5

The present impasse and steps forward

In the previous chapters, we have summarized the present state of knowledge and uncertainty on climate change. We have reviewed what is known about the climate and how it is changing, the evidence for a human contribution to the observed changes, and the range of potential changes projected for the coming century, as well as the weaker state of knowledge about potential climate-change impacts and responses. This final chapter is more political, in two senses. First, we present a detailed examination of the present deadlocked politics of the issue, reviewing both who is lining up where, and what arguments are being advanced that are contributing to the current deadlock. Second, we present our own judgments of what kind of response to the climate issue appears to be appropriate, prudent, and practical in view of present scientific knowledge and political alignments.

5.1 Climate-change politics: present positions

Although climate change has been on policy agendas for more than a decade, progress on the issue is stalled both domestically in the United States of America and internationally. As discussed in Chapter 4, there are several broad types of response to the climate issue, including mitigation (reducing emissions), adaptation, and geoengineering. But present controversy, and the present deadlock in policy-making, are nearly exclusively concerned with mitigation – whether to take near-term policy action to reduce emissions, and if so, how stringently and of what form. Mitigation is the principal focus of controversy because it is the form of response for which near-term decisions are most clearly required, and the form of response that most centrally involves the exercise of governmental regulatory authority over private actions. Both adaptation and geoengineering, correctly or not, are widely perceived as being decisions to be made in the future, or as less intrusive into citizens' lives and choices.

In the USA, there has been little progress since President Bush's 2001 decision not to ratify the Kyoto Protocol. As discussed in Chapter 1, current US policy emphasizes research and voluntary initiatives, with the weak aim of reducing national greenhouse-gas intensity – emissions per dollar of GDP – by 18 percent between 2002 and 2012. Given projected growth of the economy, this aim corresponds to a 12 percent *increase* in emissions over that period. Legislation proposed in 2003 (the "McCain–Lieberman bill") included somewhat stronger measures, capping aggregate emissions from the largest sources (about 85 percent of total US emissions) at their 2000 levels in 2010 using an emission trading system. In an October 2003 vote in the United States Senate, this bill was defeated 55 to 43, a surprisingly strong showing in view of the Senate's prior hostility to mitigation measures. In the absence of effective federal action, more than half the States have begun developing mitigation strategies, several of which include comprehensive reduction targets for statewide emissions. California has proposed the measures of greatest potential importance, using its unique authority to regulate motor vehicle pollution to require phased reductions in vehicle CO_2 emissions beginning in the 2009 model year, reaching 30 percent cuts by 2014 (although this regulation is currently facing legal challenges).

At the international level, the USA withdrawal wounded the Kyoto Protocol, but it remains unclear whether the wound is mortal or not. Protocol signatories made substantial progress over the few years following its signature, culminating in the agreements reached in 2002 in Marrakech, in defining the rules for the first round of mitigation commitments in 2008–2012. These agreements were followed by the ratifications of most major industrial nations, then in November 2004 – after several years of ambiguous and contradictory statements – ratification by Russia, which put the Protocol over the required emissions threshold and allowed the protocol to enter into force in February 2005. Most industrialized nations have adopted policies to pursue their Kyoto commitments, although the strength of these measures and their likelihood of success vary greatly. In the strongest positions are the UK and Germany, which are both likely to reduce emissions beyond their Kyoto commitments by substantial margins due to a combination of fortunate circumstances and strong policies. The EU as a whole is making progress toward its promised 8 percent reduction, albeit more slowly. Its aggregate 2002 emissions were 2.9 percent below the 1990 baseline. In addition, the EU has adopted both national targets for member states and – reversing a long-standing skeptical stance toward flexibility measures – an emission-trading system for large sources that will begin in 2005. Japan's policy to pursue its required 6 percent reduction, announced in April 2005, relies on sectoral reduction targets (especially for industry and electrical generation), backed up by a combination of voluntary measures, standards for building efficiency and renewable energy, and government purchasing of low-emissions vehicles, although there is also substantial reliance on sinks and purchased credits. Of the major industrial-country parties, Canada is the least likely to meet its targeted cut of 6 percent, having ratified late following a decade of strong emission growth and unproductive domestic consultations on mitigation measures. Even optimistic official projections suggest that mitigation measures identified and implemented to date are only likely to achieve about one-third of the reductions required under the Protocol.

On the crucial questions of extending and strengthening mitigation commitments beyond 2012, including expanding their scope to the developing nations, essentially no progress has been made. The industrialized and developing nations remain sharply divided on the linked questions of what mitigation commitments developing nations will take on, how soon, and how much financial and technological assistance they will receive in return. Several major oil-exporting states remain adamantly opposed to any mitigation and demand that they be compensated if any is enacted, while the small island and low-lying coastal states, several of them threatened by inundation from sea level rise, continue to plead for aggressive mitigation and assistance, to little effect. Overall, there is no serious international deliberation underway over how to develop an effective mitigation regime over the crucial window of the next few decades.

Among non-government actors, environmental groups predictably favor early mitigation efforts and most support the Kyoto Protocol, including US ratification. Equally predictably, most industry groups oppose the Protocol, although industry positions on broader questions of mitigation and climate policy are more mixed and more interesting. The most active opponents of any near-term mitigation are the major fossil-fuel producers, their industry associations, and their affiliated non-governmental organizations – with the conspicuous exceptions of two oil majors, BP and Royal Dutch/Shell, which are instead positioning themselves as environmentally responsible energy companies. Even the other oil majors have shown recent signs of hedging their bets and softening their anti-mitigation rhetoric. Perhaps this reflects a guess that mitigation is inevitable sooner or later and it is best to appear constructive. Alternatively, it may reflect a recognition that all the low-cost, conventionally exploitable oil and gas will be burned in any case, and consequently that the effects of mitigation policy on them will depend on who captures the benefits of the resultant price increases. Coal producers are most threatened by mitigation, except to the extent that rapid expansion of carbon separation and sequestration technologies mutes this threat, and are most forceful in their opposition.

The stance of the major non-energy industrial firms shows somewhat more flexibility toward mitigation. While none has explicitly supported mitigation policies, a few dozen support organizations that recognize the seriousness of climate change and promote constructive responses. These organizations do not support or oppose specific mitigation proposals, but instead stress the importance of any policies meeting certain principles: for example, that they be science-based, cost-effective, international, and applied broadly and equitably rather than singling out particular industries. A few business sectors have moved further toward supporting mitigation – including minor ones like the skiing industry (the "small island states" of the private sector), which endorsed the 2003 McCain–Lieberman bill, and major ones like the insurance and finance industries, which view climate change as both a risk to asset values and a potential market opportunity for new financial instruments. Thus far, however, these industry groups still carry less clout than those opposing mitigation or sitting on the fence. Overall, while an increasing number of leading firms in the USA and more in other industrialized nations are at least muting their opposition to mitigation, these movements remain small and tentative. Without leadership from governments, there are too many business risks for even the most responsible and far-sighted firms to pursue mitigation efforts on their own.

5.2 Climate-change politics: the arguments against action

A glance at the present policy debate shows that many people, including many leading figures in the present US administration, oppose near-term mitigation efforts. Opponents of mitigation advance several arguments to support their position, of three main types: attacks on the specific terms of the Kyoto Protocol; rejections of the scientific evidence for climate change; and claims that large emission reductions will be excessively, perhaps ruinously, costly. In this chapter, we summarize and critique these arguments. We address the specific arguments against the Kyoto Protocol in this section, the arguments against the scientific evidence for climate change in Section 5.3, and the arguments that mitigation is too costly in Section 5.4, where we also present our own outline of a proposed response to climate change.

Because the Kyoto Protocol is the most important current initiative in international climate policy, much of the present debate focuses on the Protocol itself rather than the broader question of what type of response to climate change, including how much mitigation effort, is appropriate. Since the initial negotiation and signing of the Protocol, opponents have argued that the Protocol is "fatally flawed" and must be abandoned, based on several lines of attack. Some of these – for example, attacks on the Protocol's flexibility mechanisms and implementation provisions for vagueness or loopholes – have declined in prominence and persuasiveness in the past few years as these elements of the Protocol have been improved. The principal continuing attacks are directed against the Protocol's emissions commitments themselves, on two grounds: that they do not require actions by the major developing countries; and that they are arbitrary and not based on science. We consider these in turn.

It is correct that the Kyoto targets do not include any developing-country obligations for the first commitment period, nor any guarantee that these countries will accept mitigation commitments in the future. The treaty was drafted this way for both practical and principled reasons. As a practical matter, negotiators recognized that industrialized countries had more technical and financial resources to make initial policy changes and investments, and were willing to make these initial commitments when developing countries were not. It was also widely argued that because past fossil-fuel use by the industrialized countries is responsible for most of the present buildup of atmospheric greenhouse gases, these nations have the obligation to take the lead in slowing the changes. Even before the Protocol negotiations, this widely endorsed normative view had found formal expression in the Framework Convention's Principle of Common but Differentiated Responsibility.

But critics of the Protocol dispute both the practical and normative basis for this approach. They argue that not controlling developing-country emissions makes the treaty ineffective, because emissions-intensive industries will simply move there rather than reducing emissions. This movement of investment will offset any reductions being made in industrialized countries, and will obstruct subsequent attempts to extend mitigation efforts to developing countries. They also argue that excluding developing countries is unfair, because these nations are already both major competitors in many sectors of world trade, and major emitters of greenhouse gases – and will soon grow to make up the majority of world emissions – so letting them not make cuts will put the nations that are cutting emissions at a major competitive disadvantage.

There is some merit in these arguments on both sides. A mitigation regime must eventually achieve near-global participation if it is to be effective, and therefore must not erect obstacles in the path of its own expansion. But this condition does not require full global participation immediately. Rather, a regime that is designed to absorb new members and that provides strong enough incentives for them to join can be viable even if it begins only with a relatively small "coalition of the willing."

Any judgment about how the burden of responding to climate change should be shared will reflect some balancing of past responsibility, projected future responsibility, and capability. Greater historical responsibility and greater financial and technological capacity both suggest that the rich industrialized countries should take the lead in initial mitigation efforts. But the projected surge in capital investment in developing countries, even in the near term, represents a major opportunity to limit future emission growth by shifting this investment toward lower-emitting technologies. Moreover, as the economic growth projected over the next few decades in the developing countries increases both their incomes and their emissions, their responsibilities to contribute to global mitigation will also increase.

With this large disparity between past responsibility and projected future responsibility, reaching agreement in advance on how to share future contributions to global mitigation may well be impossible. Rather, the appropriate balance of effort can probably only be resolved in the evolution of the regime over time, not in a once-for-all bargain or formula. The Framework Convention's principle seems to capture the required approach about as specifically as could reasonably be negotiated in advance: all must participate, but how much depends on their degree of capability, responsibility, and concern. Because these will all shift over time, the distribution of contributions to mitigation will also have to shift over time. Expanding participation over time to include mitigation efforts in the developing countries will be essential, although this does not necessarily mean that developing countries will pay the entire cost of these: there are various ways that the location of mitigation can be separated from who pays for it. But demanding global participation from the outset virtually assures an extended deadlock in which no action is taken. Indeed, sustaining the present deadlock might well be one of the unstated goals of this debating tactic.

The second major charge against the Protocol's emission limits is that they are arbitrary, not based on science, and paradoxically, that they are both too strong and too weak: too strong and thus too costly in the near term, but too weak to achieve any serious reduction of global climate change. Like the criticisms of the Protocol for excluding developing countries, the factual basis for these changes is largely correct, but their implications for action are not clear. In particular, they are not sufficient to conclude, as the critics do, that the Protocol must be rejected. Rather, reaching this judgement requires considering what the likely alternative course of action would be if the Protocol were abandoned, and whether this would be preferable.

The Protocol's targets are arbitrary, because they reflect a bargained compromise between some nations that sought stricter targets and others that sought weaker ones or none. In this respect they resemble all politically negotiated outcomes: arbitrariness is no special weakness of the Kyoto Protocol. Nor are the targets "based on science," because scientific knowledge cannot specify any particular level of emission target. Scientific knowledge can help inform decisions about targets, by projecting the consequences of alternative emission levels – faster climate change from weaker emission controls, slower climate change from stronger ones. Science might even help to identify emission paths associated with a large increase in the risk of abrupt climate changes – although this would require substantial advances from present knowledge. But without some confidently known environmental threshold that everyone would agree must be avoided, no emission target is more or less "based on science" than any other. This charge could be leveled equally against any emission target, and so is essentially meaningless.

It is also largely correct that the Kyoto Protocol's mitigation targets are too strict in the near term and too weak in the long term. Perhaps they were not too strict at the time they were negotiated in 1997, when they allowed 11–15 years to meet the targets: this is debated. But in the eight years since then, only a few nations have made serious efforts to meet the targets. With less than three years left to the start of the commitment period, nations whose efforts are not well underway face a choice between three highly unattractive options: adopting a high-cost, crash program to cut emissions rapidly (if this is even possible); violating their commitments; or relying predominantly on purchased emission credits, thereby weakening the global reductions that are actually achieved. At the same time, the Protocol lacks longer-term targets or measures after 2012, or even specific principles or guidelines for negotiating these, making it ineffective at managing climate change over the required multi-decade time horizon.

These are serious flaws, which must be corrected if the Protocol is to become an effective international instrument for managing climate change. Can they be corrected? The Protocol's flaws are widely recognized by its supporters as well as its opponents, and the most severe ones are likely to be improved – as some already have been – through further negotiations. This is how effective environmental treaties work: they do not resolve environmental issues once and for all, but progressively refine and improve their management over time. If the Protocol is retained, it must evolve as other treaties do, adapting and changing as old problems are resolved and new ones are identified, as political and economic conditions change, and as scientific knowledge and technological capabilities advance.

