), nitrous oxide (N_2O), and a number of industrially produced gases. Many activities generate emissions years after the activity itself has ceased. For example, methane emissions from decomposing biomass may occur decades after land has been cleared.

Figure 1

The **Climate Change Cycle**



Note: This figure depicts the key stages of the climate change cycle, from human activities that generate GHGs to impacts on human and natural systems. This simplified representation emphasizes the primary causal links leading from activities to impacts. A fuller representation of the cycle would show additional physical and socio-economic feedbacks among the stages. Also, the causal links are represented at the global level. At the national level, some stages are more relevant than others. A nation may have high emissions but face low risk of climate impacts, or vice-versa.

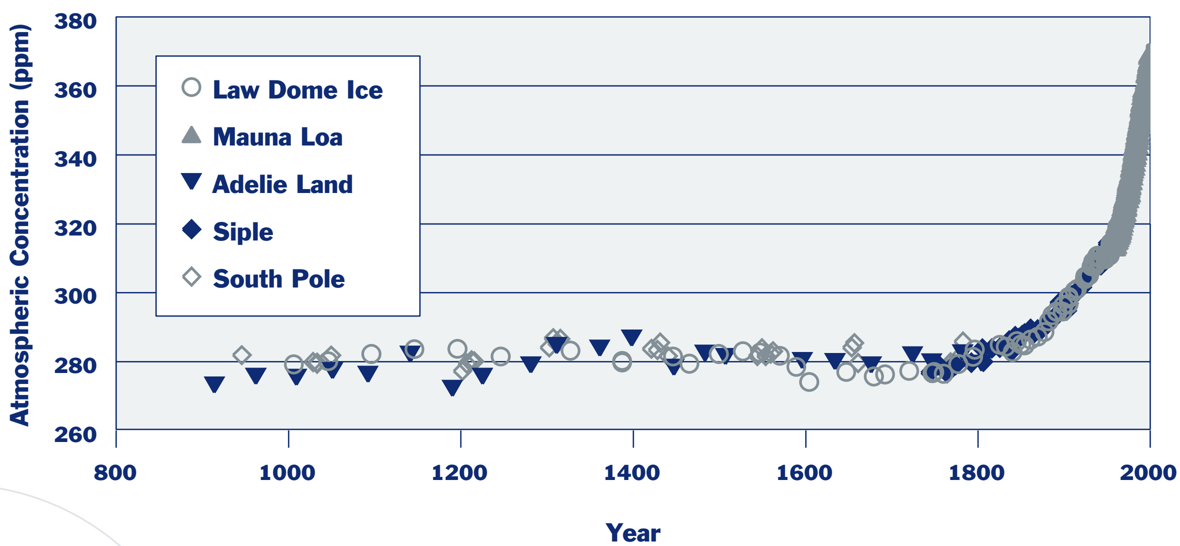
As a result of these activities, total global emissions (stage II) have increased at an essentially exponential rate since the industrial revolution. The total annual flow of CO_2 entering the global atmosphere, including that stemming from land-use changes, may have reached 8 Gigatons of Carbon (GtC) in the last decade.[9]

Rapid emissions growth has led to a rise in the *concentrations* of GHGs in the atmosphere (stage III). Carbon dioxide concentrations have been carefully measured since 1958 at the Mauna Loa Observatory in Hawaii, and measurements from ice cores and other geologic and biological features such as tree rings and coral reefs provide proxy data going back at least 400,000 years. Over the past millennium, reliable data show stable concentrations until around 1800, and an exponential increase thereafter (see Figure 2). The present CO_2 concentration is approximately 370 ppm, more than 30 percent above its pre-industrial level of 280 ppm.

Rising concentrations enhance the natural greenhouse effect that warms the planet, leading to rising average *temperatures* (stage IV). Because of the tremendous inertia in the climate system, the temperature increase occurs only gradually, and a new equilibrium temperature can be achieved only long after concentrations have again stabilized. Average global temperatures rose 0.6 ± 0.2 degrees Celsius over the 20th century. Given present emission trends, the Intergovernmental Panel on Climate Change (IPCC) projects an additional increase of +1.4 to +5.8 degrees Celsius by the end of the 21st century.

Figure 2

Evolution of **CO_2 Concentrations**



Note: Law Dome Ice, Adelie Land, Siple, and South Pole are data sets showing CO_2 concentrations in Antarctic ice cores for the past millennium. Mauna Loa represents recent atmosheric measurements.

Source: Adapted from IPCC (2001). Figure 2, p. 155.

Rising global temperatures, in turn, have *impacts* on human and natural systems (stage V). One consequence is progressive sea-level rise, due mainly to thermal expansion of the oceans and, to a lesser extent, melting of ice sheets. Other impacts include increased flooding and drought, increased frequency and severity of extreme climate events, disruption of agriculture, loss of species and ecosystems, and, potentially, sudden large-scale events such as the collapse of ice sheets. Depending on the magnitude of the temperature increase, warming may also produce localized benefits, such as increased growing seasons in northern climes, although on a global scale damages are likely to far outweigh benefits in the long term.

IV. From Activities to Impacts: Assessing the Options

It is, in theory, possible to establish a long-term target at any one of the stages of the climate change cycle. Whatever stage is chosen, however, the target-setting exercise invariably implicates all five. Any target, no matter its form, would seek ultimately to limit climate impacts (stage V) and, to be effective, must somehow influence human activities (stage I). What the target requires, then, and what it delivers can be fully understood only by working through the entire sequence. (See Appendix for a menu of possible targets and their corresponding values at each stage of the climate cycle.)

Each stage presents new uncertainties, with important implications for the ease of negotiating and implementing each given type of target. For instance, the closer a target is situated to stage V, the clearer its link to climate impacts, but the less certain its implications for mitigation policy. Conversely, a target at stage I may more readily translate into mitigation policy, but its likely contribution to reducing climate impacts is far less clear. The particular entry point could also influence the *nature* of the ensuing mitigation effort. A long-term concentration target might favor near-term goals cast as emission limits, for instance, while an activity-based target might suggest a more policies-based approach.

In physical terms, as presented above, the climate cycle quite obviously proceeds clockwise from activities to impacts. However, in assessing the practicality of target setting at each stage, we will take them up in reverse order. As the real objective of any climate change strategy is to avoid or reduce impacts, we begin the analysis there, at stage V, and work counter-clockwise back to human activities.

Stage V—Impacts

One approach to setting a long-term climate target would be to cast it in terms of the level of climate change impacts, or damages, to be avoided. Such a target could take many forms: avoiding substantial damage to coastal zones; minimizing climate-related migration of disease vectors or of natural or managed ecosystems; avoiding shifts in ocean circulation. There are compelling reasons for setting a target at this stage:

- As stated before, avoiding damages is the ultimate rationale for any action to mitigate climate change. An impacts target makes explicit the intent of the near-term effort.

- Many types of damage can be assessed in terms of cost, which can be weighed against the cost of mitigation. This allows an assessment of the value of any given level of effort.

- Many impacts are local. An impacts target with local resonance can provide a more compelling political rationale for action.

An impact-based approach is implicit in the UNFCCC's ultimate objective: avoiding "*dangerous* anthropogenic interference." However, translating "dangerous" into concrete terms is anything but clear-cut. It requires consensus on the level of acceptable risk, an inherently political determination resting on value judgments.

