Chapter 1: The Challenge of Climate Change: Scientific, Legal, and Political Elements

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> In the longer-term, we face what I term the "50-50-50 challenge." By 2050, the world's population will grow by 50 percent, reaching 9 billion people. By that time, by 2050, the world must reduce at least by 50 percent global greenhouse gas emissions. That is the "50-50-50 challenge."
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> - United Nations, Department of Public Information, *Better Global Governance Needed to Help Most Vulnerable, Stave Off Climate Change, Meet 'New Generation' Challenges, Says Secretary-General in Marrakesh*, Oct. 18, 2010, http://www.un.org/News/Press/docs/2010/sgsm13188.doc.htm.

These remarks by U.N. Secretary-General Ban Ki-moon capture well the core dilemmas facing the United States and the world in appropriately responding to climate change. Consensus science suggests that the wide range of human activities that emit greenhouse gases is causing changes in the climate that pose increasing dangers over time. Global concentrations of carbon dioxide are already at 390 parts per million as of November 2011, well above both the 280 parts per million prior to the nineteenth century's industrial revolution and the 350 parts per million that scientists suggest staying below to minimize risks of major impacts.

Policymakers in governments around the world have attempted to address these emissions and are beginning to respond to and plan for impacts. But, to date, these efforts—even with the legal progress made at the December 2011 climate change negotiations in Durban—remain woefully inadequate to address the problem. Emissions are still far too high to prevent the worst impacts, with no signs that political will exists to bring them down adequately. Adaptation planning is still in its early stages in most places. Moreover, for each of these issues, widespread debate exists about appropriate law and policy.

Deep inequalities permeate these debates. The biggest emitters have historically been rich, developed countries while many of the most physically vulnerable places are poor with limited capacity to adapt. Rapidly developing countries like China, India, and Brazil represent an increasing share of global emissions—China has passed the United States as the world's largest emitter—but their per capita emissions remain much lower and they desire to continue to raise their citizens' standard of living to that of developed countries.

This book provides an exploration of these dilemmas. It analyzes the problem of climate change and efforts to address it through law. The chapter that follows provides a guide to the book and introduces climate change science, law and policy options, and the daunting challenges that frame the chapters that follow.

A. Guide to the Book

Throughout its discussion of climate change law and policy, this book is grounded by three key principles. First, climate change is a tremendously complex problem at the interface of science, law, politics, culture, and economics. Any effective legal strategy to address climate change must take that complexity into account.

Second, and related to the first, the law relevant to climate change is not just environmental. Greenhouse gas emissions stem from behavior at the core of economies around the world, and the impacts of climate change will fundamentally alter life in many places. A legal treatment of climate change must think comprehensively and creatively about what types of law help to frame the problem and must be involved in solutions.

Finally, climate change cannot be fully addressed through international negotiations under the 1992 United Nations Framework Convention on Climate Change (UNFCCC). Those negotiations are a tremendously important piece of the legal solution, but a full treatment of climate change requires consideration of legal activity at multiple levels of government and by a wide range of actors.

The book builds from these principles to explore climate change as a legal problem that cuts across levels of government, disciplines, and substantive areas of law. This book differs from others in its effort to give fairly equal emphasis to each level of governance and the diversity of strategies being used to address climate change. This structure is intended to map the web of human interactions comprising this problem and its potential solutions.

The book identifies seven topics as critical to understanding climate change law and policy, and treats each of these topics in a chapter. This first chapter frames the rest of the book by introducing the complex nature of climate change science and of the law attempting to address emissions and impacts. It explores the way in which human action interacts with the efforts to understand climate change science, the areas of greater and lesser certainty in current science, and contemporary controversies and their implications for the future of scientific inquiry and presentation in this area. It then considers the options and challenges facing legal efforts to address this problem, with a focus on mitigation, adaptation, and the complexities of cross-cutting governance.