Many attacks on the Protocol have ignored this evolutionary character, however. They pretend that the present treaty will persist unchanged, to strengthen the case that it should simply be abandoned. In fact, many opponents of the Protocol oppose *any* near-term mitigation effort, but focus their attacks on the Protocol because its clear flaws – particularly under the ridiculous assumption that it will never be amended – make it a vulnerable target. By implying that the Protocol in its present form is the only mitigation option available, they can use its many weaknesses to appear to discredit any mitigation program.

Noting the illegitimacy of this debating tactic does not, however, answer the question of what to do with the Protocol. Supporters of a serious mitigation effort must still consider whether the Protocol should be kept and improved, or abandoned – a question that turns on comparing the Protocol to the likely alternative if it is abandoned. Is this completed but flawed treaty more likely to help or hinder the required longer-term mitigation efforts – including the expansion of mitigation to include developing countries – considering the risk that starting over could produce an extended deadlock or an even more deeply flawed instrument? We will discuss our views on this question of practical politics in the concluding section.

5.3 The present policy debate: use of scientific knowledge and uncertainty

In contrast to the state of knowledge we summarized in Chapter 3, claims are frequently made in the climate-change policy debate that present scientific knowledge does not provide evidence of serious risks from climate change, and certainly does not justify bearing any significant cost to reduce emissions. These arguments take two forms. First, some advocates dispute nearly every specific point of scientific knowledge that we have summarized. We discuss this tactic in Section 5.3.1. Second, instead of making specific scientific arguments, some advocates argue more generally that climate science is too uncertain, so we should wait for more knowledge to reduce uncertainty before taking costly actions that might turn out to be unnecessary. We discuss this broader argument in Section 5.3.2. In both cases, we explain why in our judgment these arguments should be rejected.

5.3.1 Major claims of the "climate skeptics"

In Chapter 3, we summarized present evidence that the Earth's climate is warming rapidly, that greenhouse-gas emissions from human activities are the predominant cause of the most recent rapid warming, that climate will continue to warm over the next century, and that while the precise rate and regional details of future change are uncertain, the range of projected changes includes some that would carry severe impacts. Each of these points, however, is denied by many policy actors who oppose action on climate change and by a small group of self-styled "scientific skeptics" who provide support for these policy views. These people state that the Earth is not warming; that if it is warming, human activities are not responsible; that future warming, if it occurs at all, will be predominantly due to natural causes and much smaller than present projections; and that climate change is on balance likely to be a good thing for people, for various reasons including people's general preference for warm climates and the effects of elevated atmospheric CO_2 on plant growth. Some advocates even claim that these contrarian views are in fact backed by a strong scientific consensus.

These skeptical arguments are rarely if ever advanced in scientific arenas, but in editorial pages, on the internet, or in policy arenas where more lenient standards for evidence and argument apply. Those arguments can be persuasive, both because they sound plausible to those unfamiliar with the relevant scientific literature and because they are often presented in combination with broader political arguments or effective rhetorical devices, such as painting your opponents as extremist, corrupt, or foolish. The media's tendency to uncritically balance opposing views enhances the effectiveness of these arguments, by seeming to give marginal or transparently false claims the same stature as well supported consensus scientific views. In this section, we discuss a few of the most prominent of these skeptics' claims and explain why they are wrong.

> *Skeptics' Claim 1.* ***The Earth is not warming***[1]
>
> Evidence of recent warming rests solely on the surface thermometer record. Such data are contradicted by satellite measurements, which are far more reliable. Satellite measurements show a very small warming trend since measurements began in 1979 – about 0.06 °C per decade, much too small to be noticeable.

Despite the seeming plausibility of this argument, each of its points is either outright false or highly contestable. As we summarized in Chapter 3, the first claim – that the surface thermometer record provides the only evidence of global warming – is simply false. The surface record is the single most important and comprehensive source of evidence for warming, but many other independent data sources – for example glacier retreat, shrinkage and thinning of sea ice, warming of seawater, and many forms of paleoclimatic proxy data – all support a consistent picture of a warming global climate.

The next two points – that the satellite temperature record is more reliable than the surface record, and that it contradicts the warming observed in the surface record – are also both simply wrong. Section 3.1.7 discussed the many uncertainties in the satellite data. Making different assumptions for handling these uncertainties produces widely divergent trends from exactly the same satellite data. There are also uncertainties in the surface thermometer record, of course – also

[1] The examples that follow are all composites of arguments advanced in newspaper editorial and op-ed pages and other opinion and policy sources over the past several years. For example, this composite claim is drawn from S. Fred Singer, Letters to the Editor: Bad Data Make Global Warming a Cold Case, *Wall Street Journal* (Eastern edition), Nov. 10, 2003, p. A17, and Cal Thomas, Don't succumb to warming hysteria, *Baltimore Sun* editorial page, June 12, 2002, p. 15A.

discussed in Chapter 3 – but there is no basis for claiming that these are larger than the uncertainties in the satellite trends. In 2000, a National Academy of Sciences committee conducted an in-depth study of the two records, and concluded that the satellite record is not more reliable than the surface thermometer record.

But do the satellite data contradict the warming seen in the surface record, and thereby cast doubt on the reality of global warming? Simple atmospheric physics dictates that warming in the lower atmosphere, which the satellite measures, should be slightly larger than warming at the surface. The earliest analysis of the satellite record, published in the early 1990s by the group at the University of Alabama at Huntsville (UAH), showed no warming in the lower atmosphere, contradicting the rapid warming seen in the surface data (Spencer and Christy, 1990). As the satellite record grew longer and several improvements were made in the trend calculation, the UAH group's calculated trend turned to a warming, although the trend has remained smaller than the observed surface warming. If one considers only the UAH calculation, then a discrepancy between the observed surface and satellite trends does exist. The causes and implications of such a discrepancy, however, are unclear. The 2000 National Academy of Science report examined the discrepancy as it then stood and concluded that the disparity between the surface and UAH-calculated satellite trends "in no way invalidates the conclusion that the surface temperature has been rising."

Moreover, several other scientific groups have recently published calculations of trends using exactly the same satellite data, but using different assumptions in their calculation, and have obtained trends as high as 0.26 °C per decade (see the discussion in Section 3.1.7). With satellite-derived trend estimates now ranging from 0.06–0.26 °C per decade[2] (versus a surface trend of 0.1–0.2 °C per decade), there is no longer any basis for claiming that the satellite data contradict the surface warming, let alone claiming that they invalidate the surface warming trend.

Finally, the point that warming of 0.06 °C per decade is insignificant and can simply be ignored, is a non-scientific judgment, and is highly arguable. In the first place, 0.06 °C per decade is the smallest of several estimates of the satellite trend, and there is no basis for claiming it is more likely correct than the other, higher estimates.[3] But even if the recent trend is this small, this rate of warming is certainly not too small to detect. Whether it is negligible or not depends on

[2] This does not include a possible correction for stratospheric cooling that would further increase the trends by 0.05 °C per decade.

[3] It is often claimed that the UAH calculation has been verified through comparison to weather-balloon measurements. However, weather balloons do not provide the gold-standard comparison suggested by this argument. In particular, balloons trends are susceptible to the same kinds of instrument and sampling inhomogeneities that affect the surface and MSU records. See the discussion in Mears *et al.* (2003) and the exchange in letters by Christy and Spencer, and Santer *et al.*, in *Science*, **301**, 1046–1049 (2003).

whether future warming is likely to be this small, and on the impacts of this warming. In particular, it is unlikely that future warming will be this slow: virtually all climate models suggest that twentyfirst-century warming is likely to be substantially faster than twentieth-century warming.

> *Skeptics' Claim 2.* ***The Earth may be warming, but human activities are not responsible***
>
> Even if the Earth is warming, this is probably not caused by human activities. It could be a natural climate fluctuation, perhaps part of the continuing recovery from the "little ice age," the cool period from the fifteenth to eighteenth centuries. Or it could be due to increased intensity of sunlight.

In this argument, the skeptics offer two alternative explanations for the observed warming of the twentieth century. The first is that the warming is a recovery from a global cold-period several hundred years ago known as the "little ice age." This suggestion is weakened by the fact that the little ice age, like the medieval warm period before it, appears to have been predominantly a regional variation in the climate around Europe, rather than a global phenomenon. But even if these variations had been global, this argument assumes that the Earth's climate system has a "normal" state that it pushes back to after unusually warm or cold periods, like a stretched spring returning to its normal length. While this might appear commonsensical, it has no foundation in either the record of how climate has varied or the fundamental physics of the atmosphere. The Earth's climate has no "normal" state to which the climate seeks to return, so there is no reason to expect that an unusually cool period will be followed naturally by a return to warmer conditions. This argument is really a different version of the claim that recent warming is due to internal variability of the climate system. As we discussed in Section 3.2, neither proxy records of past climate nor computer climate models suggest that climate can vary far enough or fast enough on its own (i.e. without human interference) to produce the rapid recent warming.

A related argument often heard in the public debate is that the warmth of the last few decades is not exceptional when compared to the climate of the medieval period – thereby implying that recent warming has a natural cause. The primary evidence supporting the unique warmth of the present period over the last thousand years is the proxy record plotted in Figure 3.8. This record is often referred to as the "hockey stick" plot, because it shows a long gradual decline followed by a sharp upturn in the past century, resembling the blade and handle of a hockey stick.

Several criticisms of this result have been made over the past few years. The first of these, and the most widely circulated in policy circles, was a 2003 paper (Soon and Baliunas, 2003) that reviewed the previously published climate-proxy data and concluded that the twentieth century was probably not the warmest period of the past millennium. In other words, this paper contained no new research but only reviewed previous work, yet it purported to overturn the conclusions of that previous work. This in itself provides reasonable grounds to view the paper with suspicion – especially if the previous work has been repeatedly tested by the scientific community and is generally believed to be correct. In this case, such suspicion is warranted (see the discussion of the paper in Monastersky, 2003). Indeed, the editors of the journal where this paper appeared have since suggested that it has such serious methodological errors that it should never have been published. For example, the paper erroneously treated evidence of past periods that were unusually wet or dry as if they indicated periods of unusual warmth, thereby greatly exaggerating the evidence for past warm periods. Moreover, the paper compared these questionable indicators of past climate not to the extreme warmth or rate of warming of the late twentieth century, but to the average temperature over the entire twentieth century. Since it is only the last few decades of the twentieth century that have surpassed estimated boundaries of natural variability, any comparison of the whole century to earlier periods misses the point: the relevant comparison is with the last few decades of the century. Despite these obvious problems, opponents of mitigation have repeatedly cited this paper as showing conclusively that there is nothing anomalous about recent warming. Even ignoring all the indications of serious errors in the paper, it does not support this conclusion.

More recently, there have appeared some more serious and better-founded criticisms of the mathematical methods used to generate Figure 3.8 from the scores of individual proxy records covering the planet. These recent criticisms (von Storch *et al.*, 2004; McIntyre and McKitrick, 2005) have pointed out genuine questions about the analysis, but their implications for our understanding of climate change are probably minor, for several reasons. First, they have not disproved or even attempted to disprove the primary conclusion of Figure 3.8, that today's warmth is remarkable. Rather, they argue that the uncertainty in Figure 3.8 may be greater than previously estimated, so it is *possible* that it underestimates the warmth of the medieval period (see also Moberg *et al.*, 2005). However, the possibility of errors in the hockey-stick plot has long been recognized, by the paleoclimate research community, the IPCC, and even the scientists who produced Figure 3.8. For example, the 2001 IPCC report (2001a) described the conclusion that the 1990s were the warmest decade in the past thousand years as only "likely," which indicates, in the carefully nuanced language they employed to denote degrees of confidence, as much as a one-in-three chance that the conclusion is wrong. It is unclear that these new criticisms substantially alter this confidence estimate. In addition, the hockey stick is not the only evidence that today's warming is probably mostly caused by human activities. Another strong piece of evidence is that climate models cannot reproduce recent warming unless observed increases in CO_2 and other greenhouse gases are included.

This nuanced explanation is not, of course, what climate skeptics argue. Rather, they state that recent criticisms have destroyed the hockey-stick plot – and, since the entire scientific case for global warming is built on the hockey-stick plot, that these criticisms show that global warming is a scientific fraud. This argument completely misrepresents the true state of knowledge about past climate variability and the origin of recent warming.

The second part of the overall skeptics' argument addresses solar output. Could changes in the Sun's radiation output account for the recent warming? Again as we discussed in Section 3.2, there is evidence that increased solar output contributed to warming in the early twentieth century. But satellite measurements of the Sun's output available since the late 1970s do not show enough variations in solar output to account for any significant fraction of the global climate warming of 0.1–0.2 °C per decade that has occurred over that period.

So these proposed natural causes cannot explain the rapid observed warming of the second half of the twentieth century. On the other hand, recent increases in atmospheric greenhouse gases do provide an explanation for recent warming that is theoretically well founded, and that matches the magnitude and the timing of recent warming well. As we discussed in Section 3.2, climate models that exclude recent increases in greenhouse gases cannot simulate the observed recent global climate changes, while models that include greenhouse gases reproduce recent global trends quite well. With this strong evidence in favor of greenhouse gases as the cause, and no evidence supporting alternative explanations, the strong scientific consensus is now that increases in greenhouse gases are responsible for most of the rapid warming of the past few decades.

> *Skeptics' Claim 3.* ***Future climate warming will almost certainly be very small***
>
> Even if human activities are causing the recent warming, temperature increases over the twentyfirst century and beyond will likely lie near the bottom of the projected range, or even below it.

Skeptics make two arguments that future warming will be small. The first is that the sensitivity of the global climate is much lower than presently believed, so the Earth will not warm much even if CO_2 emissions continue to grow.[4] The second

[4] Recall that the Earth's climate sensitivity measures the eventual (equilibrium) global-average warming that would follow a doubling of the pre-industrial CO_2 concentration. This is a crucial quantity for the climate-change debate, because if sensitivity is low, any specified increase in atmospheric CO_2 will cause less climate change than if sensitivity is high.

is that present projections of future emissions are too high, and that the only plausible future trend is that emissions will grow slowly or even decline – even with no effort to curb their growth.