More broadly, any impact-based target requires an adequate understanding of the likely magnitude, timing, and distribution of future climate impacts, as well as the potential steps that might be taken to offset the damages (e.g., through adaptation). However, even assuming sufficient knowledge and consensus on acceptable risk, an impacts target can effectively drive action only if it can be reflected back through the earlier stages—temperature, concentrations, and emissions—to human activities.

Figure 3 provides a schematic view of the IPCC's assessment of potential climate impacts at varying levels of temperature increase. It reflects the very broad range of impacts—from the local to the global, the environmental to the economic, and the gradual to the sudden. Across this full range, as the IPCC readily acknowledges, there are very strong limitations on our ability to project the timing and magnitude of impacts, or to distinguish them from non-climate effects.

To begin with, even if we were able to accurately forecast future temperature rises, our understanding of the climate responses, and therefore our ability to model them, remains limited, particularly at local and regional scales. Cloud modeling, for example, stands out as one of the weakest analytical components. Another is local changes in frequency and intensity of precipitation: for any given region, one model may forecast increasing rainfall while another forecasts a decline.

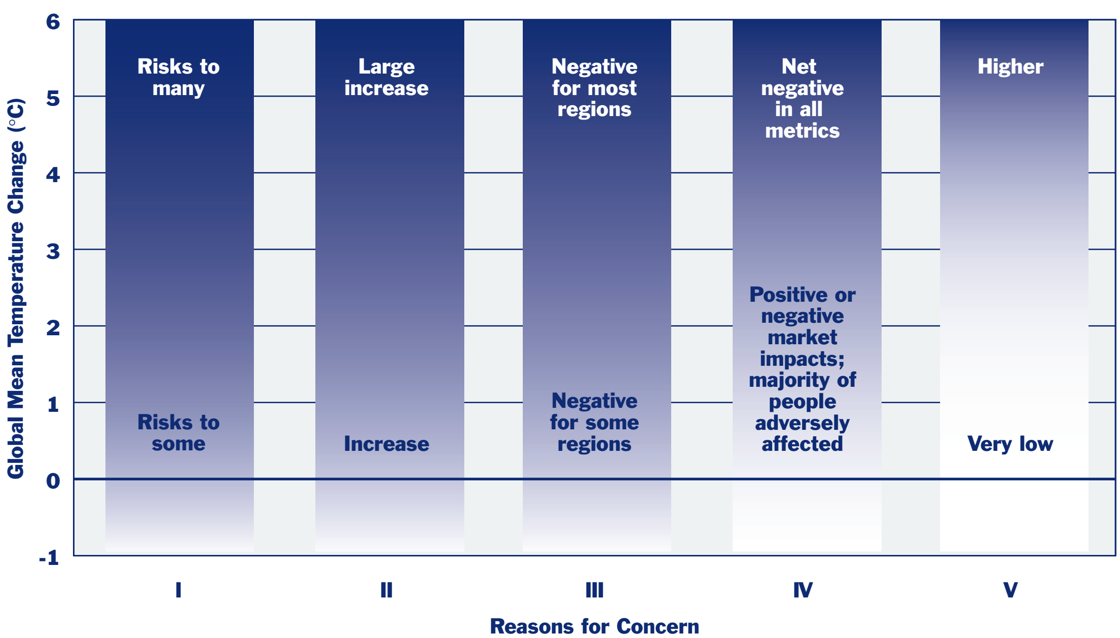
Some impacts, particularly those on ecosystems, are quite sensitive not only to the magnitude of local climatic shifts but also to the rate of change. A slow change may allow for adaptation or shifts in the spatial distribution of species, while a quick one may accelerate the rate of extinction or disrupt ecological functions in an irreversible way. Some ecosystems, such as coral reefs, are particularly sensitive to climate changes and may be irreversibly affected in a matter of a few years.

Any attempt to project climate impacts also is made difficult by the long time lags involved. Even once global temperatures re-stabilize, already a distant outcome, sea level may still keep rising for centuries, driven by the slow process of ice cap melting. In setting a target, would the appropriate time frame be a century? Ten centuries? A millennium?

The local nature of many impacts—and their sheer diversity—would further complicate a negotiation that arguably must be global in scope. Impacts will not be evenly spread throughout spatial scales, social groups, or ecosystems. Indeed, some are likely to be felt most acutely by those contributing least to their generation. Further, what is "dangerous" for one region or group might be less so or even beneficial for others.

Figure 3

Risk of **Potential Climate Impacts**



I. Unique and threatened systems (extinction of species, loss of unique habitats, bleaching and death of coral)

II. Extreme climate events (health, property, and environmental impacts from increased frequency and intensity of some climate extremes)

III. Distribution of impacts (cereal crop yield changes, decreases in water availability, greater risks to health, net market sector losses)

IV. Global aggregate impacts (globally aggregated net market sector losses, more people adversely affected than beneficially affected)

V. Large scale, high impact events (significant slowing of thermohaline circulation, melting and collapse of ice sheets)

Source: Adapted from IPCC (2001). Figure 6-3, p. 103.

One approach might be to define "dangerous" in larger structural terms—for example, irreversible or non-linear changes in ecosystems or societal systems. A long-term target may be more acceptable if it could define a threshold below which events perceived as catastrophic would be much less likely. Some have suggested that preventing the loss of "charismatic" ecosystems like coral reefs, or averting low-probability catastrophic events like the collapse of the West Antarctic Ice Sheet, could serve as powerful markers framing the long-term climate effort.[10] Yet it is in understanding the triggers for, and therefore likelihood of, such events that science and modeling are in some cases at their weakest.

Even if consensus on what constitutes "dangerous" could be reached, to be of real utility, an impacts target would have to be translated back through the other stages of the climate cycle to in some fashion redirect human activities. It is important, then, to understand the additional uncertainties that enter at each stage.

Stage IV—Temperature

The most direct consequence of rising GHG concentrations is their thermodynamic effect on the atmosphere and the planet–i.e., rising temperatures.

There are strong reasons to cast a long-term climate target in terms of global mean temperature:

- Temperature and concomitant sea level rise are the primary climate change effects we are concerned with; establishing an explicit long-term target at this stage places the emphasis on those variables.
- Thermodynamic effects are global and thus are shared by all countries and individuals.
- The link between concentrations and temperatures has been well established; it thus can serve as a useful proxy.
- Temperature is an indicator that is readily understandable by the average citizen and therefore helps make an arcane debate more accessible.
- Global temperatures are now routinely monitored in a reasonably accurate fashion.