Chapter Two considers international legal efforts to approach climate change. It begins by discussing the international treaty regime focused on climate change. It explains the framework provided by the UNFCCC, its implementation through the 1997 Kyoto Protocol, and the state of current negotiations. The chapter then explores five other ways in which international law has and continues to interact with climate change, including the Montreal Protocol’s climate change impacts, agreements among major economies, the Asia-Pacific Partnership on Clean Development and Climate, human rights and world heritage petitions to international bodies, and agreements among cities, states, and provinces.

Chapter Three provides an overview of the current state of climate change law in the United States. It begins with the legislative branch, considering the primary existing statutes focused on climate change and the difficulties in passing more comprehensive climate change action. It then turns to the judicial branch and considers the way in which litigation, especially the Supreme Court's decisions in *Massachusetts v. EPA* and *AEP v. Connecticut*, has helped to shape regulatory action under the Clean Air Act and other environmental statutes. It concludes by considering the executive branch, and the way in which its implementation of the Supreme Court's decision in *Massachusetts* and other regulatory action has led to steps to mitigate and adapt to climate change in the United States.

Chapter Four moves beyond the United States to consider and compare other national and regional action on climate change. The chapter begins by introducing the comparative law approach and the complexities of making legal comparisons among nations. It then turns to four key places that vary significantly in how they have engaged with the problem of climate change: the European Union, a model of energetic regulatory action; Canada, which initially followed Europe's lead but then did not follow through; China, a rapidly industrializing country that has become the world's largest greenhouse gas emitter; and Brazil, an emerging economic power that is home to threatened forests critical to climate stability. The chapter concludes by exploring the possibilities for global harmonization of climate change law.

Chapter Five looks within the nation-state to analyze the local, state, and provincial efforts to address climate change. The chapter first observes that subnational greenhouse gas regulation presents a puzzle: Why would a locality or state unilaterally incur the costs of encouraging or mandating greenhouse gas emissions reductions? What benefits does it receive in return? The chapter then surveys the large and diverse landscape of subnational mitigation and adaptation policy. The chapter concludes with a close look at the phenomenon of transnational collaborations, wherein localities in different national jurisdictions are cooperating in nontraditional ways.

Chapter Six moves beyond governments to examine the role of nongovernmental organizations, corporations, and individuals in climate change law and policy. It first examines the way in which nongovernmental organizations work collaboratively to influence U.S. law and engage in the international treatymaking process. It then turns to the role of major corporate emitters, both in blocking climate change regulation and in working voluntarily and cooperatively to reduce their emissions. The chapter concludes by considering the importance of individual efforts to reduce climate change, and the ways in which changes in the behavior of many individuals can add up to significant emissions reductions.

The final chapter looks to the future of climate change law and policy. It begins by considering three future scenarios and the role that law might play in each of them. In the first scenario, perhaps the most realistic, legal efforts to mitigate climate change have failed to prevent major impacts and the nations of the world have decided to attempt to intervene in the climate system to try to reverse climate change. In the second scenario, major climate change has transformed the globe, and leaders are contemplating major relocation and reconstitution of law and society in response. In the third scenario, a combination of the current approaches and regulatory innovation have mitigated emissions sufficiently to result in relatively limited climate change and accompanying adaptation. The book then concludes by considering how future lawyers and policymakers interested in this problem can work towards the third scenario most effectively and prepare for the first two.

Collectively, these chapters aim both to provide a comprehensive introduction to climate change law and policy and to challenge those who will determine our future to think creatively. We hope that by engaging the complexity of law's interaction with this problem, the book can be part of a constructive step forward.

B. Climate Change Science: Certainties and Uncertainties

Effectively assessing the problem of climate change and potential solutions from a scientific perspective is extremely complex. Not only are the interactions with greenhouse gas emissions in the atmosphere and ocean extremely complicated, but the problem of climate change also involves the interaction between human beings and their environment. Human beings are causing the increased emissions of greenhouse gases, suffering the impacts, and trying to adapt.

Moreover, while a high level of certainty exists about the big picture of climate change, more uncertainty exists over some of the particular impacts in specific places. It is difficult to have a nuanced public conversation about the details of climate change science and the appropriate legal approaches to risk. The polarized nature of the current discourse, particularly in the United States, has made such discussions even harder. These challenges have been exacerbated by public controversy over errors and inappropriate behavior by a handful of climate scientists. While independent assessments have found their mistakes to have minimal impact on the overall reliability of consensus climate change science and key institutions have changed procedures to address these lapses, these scandals have further shaken public confidence in the science.