The accepted range of sensitivity estimates has stayed roughly constant for the past few decades: 1.5–4.5 °C for a doubling of CO_2 concentration. Most of this wide range comes from uncertainty about how atmospheric water vapor and clouds will change as the climate warms. Water vapor is itself a strong greenhouse gas, and much of the warming predicted by climate models comes from increases in humidity that accompany the warming from increasing CO_2 – an effect known as the "water-vapor feedback." Consequently, one way to argue that climate sensitivity is low is to claim that humidity will not increase (or not much) as climate warms. Water vapor is so important that atmospheric scientists have spent great effort studying how it is regulated and how it will respond to climate change.[5] The conclusions of the great majority of this research have confirmed what common sense suggests: surface evaporation will increase in a warmer atmosphere, leading to increases in humidity. This conclusion remains somewhat uncertain, however, because the comprehensive, global measurements of water vapor that would definitively settle the issue are not yet available. Consequently, arguments that the water vapor feedback is very small or even negative are frequently advanced to oppose mitigation.

At present, the most prominent argument in favor of a small water-vapor feedback is the "iris" hypothesis (Lindzen *et al.*, 2001), which proposes that in a warmer climate, an increased fraction of the water vapor carried upward in tropical thunderstorms will fall out as rain. If precipitation increases more than surface evaporation does, the net result will be that a warmer climate is less humid and less cloudy. The main evidence supporting the hypothesis is the observation that upper-level cloud cover over a limited region of the western Pacific Ocean tends to decrease when the surface is warmer. By assuming that less cloud cover means less humidity, and that this correlation generalizes worldwide, the authors conclude that the atmosphere will dry out as the surface warms. If this is correct, then climate sensitivity and projected future warming would lie at or below the bottom end of the present accepted range.[6]

The iris hypothesis is often cited in policy debates as if it is conclusively established and so demonstrates that present warming projections are much too high. This argument, however, greatly misrepresents the extent to which the hypothesis is scientifically accepted. Since being published, the hypothesis has been subjected to many additional tests, and has not fared well. No subsequent study

[5] See IPCC (2001a), Section 7.2.1.

[6] The iris hypothesis is also a negative cloud feedback: as the surface warms and cloud cover is reduced, enhanced infrared emission to space puts a brake on warming.

has supported the hypothesis, and several have raised doubts about whether the observed correlation between cloud cover and surface temperature is statistically significant (Harrison, 2002), whether it can be attributed to a climate feedback process (Hartmann and Michelsen, 2002), and whether the hypothesized negative feedback would make more than a small reduction in climate sensitivity even if it were correct (Lin *et al.*, 2004). The proponents of the hypothesis have responded to these criticisms (Bell *et al.*, 2002; Lindzen *et al.*, 2002; Chou *et al.*, 2002). While the issue is not decisively resolved, the iris hypothesis presently has virtually no support in the relevant scientific community. It may gain additional support in the future and come to be accepted in some form, but it is so far from that point now that the present uncertainty range of 1.5–4.5 °C probably does a good job of incorporating any downward influence that the hypothesis will turn out to have. Any claim by policy advocates that the iris hypothesis is a well established result that overturns present understanding of climate sensitivity is an insupportable misrepresentation of present scientific opinion.

Others argue that climate will not change much because present projections of future emissions are too high, and that emissions will in fact grow little if at all. The implication is that explicit measures to limit future emissions are not needed, since emissions will not grow much in any case. This claim is highly optimistic in light of historical experience and present estimates of population, economic, and technological trends. This type of argument has also been a widely used stalling tactic in other major environmental issues: virtually every form of pollution that has been proposed for regulatory controls has been claimed by opponents of controls to be incapable of much growth. Climate change is unlike past environmental issues, however, since even if this claim were true, it would not avoid the need for mitigation efforts. Achieving long-term atmospheric stabilization will not just require stopping emission *growth*, but large reductions from present emission levels.

As with other skeptics' claims, it would be great if this were true: it would be most fortunate if emissions stopped growing without active intervention, just as it would be fortunate if the sensitivity of the climate and environment to human disruptions was actually very small. But the claim that emissions will not grow is advanced as pure assertion, with virtually no rational foundation. Any particular projection of global emissions, low or high, is likely to embed assumptions that appear unreasonable when particular small regions or countries are examined, but these usually have a very small effect on the global total. Worldwide, emissions have grown inexorably with growth of world populations and economies, and are likely to grow even faster if world energy systems shift further toward coal and synthetic fuels as cheap conventional oil and gas decline. The only support for the claim that emissions will not grow much is that over the 1990s, emissions grew substantially more slowly than estimated by the IPCC scenarios. But this discrepancy is for just one decade and says very little about future trends, particularly in view of the large shift toward coal in newly planned power plants over the past few years. The range of emission projections is wide because both very high and very low scenarios are plausible based on present knowledge – and since it is well established that people tend to estimate uncertain quantities too confidently, there is no doubt some chance that emissions will lie even outside this wide range, either above or below. The wide range of possible emission futures gives wide latitude for partisan projections: advocates of stringent cuts can claim the highest projections are the most likely, while opponents of controls can claim the lowest are most likely. In fact, either the top or bottom might turn out to be correct, but present knowledge provides no basis for betting confidently on either of them – and roughly in the middle is probably a better bet than either the top or bottom. Rather, any responsible approach to the climate issue must consider the possibility that any point in the range may turn out to be correct.

It is not possible to address all the erroneous and misleading claims advanced in the climate-policy debate. They are too numerous, and they are also a moving target. The advocates advancing these arguments typically retreat step-by-step, as their current claims shift from being merely unsupported to patently ridiculous. For example, while political commentators and editorials still occasionally claim that the Earth is not warming, most prominent scientific skeptics have retreated from this claim over the past few years – much later than the accumulation of evidence warranted, to be sure, but still an indication of their need to maintain some semblance of scientific credibility. We have also focused on the strongest skeptical arguments, giving less emphasis to those that are not just misleading, but patently false. For example, some skeptics have claimed that the surface thermometer record shows no warming over the continental United States – a brazenly false claim, which requires picking and choosing observations to exclude those that show the strongest warming.

Finally, we should note that there are ample opportunities to use biased, misleading, and erroneous scientific arguments on all sides of policy debates. In preparing this book, we have looked hard for prominent, purportedly scientific claims from environmental activists that are as biased or misleading as those discussed here from skeptics, but there is little to be found. A few individual activists make insupportably strong claims about severe human-health impacts from climate change, including asserting that climate change already occurring is implicated in the recent resurgence of infectious diseases. A few others implausibly exaggerate the technological options presently known that would allow mitigation at zero or negative cost – although technological progress could well turn these present wild exaggerations into future realities. But the climate-change statements of the major environmental groups are quite careful, and there is nothing on the environmentalist side resembling the cottage industry of climate skeptics and supporting organizations publishing their claims. Even the two most prominent recent books by climate skeptics that criticize environmentalists' exaggeration of climatic threats find little to attack. One author could find only a few general statements that climate change is one of the most important environmental challenges (or the most) that society faces – pretty tame stuff, which makes no claim to represent specific scientific knowledge, and which may well be true.[7] The authors of the second book charge unnamed environmentalists with spreading a vision of a "hellish climatic catastrophe," but can find no stronger support for this claim than a few statements by President Clinton and Vice-President Gore that recent extreme weather events *might* be linked to global warming.[8] It is certainly possible to exaggerate environmental risks relative to scientific knowledge, and environmental advocates have sometimes done it. But in the present climate-change debate, the weight of misrepresentation appears to lie strongly with the so-called skeptics and the policy actors who use their arguments to oppose greenhouse-gas mitigation.

5.3.2 Defending the boundary between scientific and policy debates: scientific assessment and policy skepticism

Chapter 2 discussed why the use of unsupported and biased scientific arguments is so widespread in policy debates, even when more legitimate non-scientific arguments could be advanced to support the same policy positions. The reason is that the tactic works: because scientific claims get special deference and respect in policy debates, they are frequently effective at persuading people, particularly when the arguments support the listener's prior policy views or are being advanced by someone whose political values they share. Moreover, the risk of being discredited for advancing weak or false scientific arguments is small, due to the lower standards of evidence and argument in policy than in scientific arenas.

As a result of these incentives, the picture of climate-science knowledge offered by the policy debate has remained contentious and uncertain, even as the actual state of scientific knowledge has grown stronger and more consensual. The supposed scientific arguments being waged in the policy debate do not mirror any present debate among climate scientists, but simply obscure or misrepresent

[7] All quoted in Lomborg (2001), p. 258.

[8] Quotes reproduced in Michaels and Balling (2000), pp. 7–9. A subsequent book of the same character (Michaels, 2004) mainly criticizes selected examples of journalists highlighting or exaggerating alarming environmental news, and finds only one borderline example of a misleading statement from an environmental group – a rather shrill 2002 press release from Greenpeace.

settled questions. At the same time, this diversion of the policy debate to specious scientific arguments has stifled discussion of economic and political questions, both positive and normative, on which a vigorous public debate should be taking place but is not.

Paradoxically, the increased prominence of distorted scientific claims on climate change over the past several years may partly be a consequence of the growing strength of scientific evidence for the reality and seriousness of climate change. Like negative political campaigns, misrepresenting scientific knowledge in policy debates is a last-ditch strategy, high in risk but potentially effective, available to a side that is losing. Ten or fifteen years ago, opponents of action on climate change could draw on moderately credible scientific claims that are no longer available to them. As scientific consensus has strengthened on key positive points that most citizens and policy-makers would judge to warrant a serious policy response, those who wish to use scientific claims to oppose action are forced to resort to increasingly tendentious, shrill, or misleading claims, or outright false ones.

A similar process has occurred on prior environmental issues as scientific knowledge converged and the issues shifted from matters of scientific dispute to policy action. Once again, the ozone layer provides the closest parallel to the climate-change issue. In the early 1990s, as a policy consensus developed to eliminate CFCs and several other chemicals, based on a strongly converging – although not complete or perfect – scientific consensus about their contribution to ozone depletion, a fierce backlash appeared that prominently circulated several real remaining scientific uncertainties and anomalies, together with all manner of long-refuted and ridiculous claims, in an attempt to roll back policies. Participants in this earlier ozone backlash included several of the same individuals who have now re-appeared as climate skeptics.

What can be done to limit the scope for partisan distortion of scientific knowledge in policy debates? One approach that is not likely to be effective is exhorting the purveyors of false and misleading scientific claims to be more honest. The powerful incentives to use scientific arguments in policy debates – good ones if you have them, bad ones if you don't – are likely to overwhelm any such attempt at moral suasion. Moreover, even if public exposure destroys the credibility of one or a few egregious liars – which seldom happens – the rewards of this role provide ample incentive for others to step up and take their place.

Rather, two approaches are likely to be more effective in reducing the influence of partisan distortion of scientific knowledge in policy debates – and consequently in reducing the incentives to practice such distortion: encouraging participants in policy debates to be more skeptical in evaluating these claims; and ensuring that authoritative scientific advice is available to policy debates through processes that are credible, legitimate, prominent, and have some protections against partisan attack.

Promoting more skeptical treatment of scientific claims advanced in policy debates is the first step, both for claims that are promoted as "skeptical" and for others, even if this cannot equal the rigor with which new claims are scrutinized in scientific settings. Skepticism toward partisan argument is indeed a virtue and it is ironic that those now advancing distorted scientific claims on climate change call themselves "skeptics," since their success depends on policy-makers and citizens not questioning their claims too closely.

An effective skeptical stance depends on asking questions about the foundation of the claim being made. If, for example, someone asserts that the Earth's climate either is, or is not, warming, it is first necessary to ask whether the source of the claim is both expert and impartial – noting that merely holding scientific credentials does not guarantee impartiality. Is the claim based on a peer-reviewed publication? Has it been verified by additional peer-reviewed studies and widely accepted by the relevant scientific community? Are there opposing scientific views? Who holds these opposing views – how many people, of what level of relevant expertise – and what are the grounds for saying that one view is right and the others wrong? Parties to a policy debate should ask these questions, just as scientists would ask them as part of their evaluation of a scientific claim.

Moreover, in policy debates, it is especially important to be skeptical of your friends. Anyone is most at risk of being misled by deceptive and erroneous scientific arguments that are consistent with their own prior beliefs. If you are generally suspicious of unregulated markets and free trade, mistrust the integrity of corporate management, and support government regulation, you are most at risk of being misled by unsupported claims that an environmental risk is well established, immediate, and grave. If you hold the opposite political views – i.e. you believe unregulated markets and free trade advance welfare, regard corporate management as basically trustworthy, and oppose regulation – you are most at risk of being deceived by unsupported claims that support the opposite conclusions – that an environmental risk is undemonstrated, remote, and probably minor. But the true state of the world, and the true state of scientific knowledge about it, takes no account of political values, yours or anyone else's. Making informed and prudent decisions on environmental issues depends on getting access to this knowledge without a political filter.

But no matter how well policy actors follow this advice, scientific claims cannot be evaluated as carefully in policy debates as they are in scientific settings. Since the central problem of scientific advice to policy is that policy actors cannot independently evaluate contending scientific claims, they must to some extent rely on trust. But how can you decide what individuals, institutions, or processes to trust? There is no foolproof guide, but there are hints. Just as publication and subsequent verification in the peer-reviewed literature provide evidence of credibility, publication in certain other outlets provides grounds for suspicion. Claims that are advanced exclusively or primarily in self-published media (for example the internet or publications of advocacy organizations) or in newspapers, particularly in editorials or other opinion pieces, should be viewed with skepticism. So should any claim that a single peer-reviewed scientific paper represents settled knowledge or, even worse, single-handedly overturns an established scientific consensus. Skepticism is particularly warranted for sources that use polemical language or make personal attacks, that state no limits to the certainty or scope of their claims, or that cannot tell what evidence does, or could, weaken their claim.