Governments and researchers have advanced several proposals that in some way employ temperature as a metric to guide action. In a 1995 proposal by the German Advisory Council on Global Change and in the "safe corridors" proposal by the Dutch government shortly before Kyoto, both absolute levels and the rate of temperature increase are considered to be critical factors.[11] The Brazilian government, in a proposal made during the Kyoto negotiations, advocated using temperature as the basis for burden-sharing criteria to establish emission targets for industrialized countries. It proposed a formula to determine each country's share of accumulated responsibility for global temperature increase.[12]

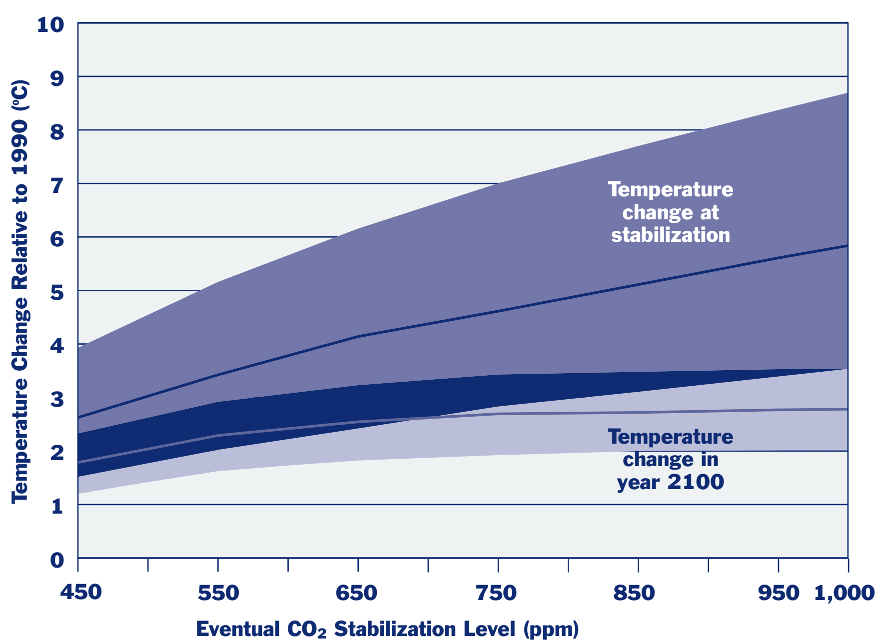
More recently, a Dutch-sponsored project called Climate Options for the Long Term (COOL) concluded that a prudent target would be a maximum temperature increase of 1.5 degrees Celsius, and a rate of maximum allowable temperature change of 0.1 degrees Celsius/decade. This proposal is based on studies assessing the consequences of such shifts to natural and human ecosystems—essentially, basing temperature targets on impacts and damages. Furthermore, concluding that a conservative path must be set to assure that the temperature targets are not exceeded, it in addition proposed a concentration target of 450 ppm.

Focusing on temperature, rather than impacts, may bypass one broad set of uncertainties: the specific impacts linked to a change in temperature. However, this stage presents its own set of uncertainties. For instance, how are we to assess the global variability in the temperature change? Temperature is projected to increase faster in the polar regions, so must we set our global target correspondingly lower, below the desired average, to ensure an acceptable level of risk at the polar extremes? Or do we set different targets for different regions? Also, while the timescales are not as open-ended as at the previous stage, we continue to face very large time lags. Do we assess the acceptability of change as a function of the long-term equilibrium effect or of the effect over the next 100 years only? And how do we know when the effects of temperature stop being linear and cross some threshold to become sudden or catastrophic?

Finally, there are uncertainties in the link between temperature and GHG concentrations, one stage back in the cycle. For any given level of stable concentrations, we can at best project a range of temperature increase, with dramatic variations in the likely impacts at the upper and lower bounds of the estimate. Figure 4 illustrates the range of uncertainty over the level of warming likely to result from different stabilized concentrations of CO_2.

Figure 4

Uncertainty in the Link Between **Concentration and Warming**



Source: IPCC (2001). Figure 6-2, p. 101.

Stage III—Concentrations

In both technical and political analyses of a potential long-term climate target, the metric most often employed is GHG concentrations. This is not surprising as it is the metric enshrined in the ultimate objective of the Framework Convention: "...stabilization of greenhouse gas concentrations in the atmosphere...." This alone may suggest to some that this is the appropriate form for a long-term climate target and could impede any effort to negotiate a target of a different type. There are a number of persuasive rationales for setting a target at this stage of the cycle:

- Increased GHG concentrations in the global atmosphere are the most direct cause of climate change.

- Even more accurately than global temperatures, global GHG concentrations are now routinely monitored.

- The dynamics of GHG concentrations are commensurate with the long-term time frame of mitigation action, reflecting, as it does, not marginal change, but the cumulative total of all global activities.

- Finally, the UNFCCC reflects a political consensus that was difficult to achieve and, as it casts its ultimate objective in terms of stabilizing concentrations, politically this may be the easiest path to a specific long-term target.

As noted earlier, several countries already have adopted non-binding concentration targets. The implications of stabilizing concentrations at given levels—for both the climate impacts that might result and the emission reductions that would be necessary—have been closely analyzed. Some of those implications are described in the box on the next page.

Stage III—concentrations—is at the midpoint in the climate cycle, halfway between stage I (human activities) and stage V (climate impacts). From the target-setting perspective, this presents both virtues and drawbacks. This stage provides a good vantage point to look in both directions—to original cause (human activities) and to ultimate effect (climate impacts)—and might therefore provide a convenient metric between them. Concentrations would thus become the nexus between damages to be avoided and effort to be undertaken. However, such an exercise is confounded by uncertainties in both directions. The difficulties in relating a given GHG concentration to global temperature and, in turn, to impacts, have already been discussed. Moving in the other direction, the most obvious difficulties are

Possible CO_2 Concentration Targets

Stabilizing at 450 ppm

As perhaps the most stringent long-term target that might likely be achieved under current circumstances, stabilization of CO_2 concentration at 450 ppm in 2100 has received particular attention.[13] It was, for example, extensively discussed in the COOL project, funded by the Dutch government.[14] According to the IPCC's Third Assessment Report, stabilizing at 450 ppm would virtually exclude the possibility of changes in mean surface temperature[15] exceeding 4 degrees Celsius (range: 1.4-4.0 degrees Celsius). As of 2100, temperature increase would range between 1.2 and 2.4 degrees Celsius. Large-scale discontinuities, such as the disruption of thermohaline ocean circulation, would be unlikely. The IPCC analysis suggests that meeting a 450 ppm target would require a reduction in *global* CO_2 emissions of about 15-25 percent below 1990 levels by 2050. A 450 ppm target might be met with already known technologies but would likely entail deep social and political transformations.

Stabilizing at 550 ppm

Stabilizing CO_2 concentrations at 550 ppm has attracted even greater analytical attention, as it roughly coincides with a doubling of CO_2 concentrations above pre-industrial levels[16] and is frequently used as a baseline hypothesis for models examining climate sensitivity. Such a level would imply changes in mean surface temperature of between 1.6 and 2.9 degrees Celsius by 2100. Eventually, temperature changes would reach equilibrium at a range of 1.5-4.5 degrees Celsius.

Only under the most favorable of the emission scenarios examined by the IPCC (see Figure 6 below) would CO_2 concentrations eventually stabilize at 550 ppm without specific mitigation efforts; most probably, significant action would be required to meet this target. Other modeling suggests that under a least-cost pathway, emissions would have to peak no later than 2030 at no more than 11 GtC and then decline, reaching 6 GtC by 2100.[17] This would call for developed countries to reduce their emissions 60 percent by 2050 relative to 2000, and for developing countries to control their own emissions starting around 2030. Stabilization at any level below 600 ppm would require reductions in energy and carbon intensities far greater than any achieved historically.

Stabilizing at higher levels (650-1,000 ppm)

For a number of the IPCC scenarios, targets in this upper range of concentrations may be achieved even without specific climate change policies. Thus, setting a high level as a target generates little if any action. Stabilizing concentrations within this range may still limit the impacts of warming to less than 4 degrees Celsius, especially if climate sensitivity turns out to be low. However, stabilizing at 1,000 ppm is likely to result in catastrophic long-term consequences. According to the Third Assessment Report, stabilizing at 1,000 ppm would not require global emissions to peak until as late as 2090, limiting the need for much near-term action.

in determining what level of concentrations can actually be achieved—and, conversely, how a given concentration target would be translated into effort required.

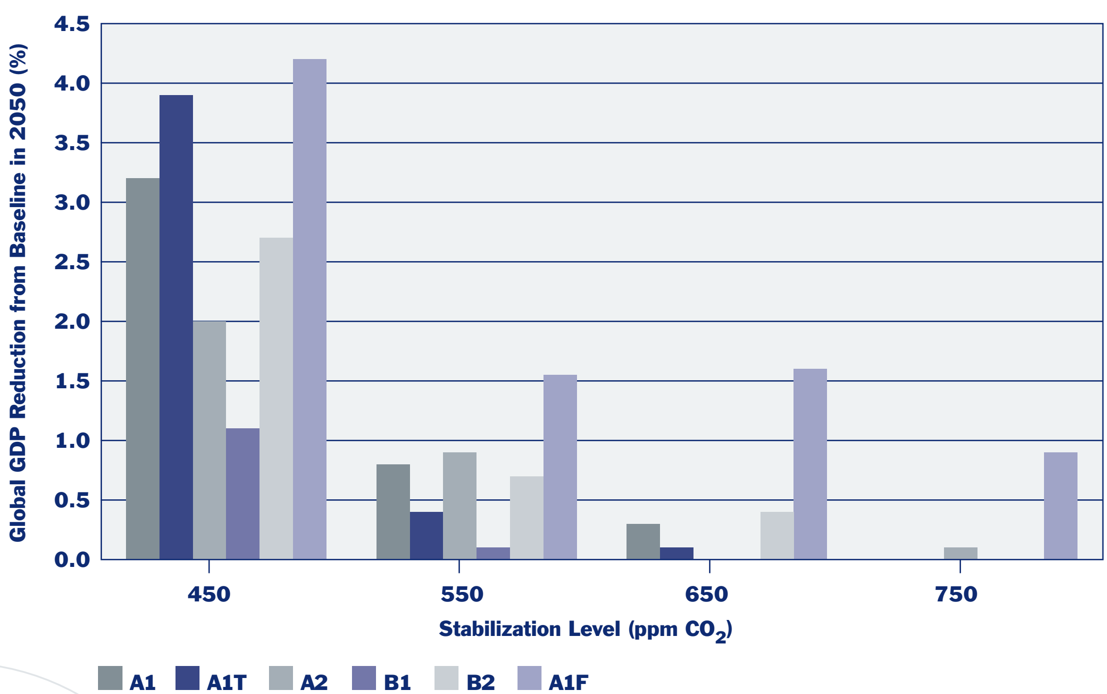
The achievability of a given concentration target rests in part on assumptions about future GHG emissions, which, as will be discussed below, are highly uncertain. Based on current emission trends, the IPCC projects that GHG concentrations could range anywhere between 540 and 970 ppm in 2100.[18] These and other uncertainties are reflected as well in the wide range of cost estimates for achieving stabilization at different concentration levels. As seen in Figure 5, these range from less than 0.5 percent to as much as 4 percent of global GDP in 2050.[19]

A concentration target effectively sets an upper bound on allowable cumulative emissions over a given period. But it leaves open the question of the most feasible or cost-effective emission trajectories consistent with that target. The higher the near-term emissions, the sharper and greater the magnitude of the future decrease that will be required if any given concentration level is to be met. Analysts have run the models "backwards" to define possible emission pathways that would lead to stabilized CO_2 concentrations at levels ranging from 450 ppm to 1,000 ppm. They conclude that any given level of stabilization would require emissions to peak and then fall well below current levels. These analyses lead to a further inescapable conclusion: in the long run, regardless of what concentration level is set, it can be achieved only when net emissions (emissions minus removals by sequestration) effectively are reduced to zero.

Moving one more stage back in the climate cycle—to emissions—allows a closer look at likely, and possible, emission trajectories.

Figure 5

Estimated **Costs of Stabilization** Under Different Emmissions Scenarios



Source: IPCC (2001). Figure 7-4, p. 120.

Stage II—Emissions

There are several compelling rationales for casting a long-term target in terms of emissions:

- Excess GHG emissions are readily understood as the cause of climate change; an emissions target is readily understood as an effort against an undesirable effluent.

- GHG emissions are frequently associated with other pollutants whose elimination is sought anyway for public health reasons.

- Every government has the authority to fully control domestic GHG emissions. As a consequence, it may adopt commitments related to these emissions and be held accountable in case of non-compliance.

- Based upon the work of the IPCC, clear methodologies, procedures, and formats exist to monitor, review, and report emissions in national inventories.

Essentially, the UNFCCC and the Kyoto Protocol have sought to intervene at this stage, establishing near-term targets in terms of allowable emissions for industrialized countries. Longer-term targets have also been proposed for this stage. For example, as noted earlier, the UK government has set an aspirational goal of reducing emissions 60 percent by 2050 and advocated the same target for all industrialized countries.

At the emissions stage of the cycle, however, we are yet further removed from climate impacts. Setting a target at this stage thus injects another layer of uncertainty in the correlation between the chosen metric and the ultimate goal of impacts avoided. The flip side, however, is that the metric is now more closely related to the underlying causes of climate change—human activities amenable to human control. This allows a more direct assessment of the kinds of actions that would be required and the costs they might entail.