The most trustworthy source of scientific information for policy debates, and a more practical source than the peer-reviewed literature itself, comes from official scientific assessment processes. As Section 2.5 discussed, scientific assessment processes synthesize, evaluate, and summarize scientific knowledge to inform a decision or a policy debate, often at the request of relevant governmental or international decision-making bodies. Establishing and maintaining effective assessment processes is the most effective way – along with cultivating policy actors' skepticism about scientific claims – to reduce the scope for partisan distortion of scientific knowledge in policy settings.

The principal scientific assessment body for climate change is the IPCC, whose history we presented briefly in Chapter 1 and whose conclusions we have drawn on throughout this book. In gradual steps, IPCC Working Group 1 has made a series of careful statements that have marked out the advance of the scientific consensus about climate change over the past decade. Their 1995 Summary for Policymakers stated that "the balance of evidence suggests that there is a discernible human influence on global climate."[9] Their 2001 summary strengthened this, to say "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities," and moreover that the warming projected for the twentyfirst century is "very likely to be without precedent during at least the last 10,000 years."[10]

The organization and operations of the IPCC are similar to the highly successful scientific assessment panel previously established for stratospheric ozone, although with the important difference that governments maintain official control over the IPCC. Although this odd hybrid status of the IPCC – partly a scientific body, but partly under governmental control – initially generated confusion and conflict, the IPCC has subsequently developed procedures that have successfully clarified and managed the boundary between its scientific and governmental

[9] See IPCC (1996), p. 4. [10] See IPCC (2001a), pp. 10, 13.

aspects. Under these procedures, governmental control has little or no effect on the detailed work of the assessment, where expert scientific writing teams have full control over the actual report and its technical summary. Governmental control matters most in formal plenary sessions, where national representatives negotiate the Summary for Policymakers – the shortest and most widely circulated product of each assessment report – line by line.

Because of the number, breadth, and stature of the participating scientists, the criticality and thoroughness with which they review the scientific literature, and the rigor with which their reports are peer reviewed, the IPCC assessments have achieved extremely high credibility and significant influence in the policy debate. There have been essentially no substantive criticisms leveled against the content of the reports. They are widely used as references by scientists working in the field or moving into it, and accepted as authoritative by virtually all policy actors engaged in the issue.

The exception to this near-universal acceptance of the consensus stated in the IPCC is in policy debate in the USA. Here, opponents of mitigation have attacked the IPCC reports and their conclusions. They have, in a sense, been compelled to make these attacks, since not doing so would amount to conceding the reality and seriousness of climate change and thereby giving up the supposed scientific basis for their policy positions. Even in the USA, however, advocates who care about their scientific credibility have rarely attacked the IPCC's substantive conclusions. Rather, they argue that the IPCC's process, and consequently the nuances of language in which its conclusions are expressed, are biased toward an alarmist view of climate science and an activist policy stance.

Such an argument might at first seem reasonable. Given the high stakes of the climate issue and the powerful status of scientific claims in policy debates, many policy actors would wish to exercise political influence over IPCC assessments if they could. But the charge does not stand up to scrutiny. IPCC reports are written by hundreds of scientists from dozens of countries, and reviewed by hundreds more individual scientists as well as member governments. All review comments and authors' responses to them are available for public scrutiny. Given the massive and diverse participation and the transparency of the process, any attempt to bias the report toward someone's preferred conclusion would be both offset by opposing pressures, and severely limited by the open character of the deliberations.

Still, on entering office in 2001, the Bush Administration was sufficiently concerned about charges of alarmist bias in the IPCC that it took the unusual step of asking the National Academy of Sciences to conduct an additional review of the 2001 Assessment. This review reaffirmed the soundness of the IPCC report and its major conclusions, as did a subsequent series of official statements by the

American Geophysical Union and the American Meteorological Society.[11] The 2001 IPCC assessment has probably been subjected to more review and scrutiny than any scientific report in history, and all reviews have supported its conclusions. If any bias operates on the IPCC process, it is scientists' general conservatism in evaluating new claims, which grants a massive, grave authority to the assessments' major conclusions.

A subtler charge of bias against the IPCC has been that while the underlying reports are impartial scientific statements, the Summary for Policymakers – a short, non-technical summary drafted by national representatives in plenary session – misrepresents the full report by exaggerating risks and understating uncertainties and qualifications. There have certainly been a few well-known past occasions when the summaries of other scientific assessments of environmental issues have misrepresented the main assessment report – although these occasions have more frequently involved understating environmental risks than overstating them – so this charge merits a serious examination. But like the broader charge of bias in the IPCC, it has not held up. The National Academy of Sciences review was specifically asked to address this charge, and found that the Summary for Policymakers of the Working Group I report appropriately represented the full report, given the need to summarize a thousand-page document into nineteen pages and simplify it for a non-scientific audience. Indeed, the conservatism that pervades the whole IPCC process is also present in the plenary sessions that compose the summary for policy-makers, despite their more political character, both because the scientific lead authors participate in this stage and because many of the government representatives who participate at this stage are in fact government-employed scientists who also worked on the full assessment.

In sum, for all the difficulties they face, the atmospheric-science assessments of the IPCC are on balance highly credible, and highly effective. Their deliberations have maintained an impressive level of independence from political interference, despite an organizational structure that could readily have threatened such independence. To the extent that true synthesis statements of the state of scientific knowledge about climate change exist anywhere, it is in the IPCC assessments. They – and other scientific assessments that achieve similar quality of participation, deliberation, and peer review – are the "gold standard" of trustworthiness of policy-relevant scientific statements, and policy actors can do no better than to rely on them. The continuance of the IPCC's independence and effectiveness

[11] Available at http://www.agu.org/sci_soc/policy/climate_change_position.html, and http://www.ametsoc.org/POLICY/climatechangeresearch_2003.html, respectively.

cannot be taken for granted, however, and policy-makers who want continued access to scientific advice of this quality must be vigilant in defending it.

This discussion applies principally to the atmospheric-science assessments produced by IPCC Working Group I. The same arguments about the solidity of the consensus, and the coherent, prominent authoritative statements of key positive points of that consensus, apply much less to the areas of climate-change impacts and options for adaptation and mitigation covered by IPCC Working Groups II and III. These areas have harder questions to answer, less developed bodies of data and evidence, a much wider range of disciplinary diversity to integrate, and longer causal chains to analyze (for example, socio-economic trends make emissions make global climate change make regional climate change make diverse impacts on ecosystems, resources, and human societies). Consequently, it is more difficult to attain an authoritative consensus declaration about the state of relevant scientific knowledge in these domains than it is for atmospheric science. Moreover, Working Groups II and III also address areas in which it is much more difficult to achieve separation between positive questions, which in principle are amenable to scientific investigations, and normative questions, which are not. Predictably in view of these difficulties, the effectiveness of the reports by IPCC Working Groups II and III has been less than that of Working Group I.

5.3.3 Uncertainty and "sound science"

The specific claims denying the emerging consensus and attacks on the scientific assessment process of the IPCC are both relatively crude tactics. The evidence for and consensus supporting each of the positive points we have summarized, and the credibility of the IPCC, are both evident to anyone who takes a moment to look. More sophisticated opponents of mitigation advance subtler arguments. Rather than disputing any specific points, they argue more generally that the science of climate change is highly uncertain, so incurring potentially large costs to protect against climate change is imprudent and wasteful.

A political strategy memo prepared by a consultant to advise Republican candidates how to address the climate-change issue in the 2004 US elections and subsequently leaked to the press provides a strikingly direct statement of this strategy and its objectives.

> [W]hile the economic argument might receive the most applause at Chamber of Commerce meetings, it is the least effective approach among the people you most want to reach – average Americans . . . The typical economic approach taken by most Republicans to oppose many environmental rules and regulations simply does not move Democrats and has only limited appeal among independents . . .

> ***The scientific debate remains open***. Voters believe that there is no consensus about global warming within the scientific community. Should the public come to believe that the scientific issues are settled, their views about global warming will change accordingly. Therefore, *you need to continue to make the lack of scientific certainty a primary issue in the debate* . . . ***The scientific debate is closing [against us] but not yet closed. There is still a window of opportunity to challenge the science*** [emphasis in original].[12]

This general argument might be summarized as follows.

> The response to climate change must be based on sound science, not on speculation or theory. We must not rush to judgment before all the facts are in. There is too much uncertainty and too much that we do not know about climate change. It would be irresponsible to undertake measures to reduce emissions, which could carry high economic costs, until we know that these are warranted.

Parts of this argument are just rhetorical flourishes, such as the statement that policy should be based on "sound science." Setting these aside, the foundation of the arguments – that there is much uncertainty in present scientific knowledge of climate change – is uncontroversial. As President Bush stated when he announced that the United States would not ratify the Kyoto Protocol, "(W)e do not know how much effect natural fluctuations in climate may have had on warming. We do not know how much our climate could or will change in the future. We do not know how fast change will occur, or even how some of our actions could impact it . . . And finally, no one can say with any certainty what constitutes a dangerous level of warming and therefore what level must be avoided."[13] But the suggestion that uncertainty is overwhelming is highly misleading. As we have shown above, there are many points of climate science on which knowledge is quite advanced, and on several key points – such as whether the climate is warming, whether human activities are primarily responsible, and whether the warming is likely to continue – there is essentially no remaining uncertainty of any significance.

Moreover, the central point of this argument – that certainty about climate change is required to justify taking costly mitigation actions, or alternatively, that some higher level of confidence is required than is provided by present scientific knowledge – is not a scientific argument at all, but a normative judgment about when it is appropriate to make costly efforts to forestall an uncertain risk.

[12] The original memo, by Frank Luntz of the Luntz Research Companies, is posted online by the Environmental Working Group, at http://www.ewg.org and discussed in J. Lee, A call for softer, greener language, *New York Times*, March 2, 2003, p. 1.

[13] Remarks by President George W. Bush, White House Briefing, White House Rose Garden, June 11, 2001.

In effect, the argument states that the *status quo*, no mitigation policy, should be retained until it can be demonstrated that mitigation is a superior policy. Moreover, by citing "scientific uncertainty" as the reason for not taking action, the argument implies that the required standard of demonstration is total or near-total elimination of scientific uncertainty.

Those advancing this argument are making an analogy, sometimes explicitly and sometimes implicitly, to two other domains of social decision-making where we require a very high standard of evidence to justify certain decisions: criminal law, and scientific research. The rules of criminal trials specify that the defendant is presumed innocent unless the prosecution succeeds in demonstrating guilt "beyond a reasonable doubt." In scientific research, as we discussed in Chapter 2, when a new hypothesis or result claims to contradict present accepted knowledge, it is not accepted until demonstrated to a highly persuasive standard and repeatedly, stringently verified by multiple, independent scientific groups.

In both these cases, the decision to require such a high standard of demonstration is based on a normative judgment about the relative severity of the two possible kinds of error. In any decision taken under uncertainty, there is always some chance of making the wrong choice. A criminal verdict can err by convicting an innocent defendant, or by acquitting a guilty one; scientific judgment can err by accepting a new claim that turns out to be incorrect, or refusing to accept one that turns out to be correct. Criminal trials demand demonstration of guilt beyond a reasonable doubt, thereby biasing the decision in favor of the defendant, because society has long judged that it is much worse to convict an innocent defendant than to acquit a guilty one. In science, the requirement that new claims be strongly verified reflects a similar judgment of the relative severity of the two possible types of error. Accepting an incorrect novel claim is quite costly, since it can confuse and misdirect subsequent research, and cast doubt on the accumulated body of related prior knowledge. But failing to accept a correct novel claim is less costly, because such rejections are always provisional. A correct claim that is not initially accepted will likely keep accumulating supporting evidence until it meets the standard for acceptance, so the cost of imposing this high standard is simply a delay in accepting the claim until more data are obtained.

The crucial point is that, in both these domains, the decision rules are based on normative judgments about which type of error is worse. The worse we judge a particular type of error to be, the more we try to make it unlikely by biasing the decision-making process against it. In doing so, we willingly accept a heightened risk of making the other type of error, because we judge it to be less bad.

But we use different biases in other areas of social decision-making, reflecting different judgments of how bad it is to err in each direction. In civil law – private suits by one party against another, in which usually only monetary damages or requirements to change behavior are at stake – there is no clear basis to judge one type of error or the other (i.e. errors that favor the plaintiff or the defendant) to be worse, so civil suits are supposed to be decided without bias, on the basis of "the preponderance of the evidence." In matters of foreign policy and national security, US policy often favors extremely costly action to defend against threats that are not just uncertain but unlikely, because the cost of being unprepared to meet a threat that does materialize is judged to be so severe.[14]

In any policy area, it is possible to bias decisions either for or against action – environmental activists often use the same argument for a pro-action bias as is made for national security – but this choice is not scientific; rather, it reflects a judgment about what errors we want to avoid. What approach to decision-making is appropriate for climate change? The argument that climate science is too uncertain to merit action, and the analogies to criminal law and scientific research on which it is based, would reject any mitigation actions until highly confident projections of severe climate-change impacts were available. This is a difficult standard to achieve: such confidence might never be achieved until the impacts were already realized or too late to avoid. But this approach would be appropriate if it was judged much worse to limit emissions too much than not to limit them enough – i.e. that the economic losses from too much mitigation were much worse than the impacts of too much climate change. There is no basis for thinking this to be the case, however; rather, the reverse situation appears more likely. If uncontrolled climate change and its impacts turn out to lie at or below the bottom of the present projected range, then an aggressive mitigation program would impose substantial unnecessary costs, presently estimated to lie between a few tenths of a percent and several percent loss of future GDP. But if climate change and impacts lie near or above the top of the present projected range, then not pursuing aggressive mitigation would likely expose the world's people to much more severe costs and risks, including a growing possibility of abrupt, perhaps catastrophic changes.