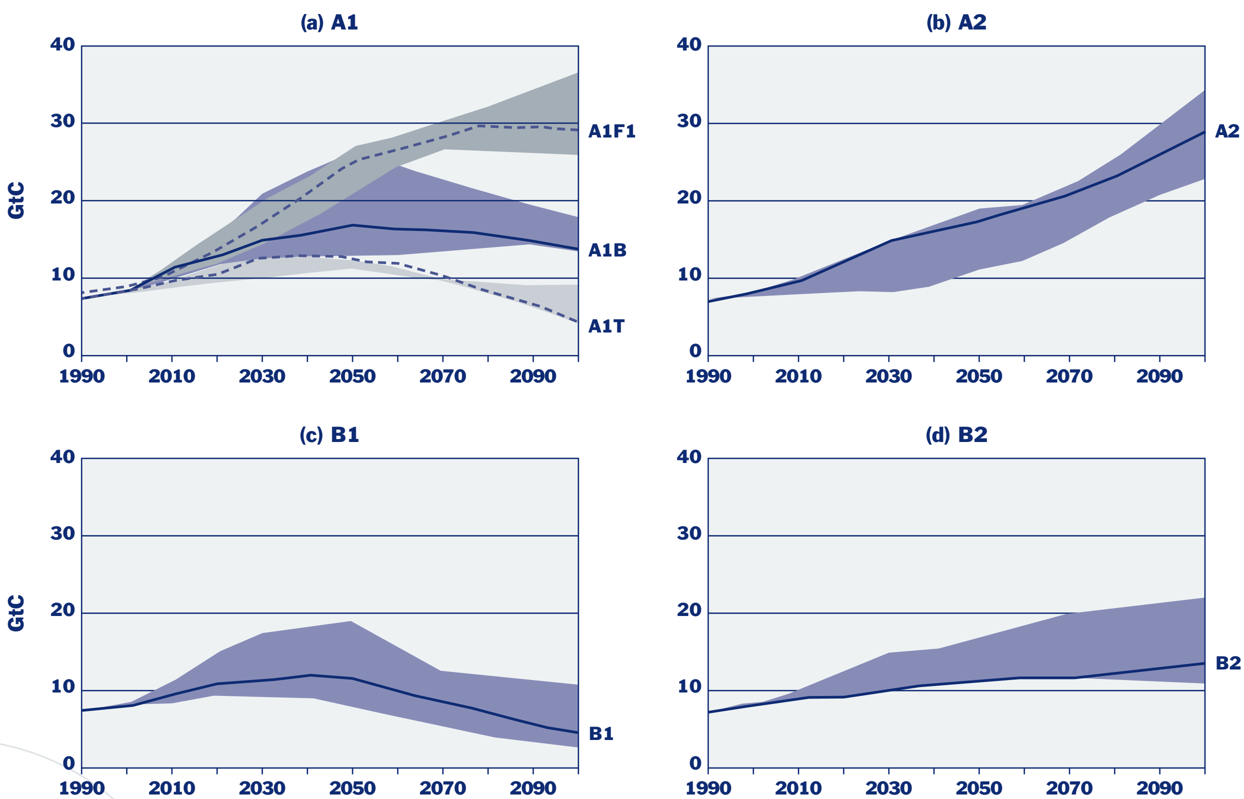
As we have already seen, such assessments rest in part on assumptions about future emission trends. These, in turn, rest on assumptions about a host of variables, including economic growth, population growth, and the rate of technological change. As no one set of assumptions can be deemed reliable, the IPCC has developed a set of scenarios illustrating potential alternative futures and their associated emission trajectories, all in the absence of specific climate initiatives. As can be seen in Figure 6, the potential emission paths vary enormously. In some cases, CO_2 emissions peak around 2040-2050 and then decline; in others, these emissions keep growing throughout the 21st century and beyond. As of 2100, the projected levels of CO_2 emissions range from below 5 GtC to above 20 GtC. This enormous variability in emission forecasts provides considerable room for conflicting assessments of the effort required to meet a given emissions target.

The calculation of effort, in turn, defines the parameters for a closely related and inherently political calculation—the *distribution* of effort. To the degree that an emissions target establishes not only an allowable level of cumulative emissions over a given time period, but also the preferred timing of the necessary emission reductions, it effectively defines allowable emissions at any given moment during that period. In that sense, it creates a finite resource—the right to emit—and quantifies it. On one hand, this can facilitate a precise apportionment of responsibility for meeting the target. On the other hand, it imbues the target itself with enormous political and economic implications. The target-setting exercise is thus implicitly laden with all the stakes of the burden-sharing exercise that would follow.

Focusing on emissions invites a more vivid and direct examination of the effort required to meet a target, the associated costs, and their distribution. At the same time, however, the emissions metric makes it yet more difficult to characterize the target as ensuring any given level of protection against climate impacts. As a political matter, the exercise may easily become one pitting large, concrete, collective costs against benefits that would be difficult to establish.

Figure 6

IPCC **Emissions Scenarios**



Note: Six scenario groups were developed by the IPCC, organized into four families. The A1 and A2 families emphasize economic development but differ with respect to the degree of economic and social convergence. The B1 and B2 families emphasize sustainable development, and also differ in convergence. Three scenarios were defined within the A1 family to describe alternative technology developments.

Source: IPCC (2000). Figure SPM-3, p. 7.

Stage I—Human Activities

Arriving finally at the first stage of the climate cycle places the focus squarely on the human activities at the root of climate change. There are strong rationales for establishing a long-term target at this stage:

- Ultimately, human activities are the proximate cause of climate change; changing these activities will change the climate system.
- We—individually and through government policies—have the capacity to change behavior and technology to curb emissions and climate impacts. Few other points in the cycle can be so directly affected.
- Long-term goals set at this stage in the cycle may have ancillary benefits (e.g., local pollution reduction and improvements in trade competitiveness) and thus bring additional political support.
- Characterizing the challenge as technological, rather than exclusively environmental, may also help broaden political support.

What might an activities-based target look like? One option is to focus on outcomes—for instance, fully decarbonizing the energy sector by 2100. Another option is to set a particular technology goal—for instance, replacing internal combustion engines with fuel cell vehicles by 2030. Both approaches define the goal in concrete terms that, in theory at least, can be readily translated into a detailed program of action. The effects these targets have for subsequent stages in the climate cycle, while not easily quantified, are nonetheless obvious.

At the first stage evaluated above—stage V, impacts—the focus is primarily on damages to be avoided and, only secondarily, on the implications for other stages, from temperature to concentrations, emissions and, ultimately, human activity. The middle stage—concentrations—allows a more balanced view extending in both directions around the climate cycle. The present stage is the furthest removed from impacts; any attempt to calculate the benefits of an activities-based target in terms of impacts avoided is thus subject to all the uncertainties introduced at each intervening stage. Such a target can be correlated to the ultimate goal of avoiding impacts only in the most general sense.

Conversely, an activities-based target minimizes uncertainties about what effort will be required. The metric employed is the variable over which we have the greatest control. We cannot change the physical behavior of the atmosphere, nor the impacts such changes will have on the climate system (although geo-engineering solutions have been proposed, none are yet considered remotely feasible). Even our ability to transform emission trajectories is only indirect, subject to vagaries such as economic growth, weather, and technological change. Our influence is most direct at the stage of human activity: we can discourage activities that generate emissions, encourage activities that emit less or that capture emissions from the atmosphere, or live with the consequences and try to adapt. A long-term target set at any stage of the climate change cycle would, in any event, have to be translated into policies reshaping human behavior.

There are, of course, drawbacks. Unless the goal is sufficiently broad or stringent (e.g., full energy decarbonization), there is no assurance that it will in fact deliver the desired outcome of reduced climate change impacts. As with an emission target, the benefits are thus far more opaque than the costs of whatever action is required. At the same time, the costs are less diffuse here than they would be at other stages in the cycle. A focus on major emissions-generating activities places the burden much more immediately on specific sectors with significant political influence. Finally, a target cast in terms of a particular technology runs the risk of locking in a less-than-ideal technology and discouraging investment and innovation that could produce a better one. From a narrow economic standpoint, it may also be less cost-effective than a target that sets a desired environmental outcome and allows the market to choose the means of achieving it.

IV. Reconsidering the Case for a Long-Term Target

At the outset, this paper presented several strong rationales for a long-term target to drive and frame the international effort against climate change. However, an analysis of the prospects for target setting at various stages of the climate cycle uncovers a host of obstacles. Some are technical; others are political.

The technical complications stem primarily from incomplete knowledge or understanding, and they are compounded at each successive stage of the cycle. Uncertain about the future of key drivers such as technological and economic change, we cannot with any confidence predict emissions pathways—and hence, extrapolate accurately to concentration levels. Even if these were clear, we do not currently have the capacity to plausibly link the resulting global thermodynamic changes with specific local damages.

The political obstacles are no less daunting. Even assuming an adequate base of scientific knowledge, the establishment of a long-term target is implicitly an exercise in defining “acceptable risk,” which is a matter of judgment, not fact. With the potential impacts of climate change so unevenly distributed, countries have widely divergent views on the level of global risk that is acceptable—or, put another way, the types of climate impacts that can be ignored. Is it possible to convince small island developing states that some sea level rise—say, enough to inundate their territory—is acceptable? How much might other countries be willing to offer to compensate for such losses?

Assuming consensus on the level of acceptable risk could be reached, target setting encounters a second set of political obstacles. It implies the need to apportion effort—to allocate emission allowances or other burdens or responsibilities. The enormous difficulty in the debate over differentiating emission targets in the Kyoto Protocol, when the commitment was only short-term, merely hints at the difficulties that might be anticipated in attempting to allocate rights and obligations over the long term. Setting the target and allocating burdens are, of course, separate exercises. But insofar as the target defines the total burden or rights to be allocated, its establishment becomes weighted with all the attendant political and economic stakes. The target is in this sense seen as a proxy for a multitude of politically charged decisions.

These political complexities beg the question of whether it might ever be possible to set a long-term target that actually serves the purpose of driving action. The more stringent the target, the more effective it is in driving action, but the more costly it is as well. (Too stringent a target can set back action, though, if its high costs elicit strong political resistance.) This suggests the negotiation is likely to yield a target less stringent than might be environmentally desirable. However, an "easy" target will drive little—if any—action. For example, unless a concentration target is set below 600 ppm, meeting it might require no action at all in the near term.[20] Thus, target setting could serve as much an excuse for delay as a goad to action. If the negotiation reaches an agreement, the target may well be ineffective. Should the proposed target be stringent enough, the negotiation may well fail.

Over time, scientific advances may overcome many of the technical obstacles and narrow the range of uncertainties. But the basic political dilemmas will always remain. There is a risk that, by diverting a limited pool of "negotiating energy," any effort to establish a long-term target could in fact be detrimental to the cause of combating climate change. It seems unlikely that any such negotiation could succeed in a period of less than five to ten years. Unless there are parallel short-term commitments, countries and industries may undertake little real emissions reduction during that period, citing uncertainty over the long-term target as a pretext. In the final analysis, the hurdles of negotiating a long-term target are such that the possibility of failure is quite real. This could seriously undermine confidence in the process and diminish the prospects for effective international action, as failing to achieve a successful outcome in a negotiation may jeopardize the morale needed to undertake subsequent ones.

If, however, the international community does resolve to undertake the negotiation of a formal long-term target, the stage-by-stage analysis above offers strong arguments for devising it at the stage of human activities. This stage is far removed from impacts; an activity target does not ensure a given level of protection, nor does it invoke the goal of avoided impacts as a driver for change. But a target focused directly on activities is spared the many layers of uncertainty and the enormous time lags encountered in trying to translate impacts avoided into action required. It employs as its metric the variable most amenable to human control. Plus, by casting the goal in terms of the practical challenges to be met, it can help define in the public mind, and build support for, the effort required.

An activity target more closely matches the approaches taken in the Montreal Protocol and the POPS Convention, as cited earlier. In the case of the Montreal Protocol, the long-term objective of phasing out ozone-depleting substances is readily translated into near-term goals identical in form. In the case of POPS, the long-term objective of protecting human health and the environment from persistent organic pollutants serves only as a guiding force. But in both cases, the operative target or commitment is set in terms of a variable over which states have control: the production, sale, and use of given compounds.

Climate goals could be formulated as:

- Achieving specific high levels of efficiency (measured as an output per unit of energy) in home or industrial appliances, transportation systems, utilities or productive processes;

- Eliminating the use of sulfur hexafluoride (SF_6) or perfluorocarbons (PFCs) in the industrial sector;

- Developing the technology for cost-effective capture and storage of CO_2 by 2025;

- Replacing gasoline in the transport sector with hydrogen produced by non-carbon emitting sources by 2050;

- Eliminating carbon emissions from the energy sector by 2060.

Such goals are within the control of political processes and may also allow fundamental shifts in the structure of the international process. For example it may be unnecessary to have a global, multilateral system in place if the intent is to develop the technology to replace fossil fuel-based electricity production. A smaller group of countries (and companies) acting in concert might generate such a technology, leaving a larger multilateral process to promote and facilitate its penetration into the global market. Such processes could, in fact, be of a more regional nature as well: countries with significant wind or solar resources may choose a different technology focus than those wishing to exploit nuclear power or biomass.

To meet any level of long-term climate stabilization, an activity target must engender a level of effort that is very robust—delivering in the long term nothing less than zero net emissions. Yet even a target or group of targets falling short of that objective will, at the very least, be moving the system in the right direction.

V. Alternative Approaches

If, for the time being, no negotiation toward a long-term target is undertaken, are there alternative approaches that might provide at least some of the benefits of a long-term climate target? Are there practical options that may help narrow the gap between short-term measures and goals that may be many decades away?

Two alternatives suggest themselves: a hedging strategy, which promotes near-term actions that leave open a range of future "targets" without committing to any one of them; and a gradual move toward consensus on an informal target that can be a general guide for action.

Hedging Strategies

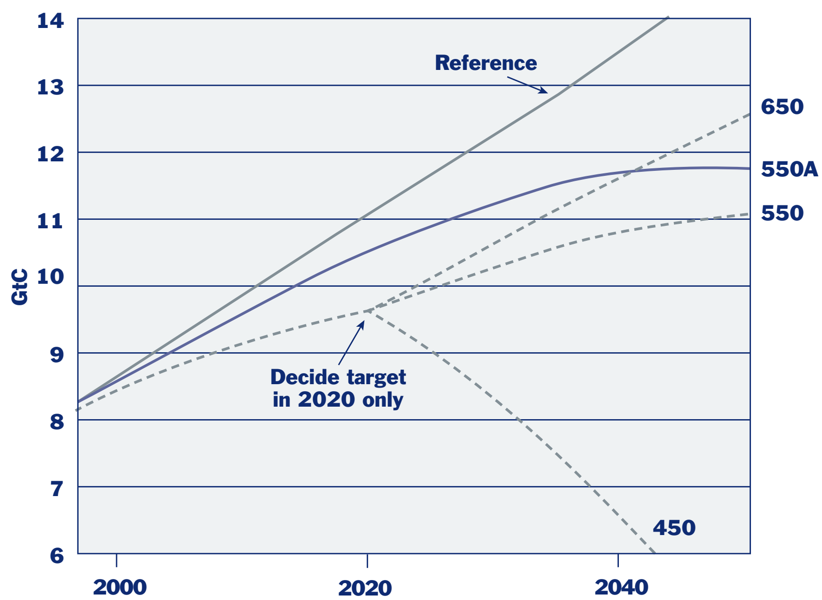
A hedging strategy acknowledges the many uncertainties in setting a long-term target and, rather than establishing one, seeks a path that keeps all reasonable options open. Such a strategy would use a notional, non-binding target—or more likely, a range of potential outcomes—and favor near-term actions that are consistent with all of them. Hedging is an iterative process that uses new knowledge as it becomes available to better weigh long-term options and the adequacy of near-term actions.