With high and uncertain stakes on both sides, a response to climate change requires decisions under uncertainty that consider risks and potential costs symmetrically, acknowledging the risks both of responding too strongly and not responding strongly enough. In this respect, climate change resembles all other first-rank policy issues, including responding to security threats such as hostile foreign powers or terrorism, making economic policy, and managing all kinds of

[14] For example, Secretary of State (at the time) Colin Powell made the following statement of why the USA was pursuing national missile defense: "[T]here is recognition that there is a threat out there . . . And it would be irresponsible for the United States, as a nation with the capability to do something about such a threat, not to do something about [it] . . . you don't wait until they are pointed at your heart. You start working on it now." (Remarks at the International Media Center, Budapest, Hungary, May 29, 2001, http://www.state.gov/secretary/rm/2001/index.cfm?docid=3126)

risks to life, health, and safety. This stance requires rejecting the argument that the mere presence of uncertainty requires delay, since waiting for near-certainty could carry high costs or take forever. It equally requires rejecting the opposite extreme stance, that climate change is a crisis demanding the maximum possible response immediately, regardless of cost or consequences. Whether this latter stance is framed as the strongest form of the precautionary principle, or by characterizing greenhouse-gas emissions as a moral wrong that must be eliminated, it is as insupportable as the stance that no mitigation should be made until decisive evidence compels it.

Unfortunately, an approach balancing risks on both sides does not gain much resonance with either side in the present, ideologically charged debate. But however unpopular this approach may be, it is essential. While there is much uncertainty about the consequences, costs, and benefits of alternative courses of action, we must consider the knowledge we do have in choosing among actions – which is sufficient to reject certain extreme courses of action, even if it is not sufficient to specify the precise course we should follow.

5.4 So what should be done? Major choices and elements of an effective response

Our judgment is that present knowledge and evidence of the risks of climate change are sufficient to demand strong action, despite continuing uncertainties of varying magnitude and significance in nearly every aspect of the issue. Given the risk of serious, slow-to-reverse harms, it would be irresponsible to wait for precise knowledge of the form and magnitude of climate-change risks before taking action to forestall the risks. The response to climate change must reflect uncertainty, of course. But this means balancing the risks of acting too strongly and acting not strongly enough, and maintaining the flexibility to adjust responses over time as knowledge advances and conditions change – not waiting for certainty before taking action.

What form should the response take? We have already laid out some of the obvious and uncontroversial elements of a response. Continued scientific research on climate and its impacts is essential, but not enough. Advance planning and building adaptive capacity, to prepare for a more uncertain and probably less benign climate than we have experienced for the past century are essential, but not enough. Supporting independent, high-quality scientific assessments to inform continuing policy decisions is essential, but not enough. In addition to these elements, an effective response to climate change must also include a strategy to reduce global emissions, starting soon and continuing for decades until most of the world's energy system has shifted to non-emitting alternatives. Such a mitigation strategy comprises four elements: a long-term target that, based on present knowledge, appears to adequately protect the global climate; feasible, well designed near-term policy initiatives to move toward the long-term goal; a political strategy that motivates participation in the required near-term actions and that is consistent with advancing toward the long-term goal; and a mechanism for adapting both goals and actions in light of evolving knowledge, experience, and capabilities.

5.4.1 Long-term goals

A climate-change mitigation strategy can benefit in several ways from having an explicit long-term goal. A goal that is challenging but attainable can focus attention, motivate action, and provide a context for choosing and evaluating near-term measures, even if the relationship between the near-term measures and the long-term goal is known only approximately. The long-term goal stated by the Framework Convention is stabilizing atmospheric greenhouse-gas concentration "at a level that would prevent dangerous anthropogenic interference with the climate system." This is a fine goal, which gains nearly universal agreement when stated at this level of abstraction, but because it depends on defining how much interference is judged to be "dangerous," it is too vague to be operational. Using global-average temperature change as the measure of disruption, proposed warming limits to avoid dangerous interference have ranged from 1 °C to 5 °C, with most proposals lying between 2 °C and 3.5 °C. (Recall that a change of 3 °C is five times the warming realized over the twentieth century. If this occurred by 2100, as present projections suggest is likely, this would represent double the rapid warming rate of 1970–2000, with this doubled rate sustained for 100 years.)

There is no bright line that demarcates dangerous interference with the climate system, of course. This is so both because of uncertainty about the impacts of different levels of greenhouse gases, and because of disagreement about what impacts are acceptable and what efforts are worth making to avoid them. There are neither precise moral principles nor decisive practical considerations that can tell whether the proper temperature limit is 2 °C, 3 °C, or 4 °C, or some higher or lower value. But waiting for either definitive benefit–cost analysis or complete political consensus to identify a precise goal – just like waiting for elimination of scientific uncertainty – would mean waiting forever – or at least so long that most desirable goals would have long become unattainable. In our judgment, limiting total global warming to 3 °C is an appropriate goal.[15] Present knowledge suggests that this limit is achievable with sustained efforts that are serious, but

[15] Note that this warming target is defined relative to temperatures before the warming of the twentieth century, so this target means about 2.4 °C additional warming above the present global temperature.

Table 5.1. *Limits for atmospheric concentration of all greenhouse gases (expressed as CO_2-equivalent in p.p.m.), for selected combinations of doubled-CO_2 climate sensitivity (an uncertain property of the climate system) and limits on global warming (a choice)*

		Doubled-CO_2 climate sensitivity (°C)		
		1.5	**3**	**4.5**
Warming limit (°C)	**2**	710	440	380
	3	1120	560	440
	4	1780	710	520

Source: calculated from Caldeira *et al.* (2003).

not overwhelming and would likely avoid the most severe risks – although it still represents extreme climate change relative to the experience of human civilization, and some scientists dispute that it would avoid severe risks.

Given this or any other specific limit on long-term global warming, and an assumed value for climate sensitivity, it is possible to infer a limit on atmospheric greenhouse-gas concentrations. If climate sensitivity is high, then limiting warming to any specified level requires limiting greenhouse gases to lower concentrations than if sensitivity is low. Suppose, for example, that doubled-CO_2 climate sensitivity is 3 °C, the middle of the estimated range. Then limiting future warming to 3 °C requires limiting greenhouse-gas concentrations to about 560 p.p.m. of CO_2-equivalent. Relaxing the warming limit to 4 °C (still assuming sensitivity of 3 °C) would let concentrations increase to about 710 p.p.m. of CO_2-equivalent, while tightening the warming limit to 2 °C would require limiting concentrations to about 440 p.p.m. Table 5.1 summarizes how the required limit on greenhouse-gas concentrations depends on the combination of the warming limit and the climate sensitivity.

These limits apply to the total climate-forcing effect of all greenhouse gases, expressed as an equivalent concentration of CO_2. Since this includes the effects of other greenhouse gases, CO_2 itself must be stabilized at a lower level. How much lower depends on how fast emissions of the other gases grow. Table 5.2 shows approximate implied concentration limits for CO_2 itself, given mid-range assumptions for growth of other gases.

These limits paint a sobering picture of our situation. They suggest that achieving any but very weak limits on global climate change (i.e. limits that allow very substantial risks), under relatively fortunate assumptions about the world (i.e. low to middle climate sensitivity) will require a massive deflection of present emission growth trends. These numbers also indicate how important it is for a mitigation

Table 5.2. *Approximate limits for atmospheric concentration of CO_2 alone (in p.p.m.), for selected combinations of climate sensitivity and limits on global warming, assuming a mid-range growth path for non-CO_2 greenhouse gases*

		Doubled-CO_2 climate sensitivity (° C)		
		1.5	**3**	**4.5**
Warming limit (°C)	2	510	320	270
	3	810	400	320
	4	1280	510	370

Source: interpolated from Wigley, Stabilization of greenhouse-gas concentrations, in Aspen Institute (2002).

strategy to include limits on non-CO_2 gases, to make the CO_2 part of the problem a little less overwhelming.[16]

Taking our proposed goal of limiting global warming to 3 °C, and assuming that climate sensitivity is 3 °C, roughly in the middle of the presently estimated range, atmospheric concentration of CO_2 must be stabilized around 400 p.p.m., or somewhat higher if substantial reductions in emissions of other greenhouse gases can be achieved. Assuming this is the case, we will examine the implications of stabilizing CO_2 around 450 p.p.m.

The present concentration and its rate of change – 380 p.p.m., increasing by 2 p.p.m. per year – give an indication of how challenging it will be to keep atmospheric CO_2 below 450 p.p.m. Indeed, some analysts of energy and emission trends regard 450 p.p.m. as already out of reach, and treat stabilizing at 550 p.p.m. – double the pre-industrial concentration – as the lowest level that is technologically, economically, and politically feasible. Yet stabilizing at 450 p.p.m. would still expose us to significant risks. One recent attempt to quantify risks of dangerous climate change found that even 450 p.p.m. was associated with a 35 to 40 percent chance of surpassing the threshold of danger. Aggressive non-CO_2 reductions and adaptation measures reduced this risk, but only to 15 to

[16] As we discussed in Chapter 3, trends in atmospheric aerosols will also influence how hard it is to limit future climate change. But because of uncertainties in both present effects and future trends in aerosols, their aggregate effect is uncertain even in its direction. Recall that SO_2 emissions produce a net cooling effect. Consequently, if their present total effect is large and they decrease rapidly in the future, then even more stringent limits on CO_2 and other greenhouse gases will be required than shown in Tables 5.1 and 5.2. On the other hand, black aerosols produce a net warming effect. Consequently, if their present total effect is large and they decrease rapidly in the future, then the required limits on CO_2 and other greenhouse gases will be somewhat less stringent than shown in Tables 5.1 and 5.2.

20 percent. Although this was a preliminary and illustrative analysis, it suggests that it might be premature, indeed irresponsible, to abandon the prospect of limiting atmospheric CO_2 to 450 p.p.m.

5.4.2 Near-term actions

What does the long-term goal of stabilizing CO_2 around 450 p.p.m. mean for emission trends and required actions in the near term? As Figure 4.3 showed, low-cost emission trajectories to reach this goal require that global CO_2 emissions begin deflecting from their present growth path in just a few years, peaking slightly below 10 GtC/yr around 2010 and then declining to about 6 GtC/yr by 2050 and less than 4 GtC/yr by 2100. It is possible to reach the same stabilization level with a somewhat later start to emissions' divergence from their present growth path, but only if their subsequent decline is substantially faster. Relaxing the concentration-stabilization goal to 550 p.p.m. would let global emissions continue to grow to about 12 GtC around 2030 before turning downward, declining to about 6 GtC by 2100. But adopting this weaker goal would mean either gambling that climate sensitivity lies near the bottom of its estimated range, or accepting a global temperature rise of more than 4 °C. If baseline emissions lie near the middle of the projected range (as shown in Figure 3.11), they will increase by about 1.5 GtC per decade over the next few decades. Consequently, emission trajectories that aim to stabilize at 450 p.p.m. will require global emissions to be reduced by about 1 GtC below the projected baseline by 2015, 5 GtC below the baseline by 2030, and 10 GtC by 2050, by some combination of increased efficiency and switching to energy sources that emit no CO_2 to the atmosphere. Considering the projected sharp growth of developing-country emissions over this period, industrialized-country reductions must be much larger, for example to about 60 percent below 2000 levels by 2050 if developing countries begin to control their emissions only around 2030.

This estimate of required reductions depends on several points that are either uncertain or matters for choice: the target for maximum global warming (a choice); the climate sensitivity (an uncertainty); the baseline emissions trend (an uncertainty); and the trajectory of non-CO_2 emissions. We cannot at present either identify a precise choice of climate-change limit, or eliminate these uncertainties. But this is of little importance for the choice of near-term actions, because what is required in the near term is similar for a wide range of targets and assumptions. Anything except a combination of weak climate-change targets and favorable assumptions will require substantial downward deflection of global emission trends starting within 10–20 years. Given how long it takes to develop and implement policies, develop and deploy technologies, write off investments, and change behavior, this means that development of effective policies and technologies to reduce all greenhouse gases, especially energy-related CO_2 emissions, must begin immediately to avoid increasing costs and risks of failure.

We have stressed the crucial role of a large increase in government spending on research and development of multiple energy-related technologies. But while such public effort is essential, the success of a mitigation program will stand or fall on how well it motivates private-sector efforts to change present products and production processes and to deploy the R&D and investments needed to bring these changes about. Mobilizing these efforts will require a strong, credible public-policy signal that emitting greenhouse gases will grow increasingly costly over the next few decades. Voluntary and information-based programs may complement and enhance core policies around the edges, but they cannot achieve the required changes. The present reliance of climate-change policy on voluntary programs, in the USA and elsewhere, is woefully inadequate in view of the severity of the challenge – as much as it would be to rely on voluntary actions to finance the government or provide for the national defense. Only binding, authoritative policies that carry real incentives can provide the structure, clarity, planning environment, stability, incentives, and leadership that are required to motivate the required changes in private decision-making, principally by business.

What form should these policies take? Many aspects of the required policies have been widely discussed and widely agreed. Policies should seek to minimize costs by allowing flexibility in implementation, through harnessing market forces to the extent feasible. They should be announced well in advance and phased in gradually, to limit costs and allow stability for planning. Beyond these agreed elements, commentators differ on whether the preferred form of mitigation policies should be national emission limits, carbon taxes, conventional regulations targeting performance in specific sectors, or some combination of these. Different forms of policy may be appropriate in different nations, even while mitigation efforts must eventually be coordinated globally. In view of present uncertainty about mitigation costs, and the risk of backlash if early costs rise too high, our view is that the preferred policy is a tradable emission permit system including an escape valve – a commitment to sell additional permits if their price rises above some specified level. For the USA, a suitable initial level for the emission cap might be somewhat tighter than the McCain–Lieberman bill but somewhat weaker than the Kyoto commitments – for example, 5 to 7 percent above 1990 emission levels in 2010 (rather than 6 percent below as in Kyoto), coupled with a pre-announced trajectory of further cuts that gradually increase in stringency. A similar target might be most suitable in the near term for those nations that face the greatest difficulties in meeting their Kyoto targets, such as Japan and Canada – although these nations are of course committed to meeting substantially stricter targets.