Figure 7 illustrates what a hedging strategy might imply for emission trajectories. In this case, it is suggested that an optimal goal—with perfect foresight—is a concentration of 550 ppm, and the optimal path to it is the one represented by "550A." But, in the absence of such foresight, and not knowing if a 450 ppm target might ultimately prove warranted, the strategy aims to keep that option open. It requires near- and medium-term actions that preserve the option of 450 ppm, but does not commit to that as a firm target.

As better information becomes available, efforts may be strengthened (should a more aggressive target be agreed) or relaxed (should the problem prove less severe than anticipated). By deferring any binding decision on a long-term target, and leaving open the possibility that a less aggressive target may ultimately suffice, a hedging strategy may fare better politically than any effort to negotiate a fixed long-term target. However, it presents political difficulties of its own. In order to keep options open, it effectively compels prompt, aggressive action consistent with the more stringent end of the potential target spectrum. In the illustration above, the emissions trajectory necessary to preserve the option of 450 ppm is lower than would be required if 550 ppm were ultimately deemed acceptable (although higher than the optimal 450 ppm path). This requires a significant commitment of near-term effort, in the absence of agreement on the long-term goal.

Figure 7

A **Hedging** Strategy



Source: IPCC (2001). Figure TS.10a, p. 67.

Once launched, a hedging strategy can create a dynamic for periodically revisiting and adjusting objectives and actions. The goal of avoided impacts would suggest preserving the option of 450 ppm, which in turn might require keeping emissions as close as possible to present-day levels. However, if the cost of the near-term actions required were too high for the political process to bear, only those actions that fall at an acceptable cost would be entertained. As long as the most stringent target is kept within the range of possible outcomes, the iterative process of continually revising the cost and damage estimates could provide adequate tension in the system to ensure long-term progress in the proper direction.[21]

As any "target" under a hedging strategy would provide guidance only, it need not be the product of a formal negotiating process. It may equally be the sum of current scientific understanding, as reflected, for instance, in discussions within the IPCC.

Alternatives to Negotiated Targets

Of course, it may be impossible to set goals that are broadly enough agreed to make the effort worth the negotiating cost. In this case, some alternative drivers may help push climate mitigation activity.

One possibility is better understanding and widespread dissemination of "good" science and information. Even if we cannot define a desirable long-term goal, we do know that continuing the present trends is not acceptable if future generations are to end up with a livable system. As long as we know that we must continue to change, this by itself constitutes a long-term goal. The clearer our understanding of the effects of climate change, and of the effectiveness of our mitigation actions, the more likely we will be to act. In this case the information provides a directional goad rather than a target with a specific magnitude.

In most of the discussion above, the target is assumed to be negotiated and accepted by most or all nations. However, two alternatives may also generate significant levels of effort without being globally agreed: a target set by one (or a few) countries, or a target that becomes the implicit basis for analysis and policy making but never becomes the basis for any negotiated agreement.

In the first case, countries may use the target to drive their own domestic agendas. Then, while never signing on to the target itself, others may begin to compete on global markets using the technologies and drivers that are promoted by the target-setting countries. We are already seeing some movement in this direction: with the Kyoto Protocol's entry into force multinational companies would be required to meet emission standards in countries with targets—even if they are based in countries with no targets at all. Should long-term goals such as those advocated by the UK become widely agreed, a similar process could ultimately unfold at this more stringent level. The world will thus be pushed to accept the goal—if not the specific strategies—of a small and determined group of standard-setting players.

Perhaps the best example is California, with its standards for vehicle emissions. Because auto companies are unwilling to forego the California market, the world has seen an increasing number of vehicles meeting its emission requirements—even though virtually no other state or country has adopted similarly stringent levels.

Alternatively, some metric broadly accepted in the scientific community as a common basis for analysis could begin to take on characteristics of a goal. For example, most efforts to model emission trajectories and potential climate impacts assume a CO_2 concentration of 550 ppm—or approximately doubling pre-industrial levels. The science community began using 550 ppm as its standard value in the IPCC's First Assessment Report. Soon, the vast majority of models and analyses were run with this value. It is not likely a coincidence that the international target most often proposed is at a similar level

VI. Conclusions

For all the uncertainties in our scientific understanding of climate change, this much is clear: the steady buildup of GHGs in the atmosphere poses significant long-term risks, both environmental and economic; and mitigating those risks requires action that is both global and sustained. It is in driving and framing this action that a long-term target would have its greatest value. A target would help define the scope and nature of the action required, and would serve as a constant prod, or lever, to ensure that action is taken.

The search for a long-term target encounters uncertainties at each turn. The greater the uncertainties are, the greater the opportunities for discord and delay. An activity target shortcuts the analysis; it bypasses several layers of uncertainty to focus attention on the factors most responsive to human intervention. As a consequence, it is substantially removed from the primary motivating force—the avoidance of impacts—and it starkly reveals the costs of any proposed undertaking.

A hedging strategy essentially declares the uncertainties too great to allow a firm or binding consensus on a target right now. It tries to buy time—keeping options open until better information narrows the range of uncertainty and consensus can be reached.

A long-term target is a tool, one of many that could be employed in the effort against climate change. Ultimately, though, the vigor and success of any such effort rests less on our choice of tools than on our willingness to act. Climate change will be effectively addressed only if there is sufficient political will. If the process of developing a long-term target helps to generate political will—if it indeed serves as a catalyst for action—then it may be worth undertaking even if in the end there is no agreed outcome. If, on the other hand, the search for a long-term target diverts what political will exists into a fractious and fruitless exercise, it winds up serving not as a lever for action, but an excuse for inaction.

Appendix

Correlating Concentrations, Temperature, Impacts, Emissions, and Cost

The table below shows how a long-term target set at a given stage of the climate change cycle—e.g., concentrations or temperature—would correspond to values at other stages of the cycle or to other parameters within a given stage.

Eventual CO_2 Stabilization Level†	Time of Stabilization*	Mean Surface Temperature Change by 2100**	Mean Surface Temperature Change (at Equilibrium)**	Cumulative Carbon Emissions 1990-2100 (GtC)	Possible Pathway (Global Emissions Peaking at… GtC/Year, by Year…)	Cost: Global Average GDP Reduction in Year 2050
450 ppm	2100	1.2-2.3°C	1.5-3.9°C	630-650	9 GtC by 2020	1.0-4.1%
550 ppm	2150	1.6-2.9°C	2.0-5.0°C	870-990	11 GtC no later than 2030	0.1-1.7%
650 ppm	2200	1.8-3.1°C	2.4-6.1°C	1030-1190	___	0-1.5%
750 ppm	2250	1.9-3.4°C	2.8-7.0°C	1200-1300	13 GtC by 2070	0-1.0%
1,000 ppm	2375	2.0-3.5°C	3.5-8.7°C	___	___	___

† Concentrations here refer only to CO_2. Adding the effect of non-CO_2 gases would entail a substantial increase in total CO_2-equivalent concentrations. For instance, a CO_2 stabilization target at 450 ppm would imply 550 ppm CO_2-equivalent when the other GHGs are taken into account.