The purpose of the escape valve is to limit economic harms from unexpectedly high costs that might arise if the emission limit is tightened too fast, by putting a ceiling on marginal cost. To keep the emission limit meaningful, however, the escape-valve price should be set high enough that it is relatively unlikely to be reached: a suitable initial value might be $75 to $100 per ton of carbon, equivalent to about 18 to 24 cents per gallon of gasoline or 0.8 to 2.4 cents/KwH of electricity, depending on the fuel source. To reduce the total cost burden and help smooth out energy price fluctuations, the escape-valve price could be decreased in parallel with fuel price increases above a certain level, so permit prices would be allowed to rise higher when fuel is cheap than when it is expensive.

Although the most efficient way to distribute permits initially would be by auction, securing enough support to establish the scheme would probably require that some fraction of the permits be distributed free of charge to present emitters. While including the broadest possible collection of greenhouse gases, economic sectors, and activities within the trading system would reduce the cost of achieving the reductions, this advantage of a broader emission-trading system must be balanced by practical concerns about how well it is possible to monitor and account for emissions. A system that includes only energy-related CO_2 emissions is not ideal, but may be all that can be practically implemented as a first step. As the ability to monitor other emissions advances, the scope of the permit system should be broadened to include additional emission sources and gases.

The tradable-permit system and escape valve would provide the central component of a mitigation policy, but other policies could complement them. In particular, there would be a role for additional regulatory policies, either market-based or conventional, in areas where two conditions apply: the technical potential for emission reductions at relatively low cost appears to be large; and there is reason to doubt the effectiveness of energy-market price signals induced by emission limits. Regulation of vehicle fuel economy is a prime example, because the technical efficiency characteristics of cars and light trucks have a large impact on overall emissions but respond only weakly and slowly to changes in fuel prices. Stronger policies could motivate substantial improvements in vehicle efficiency, although ideally this should be achieved through a new policy more efficient than the present, conventional regulatory system, known as the CAFE standard. For example, a system of tradable permits or fees could be applied to the standardized fuel consumption of newly manufactured or imported vehicles, both automobiles and light-duty trucks. Another promising example would be abandoning the long-standing preferential treatment on air pollution from old power plants under the US Clean Air Act. This policy has the effect of keeping inefficient old plants, which are far worse than new plants in their emissions of greenhouse gases as well as conventional air pollutants, in service long after their expected lifetime.

How much will these mitigation policies cost, and are they worth it? Opponents of mitigation assert that costs will be high, perhaps ruinous, so only very limited efforts are warranted, at least for the near term. But the safety valve would eliminate the risk of the highest projected costs in the event that mitigation turned out to be unexpectedly difficult and expensive. Moreover, as we discussed in Chapter 4, how sharply we would wish to cut emissions depends not just on the cost of mitigation, but on the balance of costs of climate impacts, mitigation, and adaptation, all of which are quite uncertain. While climate impacts will likely be modest for rich countries in the near term if climate change lies near or below the middle of the range of present projections, the principal concern with climate change is not these impacts, but the possibility of far more serious impacts from changes near the high end of present projections, or from mid-range changes sustained beyond 2100, or from potential abrupt changes that present projections do not consider. These higher impact scenarios, which are virtually ignored in present climate-impact assessments, carry a small, non-negligible probability of very serious harms – an uncertainty that cannot be eliminated until the actual changes, whether severe, modest, or in between, are upon us and cannot be reversed for many decades or longer.

Mitigation costs also carry uncertainty, but the origin and implications of this uncertainty are quite different from uncertainty in climate impacts. The substantial uncertainty in mitigation costs that comes from different policy assumptions simply provides guidance for how policies should be designed to keep costs as low as possible. The remaining uncertainty – which mostly concerns how much technological innovation can reduce the cost of cutting emissions – can, like climate-impact uncertainty, best be reduced through experience. In the case of mitigation, this experience in part will mean actual efforts to develop and deploy new low-emitting technologies. Motivating the required efforts, which must principally come from the private sector, will require policies that generate strong enough incentives, and that send credible signals that the incentives will not be removed next year.

We cannot know the results of such efforts until we make them, but in general they are likely to lead to identification of more opportunities to reduce emissions and reduced estimates of the cost of doing so. Experience from other environmental issues suggests that costs for reducing most forms of pollution turn out to be lower than they are projected to be in advance. Moreover, the highest present mitigation cost estimates make assumptions about technological response to incentives and the ease of substitution in the economy that are about as pessimistic as could plausibly be true. Consequently, in contrast to climate-change impact projections, actual mitigation costs are quite unlikely to lie well above the present range of estimates. There is one important qualification to this claim: inefficient, badly designed policies could drive mitigation costs far above what they need be. This is a serious political risk that cannot be ignored. But except for this risk, the process of resolving uncertainties and learning more about mitigation is likely to push the present range of projected mitigation costs down, not up. Moreover, even if mitigation costs decline only slowly, any harm suffered from reducing emissions too fast is likely to be more readily reversible than the harm from allowing too much climate change to happen, particularly if the mitigation policy includes an escape valve or other provisions to slow emission cuts in the face of persistently high costs.

5.4.3 A political strategy

At present, the world is far away from having any mitigation regime that could make a serious contribution to limiting climate change. A few countries are developing serious mitigation policies, but even these fall well short of what will be needed to achieve the required shifts in emissions. Most nations have policies vastly too weak for the job, or none at all. The essential political problem of managing global climate change is to identify a series of achievable steps to move progressively from this present state, toward the goal of widespread adoption of serious, cost-effective, coordinated mitigation policies. Because nations cannot be coerced to join an international climate-change regime, a feasible political strategy will require deploying incentives that will lead the required participants to join the regime, and to meet their obligations under it, voluntarily.

An effective international mitigation strategy must be able to produce the required large-scale reduction in global emissions, and transformation of the world energy system, over the next several decades. Achieving this requires a mitigation strategy to satisfy several criteria. It must include a feasible first step that can break the present deadlock. Early steps must promote, not hinder, subsequent movement toward progressive reductions of emissions and expansion of participation. Because expanding mitigation opportunities requires large increases in R&D and investment in energy technologies, the strategy must support and motivate these investments. Because the costs of greenhouse-gas mitigation are likely to be substantial, the strategy must be cost-effective – i.e. it must be structured to achieve the required energy-system changes and global emission reductions as cheaply as possible, over the entire relevant time horizon. The strategy and its implementation must also provide adequate incentives for both governments and private actors to participate, and to make good-faith efforts to meet their commitments.

Finally, the strategy must be sufficiently equitable in its distribution of burdens to gather widespread support. In particular, it must reflect some defensible interpretation of the principle of common but differentiated responsibility, so developing-country burdens reflect their different status and do not obstruct their development. This is both a normative requirement and a practical one, since starkly inequitable approaches are unlikely to gain the widespread support and legitimacy necessary to motivate participation and good-faith performance. Note, however, that this is a substantially weaker condition than often proposed in climate policy debates. It does not require explicit negotiation of equity criteria or burden-sharing formulas. Nor does it require that the climate-change regime make a large contribution to redressing present global inequities.

In choosing an international mitigation strategy in light of these criteria, the most basic near-term political choice is whether to stay with the present structure, as embodied in the Framework Convention and the Kyoto Protocol, or to make large-scale departures in the architecture of agreements or the set of participants.

The Kyoto Protocol is in an awkward situation. Rather than dying, as its opponents hoped, it has entered into force. But it has several fundamental problems, on which little progress has been made for several years. First, no industrialized country appears likely to achieve large enough domestic emission reductions to meet its first-round emission obligations except the EU, and even they may fall slightly short. Parties may formally meet their commitments by buying surplus credits, of course, but few would regard large-scale reliance on this means of compliance as success – and the prospect of sending large checks to Russia may provoke substantial opposition to complying via this route. In addition, parties have made very limited progress in negotiating further emission cuts after 2012; no progress in engaging the USA, despite increasing indications that other parties are willing to offer almost any adjustment of the current US commitment; and no progress at all in engaging developing countries in serious negotiations about their future mitigation commitments.

Many elements of the Protocol can in principle be renegotiated: the form and level of mitigation commitments, of course, but also the mechanisms for implementation, reporting, and compliance; the terms of the flexibility mechanisms; or what emissions and activities are included and how they are counted and converted. Other aspects of the current approach are more firmly embedded, such as the basic approach of controlling emissions via quantified national emission targets, the decision to allow various forms of flexibility in meeting these targets, and strong differentiation of commitments between industrialized and developing countries. This differentiation is firmly established in both the Protocol and the Framework Convention. Indeed, although many proposals are being made to extend mitigation commitments to developing countries – for example by nations "graduating" to stricter targets as they pass pre-agreed GDP thresholds – the listing of particular nations in Annexes 1 and 2 of the Convention makes such expansion awkward to negotiate,[17] and there is little indication that developing countries are willing to consider such approaches.

The most basic structural aspect of the present approach, however, is universal participation. Both the FCCC and Kyoto Protocol have sought the broadest possible participation from the outset. Virtually all nations of the world participate in climate-change negotiations (as of April 2005, the Framework Convention has 194 parties, the Kyoto Protocol 148), and all the rich industrialized countries and many former Soviet states and allies initially agreed to emission limits in the Protocol's first commitment period. Universal participation has been pursued both because it is expected to lower costs and because it is viewed as more legitimate. Broad participation in mitigation is expected to lower costs through the Protocol's flexibility mechanisms, because they allow international shifting of mitigation effort to where it is cheapest – in the first commitment period, principally by buying unused emission credits from Russia. Broad participation in negotiations is also valued because climate change and responses to it have the potential to transform many areas of national policy and international relations. With such stakes, all nations reasonably wish to be involved in the early negotiations that might shape the subsequent direction of the regime.

Proposals to escape the present deadlock fall into three broad categories: some propose to keep all major elements of the Protocol but negotiate specific, relatively minor changes to resolve the present problems; others propose more substantial revisions to the architecture of the Protocol and/or Convention – for example changing the form of mitigation commitments – while still working within these instruments and retaining universal participation for all negotiations. The most radical proposals would abandon universal participation – at least as a transitional stage – and seek other vehicles for international cooperation involving smaller groups of nations. We briefly consider each of these.

Many specific, relatively minor changes to the Protocol have been considered. These proposals all retain universal participation, national emission targets with flexibility mechanisms, and differentiation of commitments. Some of them focus on particular improvements to the implementation system or flexibility mechanisms, or propose tuning the mitigation commitments to more closely follow a low-cost path toward some concentration stabilization level. Others focus on specific changes intended to persuade the USA and the developing countries to accept mitigation commitments: for example, for the USA, a looser target in the first

[17] Changing the countries on these lists, or replacing the lists with criteria or procedures to determine who is in each group, would require amending the Convention. Amendments require the support of at least three-quarters of the parties and, even if adopted, only become binding on parties that formally accept them via a process equivalent to ratification of the original treaty.

commitment period, a different baseline year, or a large one-time credit for sinks; and for the developing countries, a promise to reinvigorate the Clean Development Mechanism (a mechanism to finance emission reductions in developing countries), or the offer of emission targets that follow or even exceed their projected baseline emissions in the near term, to reduce their risk and let them sell extra credits. These generous developing-country targets are intended to hold them harmless, or even to let them profit from joining the mitigation regime, at least for the first few decades.

The difficulties with these proposals are clear from the very fact that they have been thoroughly circulated and discussed over the past few years, with no progress. Persuading the USA and the developing countries to join by such modest changes is not impossible, of course. But it would require a large departure from present positions, and larger-scale political postures, on the part of both. US opposition to the Protocol goes deeper than objections to the first-round US target. It includes significant opposition to the structure of commitments, and the expectation that any commitments now being proposed, even in future periods, would differentially disadvantage the USA – principally because of the higher pre-existing energy taxes in other industrialized countries. Similarly, developing-country resistance to accepting mitigation commitments goes beyond simply wanting favorable allowances. In addition, their opposition reflects both the principled view that industrialized countries must show real efforts and progress before developing countries are asked to follow, and the suspicion that with large uncertainty in future emission growth, even seemingly generous initial allocations might constrain development, and that if they accept the principle of developing-country emission limits they would risk being pressured in subsequent negotiations to accept much tighter limits that would erode any advantage they held and shift the burden to their disadvantage.

In the most hopeful scenario, the USA and the developing countries might each be willing to join some form of mitigation commitments if the other does – i.e. there are no concessions by present parties that could bring them in separately, but they could be brought in together. The role of the present Kyoto parties would be to broker a deal between the USA and the developing countries for their joint accession, with whatever modifications to the Protocol are necessary to let this happen. But if there are potential mutually advantageous agreements to be found between the USA and the developing countries, there is no clear advantage to them in letting the present parties play that role. They would surely prefer to do it on their own, outside the framework of the Kyoto Protocol, and keep control of the negotiating agenda between themselves. We discuss this prospect below.

Alternatively, many commentators have proposed more far-reaching revisions to the architecture of the Kyoto Protocol that still keep the fundamental elements of differentiated commitments and universality. These proposals are numerous and diverse. They include, for example, more complex trading systems with permits of multiple durations to help manage risk; adding an internationally established escape valve to the international trading system; permits whose initial distribution is so abundant that they do not constrain emissions, but some of which are subsequently repurchased and retired by an internationally financed authority; letting developing countries voluntarily accept high pseudo-baselines that represent not a regulatory requirement, but only an accounting point below which they are allowed to sell permits; shifting negotiations away from national emission limits toward mutually agreed actions, such as a common carbon tax, support and incentives for R&D, technology-based standards for major emitting sectors, or some broad collections of policies and financial and technical assistance.