* According to the scenarios in Wigely et al. (1996). Concentrations have to be close to stabilization level some decades before the final time of stabilization.

** Low and high estimates (for climate sensitivities of 1.7 and 4.2 degrees Celsius respectively).

Source: IPCC (2001).

Endnotes

1. UNFCCC, Article 2; http://unfccc.int/resource/docs/convkp/conveng.pdf. Article 2 further states: "Such a level should be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."

2. The Millennium Development Goals are an agenda for reducing poverty and improving lives that world leaders agreed on at the Millennium Summit in September 2000. For each goal one or more targets have been set, most for 2015, using 1990 as a benchmark. They include goals for poverty and hunger eradication, universal primary education, gender equality, reduction in child mortality, improvement in maternal health, combating AIDS and other diseases, ensuring environmental sustainability, and promoting global partnerships for development. For details see http://www.undp.org/mdg/.

3. See http://www.pops.int/documents/convtext/convtext_en.pdf.

4. In this paper, long-term is defined as a time frame extending from 2050 to the end of the 21st century and beyond. A target is defined as an outcome that the international community seeks. A target can take a weak, notional form (where the desirability of the outcome is broadly recognized but the outcome is not obligatory) or a strong form (one that would require specific decisions to guarantee the timely occurrence of the outcome itself). The short-term leverage provided would vary accordingly.

5. Klimatkommittén (2000).

6. The New Economics Foundation (2002), for example, advocates a formal, binding, internationally agreed concentration target as absolutely necessary in the context of the UNFCCC.

7. Perhaps the most famous such target was the pledge made by U.S. President John F. Kennedy that the U.S. would "put a man on the moon by the end of the decade." This target mobilized society and induced technological changes—in some cases leading to the development of entirely new technologies.

8. Human activities may also determine changes in the atmospheric presence of aerosols or very light airborne particles. Most of them (e.g., sulfates deriving from sulfur dioxide emissions) result in a negative radiative forcing, that is, they would induce a global cooling effect. Other aerosols (e.g., soot) have the opposite effect. Their presence must be taken into account, along with natural effects such as the dynamics of solar radiation output, to adjust climate change models. Aerosols are not considered in this paper.

9. See IPCC (2000a), Table 2, p. 5. Average annual budget of CO_2 for 1989-1998. Emissions from fossil fuel combustion and cement production: 6.3 ± 0.6 GtC yr^{-1}; emissions from land-use change: 1.6 ± 0.8 GtC yr^{-1}.

10. O'Neill and Oppenheimer (2002).

11. German Advisory Council on Global Change (1995); Kreileman and Berk (1997).

12. For a copy of the Brazilian Proposal, see: http://unfccc.int/resource/docs/1997/agbm/misc01a3.pdf.

13. If the concentration target refers only to CO_2, the presence of non-CO_2 GHGs will represent nearly an additional 100 ppm of CO_2 equivalent. For a discussion of the relative warming potential of the major greenhouse gases, and the uncertainties associated with each, see Reilly et al. (2003).

14. Berk et al. (2001).

15. Reference year is 1990.

16. For an analysis of the rationale for adopting 550 ppm as a stabilization target, see UK government (2003).

17. Wigely et al. (1996).

18. The IPCC scenarios project concentration levels in 2100, but these do not represent ultimate stabilization levels, as concentrations will continue to rise over several centuries due to the slow decay of GHGs in the atmosphere.

19. The costs estimated in this figure are, at best indicative. Costs depend on a variety of factors, including the baseline (i.e., what the trend would have been without a mitigation policy); burden-sharing arrangements and access to market flexibility mechanisms; how transaction costs, information availability, and market clearing are accommodated; questions related to net present value of future costs, discount rates, future technological innovations, and induced technological change, and possible learning curves. Many models do not include ancillary benefits of mitigation action (benefits to public health and local pollution may be significant—and difficult to measure), or rates of natural uptake of carbon. Finally, for perspective, it is important to bear in mind that global GDP in 2050, the baseline for the cost figures presented, is projected to be 4 to 9 times higher than in 1990.

20. It is true that, even for more stringent targets, trajectories can be proposed that require little near-term action and shift the burden instead to later years. However, given the required magnitude of such out-year reductions, it seems unlikely that the technical or political capacity would exist to implement such rapid changes.

21. Such an idea underpins the work of Pizer (1997) and the IEA (2002).

References

Berk, M.M., J.G. Van Minnen, B. Metz, and W. Moomaw. 2001. "Keeping our Options Open. A Strategic Vision on Near-Term Implications of Long-term Climate Policy Options." COOL-project. Programme Office NRP, Bilthoven, The Netherlands, November.

German Advisory Council on Global Change. 1995. "World in Transition: Steps Towards Global Environmental Solutions," Annual Report to the Federal Ministers of the Environment, and of Science and Technology.

German Ministry for the Environment and Nuclear Safety. 2003. ECOFYS "Final Draft Report on Evolution of Commitments under the UNFCCC: Involving newly industrialized economies and developing countries."

IPCC. 2000a. *Land Use, Land-Use Change, and Forestry*. Watson, R.T., I.R. Noble, B. Bolin, N.H. Ravindranath, D.J. Verardo, and D.J. Dokken (Eds.). A Special Report of the IPCC, Cambridge University Press, United Kingdom.

IPCC. 2000b. *Special Report on Emissions Scenarios, SRES*, A Special Report of Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press, United Kingdom.

IPCC. 2001, *Climate Change 2001. Third Assessment Report. Working Group I: The Scientific Basis; Working Group II: Impacts, Adaptation and Vulnerability; Working Group III: Mitigation*. WMO/ UNEP.

Klimatkommittén. 2000. "Proposed Climate Strategy," SOU 2000: 23.

Kreileman, G.J.J. and M.M. Berk. 1997. "The Safe Landing Analysis: Users Manuel," RIVM Report 481508003, Bilthoven, The Netherlands. Available at http://www.rivm.nl/bibliotheek/rapporten/481508003.html.

IEA. 2002. *Beyond Kyoto—Energy Dynamics and Climate Stabilisation*, OECD/IEA, Paris.

The New Economics Foundation. 2002. "*Fresh Air? Options for the Future Architecture of International Climate Policy*," United Kingdom.

O'Neill, B.C. and M. Oppenheimer. 2002. "Climate Impacts and the Kyoto Protocol," *Science* 296: 1971-2.

Pizer, W.A. 1997. "Prices versus Quantities Revisited: The Case of Climate Change," Discussion Paper 98-02, Resources for the Future, Washington D.C., October.

Reilly, John M., Henry D. Jacoby, and Ronald G. Prinn. 2003. "Multi-gas Contributors to Global Climate Change," Pew Center on Global Climate Change, Arlington, VA.

Swedish Environmental Protection Agency. 2002. "Kyoto and Beyond. Issues and Options in the Global Response to Climate Change," Stockholm.

UK Government. 2003. "The Scientific Case for Setting a Long-term Emission Reduction Target," a companion document of the *White Paper on Energy*, February.

Wigley, T.M.L., R. Richels, and J.A. Edmonds. 1996. "Economic and environmental choices in the stabilisation of atmospheric CO_2 concentrations," *Nature* 379: 242-245.