Each of these proposals responds to one or more identified problems with the present approach, and these proposals hold somewhat more promise to break the current deadlock than the modest revisions discussed above. But all these approaches still suffer from fundamental weaknesses that are related to universal participation and to commitments so strongly differentiated that many nations have none at all. Universal participation in negotiations, together with a norm of decision-making by consensus, creates powerful opportunities for obstruction. A group of nations who are willing to take on some mitigation commitments cannot negotiate their terms, design, or implementation without many other nations who are not accepting the commitments having a voice, or even a veto.

This mismatch between who is undertaking efforts and who is negotiating the terms of the efforts obstructs effective negotiation in many ways. It can separate negotiations from considerations of practicality, since most negotiating parties will not have to do what they are discussing. It can obstruct attempts to negotiate changes in the set of nations that have mitigation obligations, or to develop incentives to motivate additional nations to accept them. It can allow negotiation of initial mitigation commitments to become a vehicle for non-participating nations to secure favorable precedents and maneuver for long-term advantage. Most seriously, universality empowers some states, principally major fossil-fuel exporters, who oppose any attempt to establish a mitigation regime. Because these nations seek not just to avoid mitigation commitments themselves, but also to prevent others from adopting them, their primary objective in negotiations is to obstruct progress. While the universality of the Convention and Protocol means that these nations cannot be excluded from mitigation negotiations, the norm of consensus decision-making means that their obstructive tactics are frequently effective.

In view of the clear obstacles to negotiating a mitigation regime through any universal process, some commentators have proposed moving outside the Kyoto framework. The most prominent suggestions include building international permit markets before negotiating emission limits; negotiating a bilateral deal between the USA and China; and negotiating stronger commitments among a relatively small group of industrialized nations most committed to establishing a mitigation regime.

One proposal would shift the focus of initial international activity away from negotiating emission targets and toward first constructing a well-managed international market in emission permits (see, for example, "proposal 3" in Victor, 2004). Several emission-trading systems are already in operation. The EU's system is the most developed, with compulsory participation for major stationary emission sources, substantial penalties for emitters who exceed their allowance, and a requirement for annual emission reductions. Substantial trading systems are also in operation inside several major multinational corporations, and among the 75 major US industrial firms who are members of the Chicago Climate Exchange. This proposal would move toward global emission control by progressively strengthening, linking, and expanding emission-trading systems, thereby allowing exchanges over a progressively wider set of regions and activities. The proposal would seek to develop permits to emit a unit of greenhouse gases into a new global financial instrument – albeit, one that would only influence emissions if every participating nation took steps to ensure the integrity of the instrument. For example, every participating nation would have to set a limit on the number of permits it issues, monitor emissions within its territory, and effectively enforce the requirement that emitters hold a permit. Someone – perhaps the largest sponsor nations or the exchanges where permits are traded – would also have to assess how well each participating nation meets these requirements, and also how reliably the reductions from various activities can be counted and verified. For example, sequestration in forests and soils is potentially a large sink for CO_2, but is both hard to measure and at risk of returning to the atmosphere early if environmental or economic conditions change. Liability for accounting errors and project failure would need to be assigned, most likely to the buyers of permits. Under this condition, permits generated by activities that are hard to monitor and ensure, and those issued by countries with lax monitoring and enforcement, would be expected to trade at a discount relative to permits based on clear, secure, and well enforced reductions.

The fundamental problem with this approach – at least in the pure form that completely separates establishment of an emission permit market from negotiation of national emission limits – is that it leaves the decision of how many permits to issue up to each participating nation. This would make the collective-action problem among nations even more severe than in explicit negotiations over national emission limits. Nations issuing excess permits do not merely get to free-ride on leaders' efforts, or gain some inflow of emissions-intensive investment; they can thwart leaders' attempts to reduce emissions even in their own territory, because permits issued by countries issuing many can be sold to emitters in nations issuing fewer. Avoiding this situation would require negotiations to limit how many permits each nation issues, which would be as difficult and as unlikely to achieve significant reductions as current negotiations over national emission limits. But in the absence of agreed binding limits, permits would be so abundant that their value would be near zero – except to the extent that, like the present US voluntary permit market, they price the risk of more stringent controls being imposed in the future. With permits nearly worthless, nations and permit-holders would have little incentive to invest in the monitoring and enforcement that will be necessary to defend the integrity of a permit system when values grow higher. In view of all these difficulties, it is unlikely that the prior creation of an international permit market can avoid the hard negotiations and need for political will that are necessary to impose non-trivial limits on emissions.

Moreover, a central thrust of any proposal to establish a permit market as an *alternative to* negotiating national emission reductions – rather than as a *means to efficiently implement* a negotiated agreement on national emission reductions – is to fix national baselines, and consequently the starting point for any future mitigation negotiations, at present levels. By enshrining the status quo, this approach consequently avoids any consideration of equitable global distribution of emissions. While we have criticized the universal approach of the Kyoto Protocol as encouraging too much preoccupation with broad questions of global equity, a system that goes no further than solidifying present inequities would in our view have little hope of gaining the widespread participation necessary to make any significant contribution to limiting global emissions.

A second approach that moves outside the Kyoto framework would be bilateral negotiations between the USA and one of the largest developing country emitters – in most proposals, China (see, for example, Stewart and Wiener, 2003). These bilateral negotiations would establish a firm baseline emission trajectory for each nation, a reliable system to account for emissions, and a mechanism to exchange emissions either at national or project level. Pursuing cost-effectiveness would probably require that the bulk of near-term mitigation activity take place in China rather than the USA. Because this mitigation would in all likelihood carry a cost (even after accounting for the higher efficiency of new capital equipment, and the prospect of co-benefits such as air pollution reduction and energy supply security), the arrangement would have to include adequate incentives for China to participate, probably in the form of enough excess emission permits that the revenue they can expect from selling them will offset the costs they incur from mitigation, leaving them at least as well off as under their baseline emission growth projection.

By engaging China in a market that puts a significant price on emissions immediately, this proposal holds the promise of influencing the rapid buildup of capital investment now underway there – motivating additional investments to improve the efficiency and reduce the associated emissions of the new capital stock, and so gaining emission-reducing benefits for decades.

Negotiating a comprehensive, well implemented trading system bilaterally would also have the advantage of being vastly simpler than attempting to negotiate such a system in the global context of the Kyoto Protocol. It could allow the orderly construction of a permit market initially at a manageable scale, with the possibility of experimentation and revision of specific institutional details. It could also provide a prominent model of a deal between industrialized and developing countries that reduces emissions and is advantageous to both parties. Once established bilaterally, the arrangements could be expanded through voluntary accession to the system by additional countries, both industrialized and developing, thereby expanding the scope of the trading system and the associated opportunities for cost savings. Although the initial development of this approach would proceed entirely outside the Protocol, the aim would be eventually to negotiate a merger of the systems.

In our view, this approach holds more promise than the previous suggestions. It would of course require much more serious engagement from both the USA and China than either has demonstrated so far: in effect, it presumes that the unwillingness of each of them to participate can be overcome by securing the participation of the other. This might be so – or might come to be so, given imaginable political shifts in each country. The most serious question about the viability of this proposal concerns the size of financial transfers implied by allocating excess permits to China, whether these come from public sources or from firms paying to avoid domestic mitigation obligations. In the present budgetary and political context, it is not clear whether the USA would be willing or able to pay these costs to secure Chinese participation in mitigation.

There is one more potential path leading from the present deadlock toward a viable global mitigation regime that in our view is more promising than any discussed so far: development of a serious mitigation strategy by negotiations among a relatively small group of similarly situated, rich industrialized countries – a "coalition of the willing." The best candidates for this coalition are those nations that have demonstrated the most serious commitment to mitigation thus far – principally the European Union, perhaps with additional industrialized-country parties to the Protocol. These countries would negotiate initial agreements on a long-term atmospheric target, and progressively more stringent near and medium-term national mitigation obligations consistent with that target, with accompanying measures to limit the associated risks.

There are three types of risk associated with this approach that must be limited: that the participating coalition might be ineffective because it is too small to deploy the incentives required to shift global private-sector R&D and investment; that participants might suffer competitive disadvantages so severe that the approach is politically unsustainable; and that the approach might obstruct subsequent expansion toward near-global participation in a mitigation regime.

We have argued above that effective mitigation policies must be globally coordinated *eventually*, but full global participation is not necessary immediately. But how many are enough: which nations must join at the start for a mitigation regime to be effective, politically sustainable, and consistent with movement toward global participation? The first condition, effectiveness, depends principally on the total size of the participating economies. The participating nations must make up a large enough market that their policies can influence the research, investment, and operational decisions of both domestic and foreign firms to reduce emissions from their products and production processes. They must also be big enough collectively to deploy incentives that other nations will take seriously in formulating their own policies, and to attract enough attention to shape the agenda for subsequent international negotiations. A hint about the required scale of initial participation is provided by the several decades of success of California at independently regulating pollution from automobiles and driving technological advances that have improved emission performance worldwide. In view of the success of this small jurisdiction – about 3 to 4 percent of the world's economy and its market for automobiles – it is highly likely that either the EU or the United States, or any broader coalition of rich industrialized countries, would be big enough to take the first step in establishing an effective mitigation regime.

We discussed above the practical and principled reasons to favor broad participation in mitigation. These reasons are valid and important, but the present approach based on universal participation has not brought any significant progress toward an effective international mitigation regime. We contend that the practical advantages of starting with narrower participation may be so great that they outweigh the advantages of breadth.

Indeed, the importance of the cost advantage from breadth and international flexibility in the Kyoto Protocol may be over-rated. In the case of acquiring excess credits from Russia, this cost saving is essentially fictitious: to the substantial extent that these acquired credits represent Russian emissions that would not have occurred in any case, these exchanges lower the cost of emission reductions by not reducing emissions. But even where real reduction effort is moved abroad rather than avoided entirely, the cost advantage mainly comes from exploiting cheap opportunities to replace or upgrade old and inefficient equipment using newer and more efficient – but presently available – technology. This is clearly worth doing, and the associated shifting of effort does reduce costs in the short run. But the opportunity to shift reduces the stringency of incentives to reduce, and to develop lower-emitting technologies, that are felt by firms and countries that face high marginal costs – who in many cases will also be those with best access to the financing and technological capability to pursue these innovations. Short-term cost minimization may consequently come at the cost of weakening incentives to develop the new technologies required to reduce the cost of larger, long-term reductions, and may thus serve to delay the development of needed capabilities to resolve the climate issue.

Narrower initial participation in the mitigation regime would sacrifice some of this near-term cost-saving opportunity but deploy stronger incentives to develop new, non-emitting technologies capable of making larger contributions to long-term emission reduction. Limiting initial participation to a group of willing, similarly situated, rich industrial countries would greatly limit incentives and opportunities for procedural obstruction, and would allow negotiations to concentrate on practical details of the schedule of emission goals and the design and implementation of policies to pursue them, without having to address broad, contentious, and potentially unresolvable questions of global equity. While early participants would bear higher mitigation costs with narrower participation, these costs may well be perceived as less objectionable than smaller costs that take the form of payments to other countries with extra emission credits to sell. These costs would also to a substantial extent take the form of investments in new technologies and expertise, which could have substantial commercial value subsequently as the mitigation regime expands. The approach would powerfully demonstrate the participating countries' commitment to take responsibility for their historical contribution to climate change, by leading the creation of a serious mitigation regime and accepting the costs of doing so. This is how it would justify, morally and politically, excluding nations unwilling to undertake initial serious mitigation commitments from negotiation of the details of the regime.

Whatever group of nations participates in the mitigation regime initially, the regime cannot stay limited to these participants if it is to be effective. Although starting with a few willing participants carries many practical advantages, it is essential that the initial agreement must promote, not obstruct, its own subsequent expansion. This imposes two requirements on the initial policies. They must limit the incentives for high-emitting industries to move to countries outside the agreement; and they must create the incentives for additional countries to join. To meet these two requirements, the coalition's initial mitigation agreement must include trade measures, to roughly equalize the cost burden from mitigation policies between internationally traded and domestically produced goods. Depending on the form of the mitigation policy adopted by the coalition, the required trade measures could take two principal forms. The first would be a border-tax adjustment, which would charge a tax on the emissions represented by imported products at the same rate as the cost per unit emission borne by domestically produced products, and rebate the mitigation cost to domestically produced goods being exported. The effect of a border-tax adjustment is to equalize the cost burden of the mitigation policy between equivalent goods produced inside and outside the coalition, wherever these are sold. An alternative measure with roughly the same effect would be to require imports to purchase emission permits as they enter the coalition, and to grant transferable emission permits to exports as they exit the coalition. The quantity of permits required or granted would be set to approximate the emissions that were generated in manufacturing the product. The calculation of border adjustments would have to be accurate enough in attributing emissions to imported products, accounting for both the energy system of the exporting country and the production technology of the traded goods. This would pose a serious challenge to data and administration systems, but probably not an insurmountable one. These trade measures would also have to be judged acceptable under the rules of the World Trade Organization (WTO). Their legality has not yet been precisely tested, although their prospects appear substantially more promising following a series of crucial recent WTO decisions (see, for example, Howse, 2002). Border adjustments for both exports and imports would be set at a lower level for trade with developing countries, perhaps initially at zero, than for trade with non-participating industrialized countries.

Even if an initially narrow mitigation regime is constructed with the right incentives to facilitate subsequent expansion, starting narrowly risks missing the opportunity to shift the rapid build-up of investment now underway in major developing countries, especially China, toward more advanced low-emitting technologies. This is a risk of this approach, albeit one it shares with every other proposal we have discussed except the bilateral USA–China approach. Indeed, it is possible that this approach would do better at exploiting the opportunity than any of the other proposals we have discussed – and it is not incompatible with the USA and China also pursuing a bilateral arrangement. Quick establishment of even a narrow rich-country coalition for serious mitigation would signal rich countries' commitment to address the issue more credibly than the present stalling and squabbling do, and would also immediately create some incentives for non-participating countries to lower their emissions. The proposed border measures would create such incentives immediately in export-oriented non-participating countries and investors in them, so long as the calculation of adjustments is sufficiently accurate and fair for imports entering the regime.

Creating incentives for initially non-participating countries to join, particularly developing countries, will be a crucial element of the approach, which will be more delicate than the superficially similar problem that was addressed in the early days of the Montreal Protocol. In that case, the risk of developing a parallel world economy outside the ozone treaty, producing and trading ozone-depleting chemicals and associated products among themselves, was occasionally mentioned but was never credible. But given the greater economic force of the developing countries today and the greater economic stakes in greenhouse-gas mitigation, the risk of a badly designed initial mitigation regime creating a parallel, outside coalition producing and trading with old, high-emitting technology is quite plausible and must be guarded against vigilantly. Initial design of an international mitigation regime must avoid creating such a hard-to-reverse split in the world economy.

A primary requirement for avoiding such a split will be addressing developing country governments' concerns that if they are not involved in negotiation of the initial mitigation strategy, the details of the strategy or the terms on which they are subsequently able to join might be biased against them. Two concerns are likely to be most important. The first is the risk that the border-tax measures will be too strict, conferring trading advantages on coalition producers rather than merely neutralizing the disadvantages imposed by their mitigation policies. This is a serious concern, although several factors would help to diminish it. First, since the adjustments will not be set by any single country but jointly by the whole coalition, divergent trade interests among them (i.e. which industries they would wish to favor, and by how much) will help restrain attempts to distort the adjustments for trade measures. Since the measures must be set multi-laterally, they will require some multi-lateral expert body to conduct the analysis and recommend the levels. This body could be designed to provide some insulation against political interference and provisions for appeal of its decisions. Moreover, the possibility of WTO challenge should discipline any attempt to use these measures to provide disguised trade advantages.

Developing countries' second major concern will likely be the terms on which they are able to join the mitigation coalition – their obligations to limit or reduce emissions, and any accompanying provisions for assistance in controlling their emissions. These negotiations will be complex and difficult, but similarly difficult negotiations would be required under any approach to developing a global mitigation regime. Relative to the other proposed approaches, this one has two advantages: that initial mitigation action need not await agreement on the terms of developing-country participation, and that the design of the initial mitigation strategy gives substantial incentives for additional countries, both industrialized and developing, to join. The most promising approach to negotiating developing countries' accession would resemble several of the proposals discussed above:

negotiating developing countries' accession to the regime relatively early, with emission limits somewhat above their projected emissions growth paths for the next 10 to 20 years, but which begin slowing emissions growth and then declining another 10 to 20 years thereafter. The specific terms could be negotiated so developing countries carry only a small share of the burden, or even receive a net benefit. Since flexible international shifting of mitigation effort among participating nations through voluntary transactions would be allowed, this approach would also allow international planning and negotiation for emission-reducing projects in developing countries to begin early, with clear accounting for their aggregate effects on emissions once national baselines were established.

This approach starts entirely outside the Kyoto Protocol. The coalition's initial approach could borrow elements from the Protocol, such as the design of flexibility mechanisms, but they cannot act within the Protocol because they need full control over negotiation of their initial mitigation commitments. But like the other proposals for parallel activity to advance mitigation outside the Protocol, this approach would also aim for eventual merger with the Protocol to create a single, comprehensive global climate-change regime.

This proposal is extremely challenging. It demands much political courage in the initial coalition of leading nations, and its subsequent development will require challenging negotiations between the initial coalition and the developing countries. Most difficult of all will be its implications for Europe–USA relations, particularly if political sentiment in the USA remains strongly opposed to significant mitigation efforts. Yet of all the approaches that have been proposed, we judge this one to have the greatest promise of success. It builds on existing evidence of political commitment, rather than assuming a large-scale change of heart on the part of nations presently resisting joining; it allows an orderly negotiation of the terms of an initial mitigation regime, under the control of those actually taking on commitments; it limits the risks borne by these early movers through trade measures that offset the competitive disadvantages they would otherwise suffer; and it provides a feasible path for the required expansion to global participation.

5.4.4 Adjusting responses over time

The final element required of a mitigation strategy is a procedure for reassessing and adjusting efforts over time. Although mitigation efforts must begin despite present uncertainty, the presence of uncertainty means that mitigation policies cannot be established once and for all. Expanding toward global participation is one dimension which a mitigation regime must adopt over time, but it is the simplest and most foreseeable dimension. In addition, the form and stringency of policies, the mix of technologies being developed and adopted, and even the long-term goal for climate stabilization, will all have to be repeatedly re-assessed and potentially revised over the many decades it will take to stabilize the climate. Many types of future changes in knowledge or capabilities may call for changes in these choices, including new scientific knowledge about the climate's sensitivity and speed of response to human forcing, the nature and severity of climate-change impacts, and the possibility of abrupt changes – as well as changes in technological capabilities to reduce emissions, new evidence on the effectiveness of policies, and other changes in relevant social and political conditions. In general, evidence of higher climate sensitivity, faster climate change, more severe impacts, or lower mitigation costs will call for strengthening mitigation efforts, despite the long lags between such efforts and their climatic effects. Conversely, evidence of lower climate sensitivity, slower changes, less severe impacts, or higher mitigation costs will suggest a decrease in the intensity of mitigation efforts.

It is not possible to anticipate what form changes in future knowledge or capabilities might take, so the details of how to adjust future efforts cannot be negotiated in advance. Rather, some future decision-making bodies will have to be given authority to assess changes and adjust policies in view of some agreed enduring principles or criteria. The outline of such a process for review and adjustment of commitments already exists in the Framework Convention, and a similar process has been used to great effect in the Montreal Protocol. As a more detailed and challenging set of mitigation commitments is developed, the process for reviewing and adjusting these over time will of course require further elaboration.

The most serious challenge for such a process will be balancing the need for policies to respond flexibly to new knowledge and capability with the need for a stable and credible policy trajectory to allow orderly investment and planning. There are various ways to balance these two priorities. For example, mitigation policies might be adopted as rolling long-term plans, with any significant adjustments being phased in gradually over periods of 5–10 years or longer. In addition, the disruptions from adjusting mitigation policies could be spread across the economy at minimum cost if they were implemented through market-based operations. In such operations, governments would change the availability of emission permits for some future year by buying back permits on the open market to decrease the supply, or by auctioning additional ones to increase the supply.

5.5 Conclusion

In this book, we have summarized present scientific knowledge about how and why the climate is changing, how it is likely to change over the coming century, what the associated impacts might be, and what can be done about it. Our conclusion is that scientific knowledge about present and likely future climate changes calls for an urgent, high-priority response – principally but not exclusively through international negotiation of coordinated national policies – to reduce future emissions and to prepare for a much more uncertain and potentially less benign climate than we have been fortunate to live in for the past century. Concrete efforts to construct such a response must begin immediately.

But we do not yet have a serious response. There are many reasons for this. Some are related to the intrinsic difficulty of the issue, which challenges our present decision-making systems. Some are related to the inevitability of scientific uncertainty – which does not justify a stance of inaction, but which does provide rhetorical opportunities for opponents of action to confuse the issue and advocate delay. Whatever the mix of reasons, the present policy response is utterly inadequate in view of the gravity of the climate-change issue. A few nations are approaching the starting line of taking the issue seriously, but most are not even close. The state of international decision-making, where the main action must occur, is ineffective, incoherent, and deadlocked.

In view of the present grave situation, the previous section has sketched and briefly assessed the major alternatives proposed to the present approach. While many of these appear unpromising, two appear to hold some prospect of success: a USA–China bilateral agreement; and more promisingly, an industrialized-country "coalition of the willing" taking on significantly stronger mitigation goals and measures, and adopting trade measures that would both reduce their resultant competitive disadvantage and give other nations incentives to join them. These alternatives, including the one we judge most promising, were presented as sketches rather than detailed policy proposals. They were intended to make the case that movement toward a serious mitigation regime with commitments to real, long-term emission reductions, is not just essential to forestall serious future climatic risks, but is also practically and politically feasible.

More important than the precise details of initial mitigation policies is the structure of continuing research, periodic assessment, and review of policies and goals through which they are progressively adapted over time as knowledge and capabilities advance. Over time, relevant uncertainties – about climate change, impacts, and options to adapt or reduce emissions – can be reduced through sustained programs of research, development, and assessment, although not eliminated. Policies should be designed to pursue complementarities and multiple benefits – in terms of harnessing positive feedbacks in innovation, and in terms of seeking directions of innovation that promise joint management of multiple environmental or other issues. We will have to continue to make decisions under uncertainty, and the details of policy will have to be worked out progressively through negotiation, experimentation, and review. At present, precious little is being done to pursue any of these seemingly reasonable and modest directions.

Getting to a climate-policy regime that will be sustainable, adaptable, and practical, depends on taking the first steps, even if our knowledge of where our ultimate destination lies is only approximate.

Managing human influences on the Earth's climate is like piloting a supertanker through dangerous waters. We do not know for sure, but it looks increasingly likely that there are rocks ahead: in fact, we might be pointed right at one. We know what direction we need to steer, but do not know how far we must steer to avoid this rock, whether there are other rocks around, or how hard we can steer without risking damage to the ship. Moreover, a big ship like this one takes miles to change course. Unfortunately, no one is at the wheel right now. The crew is downstairs, arguing about whether there really are rocks ahead, what the precise course is that we must steer to reach our ultimate destination, and whose job it is to steer. While the crew is arguing, the ship is getting closer to the rocks. Somehow, what we need is to get someone upstairs to start steering us away from the rocks – now. Because the steering is so slow, it must start right away. At the same time, we need to learn more about where the rocks are – and also to learn, by starting to steer, about how the ship responds and how hard we can steer it. But neither of these needs to learn more justifies waiting to start the steering: they just mean we must steer very carefully, and be vigilant to everything we can learn about the ship and the hazards in the waters, while we do it. We can probably avoid the rocks, but we need to start now.

Further reading for Chapter 5

Aldy, J. E., Ashton, J., Baron, R., Bodansky, D., Charnovitz, S., Diringer, E., Heller, T., Pershing, J., Shukla, P. R., Tubiana, L., Tudela, F., and Wang, X. (2003). *Beyond Kyoto: Advancing the International Effort Against Climate Change*. Washington, DC: Pew Center on Global Climate Change, December.

A collection of six essays examining specific aspects of a potential international climate-change regime, including long-term targets; near-term commitments, international equity, costs, and the connections of climate-change policy to economic development and international trade.

Aspen Institute (2002). *U.S. Policy on Climate Change: What's Next?* A report of the Aspen Institute Environmental Policy Forum, Frank Loy and Bruce Smart (co-chairs), ed. John A. Riggs. Aspen, Colorado: Aspen Institute.

The results of a senior bipartisan forum convened by the Aspen Institute in 2002. In addition to the chairs' summary of the major conclusions of the forum, the report includes brief background papers that review major areas of the current policy debate about emission trends, technologies, costs, and potential policy responses.

Howse, R. (2002). The Appellate Body Rulings in the Shrimp/Turtle Case: a new legal baseline for the trade and environment debate. *Columbia Journal of Environmental Law*, **27**(2), 489–519.

A discussion of crucial recent WTO rulings on the US ban on imports of shrimp harvested by nations that do not match the US policy requiring turtle-excluder devices. Although the initial US policy was rejected for being discriminatory in its application, the decision greatly strengthened the ability of environmental measures that are not discriminatory to use trade restrictions in pursuit of environmental objectives.

Parson, E. A. (2003). *Protecting the Ozone Layer: Science and Strategy*. New York: Oxford University Press.

This history of the interwoven progression of scientific, technological, and political debates concerned with depletion of the stratospheric ozone layer identifies several central lessons from the failures and successes of the ozone regime that can be applied to help break the present policy deadlock on global climate change.

Rowland, F. S. (1993). President's Lecture: The Need for Scientific Communication with the Public. *Science*, **260** (11 June), 1571–1576.

In this President's Address to the 1993 annual meeting of the American Association for the Advancement of Science, Rowland reviews some of the pseudo-scientific claims about ozone depletion then circulating in popular and policy settings, notes how easy it is to make such claims appear persuasive to a non-scientific audience, and argues the need for greater scientific education of the public and policy-makers – including greater education for skeptical examination of scientific claims advanced in policy settings.

Sandalow, D. B. and Bowles, I. A. (2001). Fundamentals of treaty-making on climate change. *Science*, **292** (8 June), 1839–1840.

A brief summary of the status of international climate policy after the Bush Administration's rejection of the Kyoto Protocol, and a discussion of those aspects of international policy that are widely accepted as necessary elements of a resolution of the issue.

Stewart, R. B. and Wiener, J. B. (2003). *Reconstructing Climate Policy: Beyond Kyoto*. Washington, D.C.: American Enterprise Institute.

This monograph argues that it is in America's national interest to take a more active stance on climate change, and proposes a path forward based on bilateral USA–China negotiations of joint emission limits and a well managed emission trading system, which could be subsequently expanded by the accession of additional countries and would eventually aim at merging with the Kyoto Protocol.

Taubes, G. (1993). The ozone backlash. *Science*, **260** (11 June), 1580–1583.

A news article by a staff writer of *Science* magazine provides greater detail on the events and specific claims advanced in the "ozone skeptics" backlash of the early 1990s. Best read in conjunction with Rowland's presidential address, cited above, which appears in the same issue of *Science*.

Victor, D. G. (2004). *Climate Change: Debating America's Policy Options*. New York: Council on Foreign Relations.

In addition to general background on climate-change science and policy, this briefing note includes sketches of three alternative paths for US climate policy: a relatively passive response that relies on adaptation and technological change to manage the issue; an attempt to develop global emission-permit markets independent of negotiation of emission limits; and an attempt to re-engage the Kyoto Protocol process and take the lead in addressing its weaknesses.