This Section explores these issues. It begins by examining the current state of climate change science, and then considers the barriers to scientific understanding and the way in which controversies over science interact with public perceptions of risk.

1. The Current State of Climate Change Science

Climate change science not only involves complicated interactions among the ocean, atmosphere, land masses, and people, but is also developed and communicated in a complex political, legal, economic, and cultural context. This section provides an overview of the current state of climate change science by providing an excerpt from the leading organization in the world assessing climate change science, the Intergovernmental Panel on Climate Change (IPCC).

Since its establishment in 1988, the IPCC has examined the state of climate change science through a comprehensive assessment of peer-reviewed work of scientists around the world. That year, the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) created the IPCC and the United Nations General Assembly passed a resolution providing it with responsibility for producing a comprehensive review and recommendations. From the start, the IPCC was charged with not only assessing the physical science, but also analyzing its interaction with people and proposing strategies for addressing both causes and impacts.

The IPCC has produced four comprehensive assessment reports and numerous specialized reports since its creation. It has three primary working groups: one that focuses on the state of the science; another which examines impacts, adaptation, and vulnerability; and a third which analyzes mitigation. The IPCC's assessment reports, which have come out every few years beginning in 1990, contain a volume on each of these three areas and a synthesis volume that considers the way in which these three aspects of climate change interact. The fourth IPCC assessment report came out in 2007 and the fifth one is due out in 2013-2014. Recent IPCC specialized reports include 2011 reports on *Renewable Energy and Climate Change Mitigation* and *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*.

The following excerpt from the IPCC's 2007 *Synthesis Report* describes the complex interactions that constitute the problem of climate change. It provides background on the IPCC, explores human interactions with the climate system, and considers options for the future.

> **INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, SYNTHESIS REPORT, Foreward & Policy Summary (2007), *available at* http://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html.**

Forward

The Intergovernmental Panel on Climate Change (IPCC) was jointly established in 1988, by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), with the mandate to assess scientific information related to climate change, to evaluate the environmental and socio-economic consequences of climate change, and to formulate realistic response strategies. The IPCC multivolume assessments have since then played a major role in assisting governments to adopt and implement policies in response to climate change, and in particular have responded to the need for authoritative advice of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), which was established in 1992, and its 1997 Kyoto Protocol.

Since its establishment, the IPCC has produced a series of Assessment Reports (1990, 1995, 2001 and this one in 2007), Special Reports, Technical Papers and Methodology Reports, which have become standard works of reference, widely used by policymakers, scientists, other experts and students. The most recent publications include a Special Report on "Carbon Dioxide Capture and Storage" and one on "Safeguarding the Ozone Layer and the Global Climate System", published in 2005, and the "Guidelines for National Greenhouse Gas Inventories" re-edited in 2006. A Technical Paper on "Climate Change and Water" is under preparation.

This Synthesis Report (SYR), adopted in Valencia, Spain, on 17 November 2007, completes the four-volume Fourth Assessment Report (AR4), which was released in various steps throughout the year under the title "Climate Change 2007". It summarises the findings of the three Working Group reports and provides a synthesis that specifically addresses the issues of concern to policymakers in the domain of climate change: it confirms that climate change is occurring now, mostly as a result of human activities; it illustrates the impacts of global warming already under way and to be expected in future, and describes the potential for adaptation of society to reduce its vulnerability; finally it presents an analysis of costs, policies and technologies intended to limit the extent of future changes in the climate system.

The AR4 is a remarkable achievement involving more than 500 Lead Authors and 2000 Expert Reviewers, building on the work of a wide scientific community and submitted to the scrutiny of delegates from more than one hundred participating nations.

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1. Observed changes in climate and their effects

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.
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2. Causes of change

Changes in atmospheric concentrations of greenhouse gases (GHGs) and aerosols, land cover and solar radiation alter the energy balance of the climate system.

Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004

Carbon dioxide (CO_2) is the most important anthropogenic GHG. Its annual emissions grew by about 80% between 1970 and 2004. The long-term trend of declining CO_2 emissions per unit of energy supplied reversed after 2000.

Global atmospheric concentrations of CO_2, methane (CH_4) and nitrous oxide (N_2O) have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years.

Atmospheric concentrations of CO_2 (379ppm) and CH_4 (1774ppb) in 2005 exceed by far the natural range over the last 650,000 years. Global increases in CO_2 concentrations are due primarily to fossil fuel use, with land-use change providing another significant but smaller contribution. It is very likely that the observed increase in CH_4 concentration is predominantly due to agriculture and fossil fuel use. CH_4 growth rates have declined since the early 1990s, consistent with total emissions (sum of anthropogenic and natural sources) being nearly constant during this period. The increase in N_2O concentration is primarily due to agriculture.

There is very high confidence that the net effect of human activities since 1750 has been one of warming.

Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations. It is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent (except Antarctica)

During the past 50 years, the sum of solar and volcanic forcings would likely have produced cooling. Observed patterns of warming and their changes are simulated only by models that include anthropogenic forcings. Difficulties remain in simulating and attributing observed temperature changes at smaller than continental scales.

Advances since the TAR show that discernible human influences extend beyond average temperature to other aspects of climate.

Human influences have:

- very likely contributed to sea level rise during the latter half of the 20th century
- likely contributed to changes in wind patterns, affecting extra-tropical storm tracks and temperature patterns
- likely increased temperatures of extreme hot nights, cold nights and cold days
- more likely than not increased risk of heat waves, area affected by drought since the 1970s and frequency of heavy precipitation events.
- Anthropogenic warming over the last three decades has likely had a discernible influence at the global scale on observed changes in many physical and biological systems.

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3. Projected climate change and its impacts

There is high agreement and much evidence that with current climate change mitigation policies and related sustainable development practices, global GHG emissions will continue to grow over the next few decades.

The IPCC Special Report on Emissions Scenarios (SRES, 2000) projects an increase of global GHG emissions by 25 to 90% (CO_2-eq) between 2000 and 2030, with fossil fuels maintaining their dominant position in the global energy mix to 2030 and beyond. More recent scenarios without additional emissions mitigation are comparable in range.

Continued GHG emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century.

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There is now higher confidence than in the TAR in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation and some aspects of extremes and sea ice.

Regional-scale changes include:

- warming greatest over land and at most high northern latitudes and least over Southern Ocean and parts of the North Atlantic Ocean, continuing recent observed trends
- contraction of snow cover area, increases in thaw depth over most permafrost regions and decrease in sea ice extent; in some projections using SRES scenarios, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century
- very likely increase in frequency of hot extremes, heat waves and heavy precipitation
- likely increase in tropical cyclone intensity; less confidence in global decrease of tropical cyclone numbers
- poleward shift of extra-tropical storm tracks with consequent changes in wind, precipitation and temperature patterns
- very likely precipitation increases in high latitudes and likely decreases in most subtropical land regions, continuing observed recent trends.

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Some systems, sectors and regions are likely to be especially affected by climate change.
Systems and sectors:

- particular ecosystems:

  - terrestrial: tundra, boreal forest and mountain regions because of sensitivity to warming; mediterranean-type ecosystems because of reduction in rainfall; and tropical rainforests where precipitation declines
  - coastal: mangroves and salt marshes, due to multiple stresses
  - marine: coral reefs due to multiple stresses; the sea ice biome because of sensitivity to warming
- water resources in some dry regions at mid-latitudes and in the dry tropics, due to changes in rainfall and evapotranspiration, and in areas dependent on snow and ice melt
- agriculture in low latitudes, due to reduced water availability
- low-lying coastal systems, due to threat of sea level rise and increased risk from extreme weather events
- human health in populations with low adaptive capacity.

Regions:
- the Arctic, because of the impacts of high rates of projected warming on natural systems and human communities
- Africa, because of low adaptive capacity and projected climate change impacts
- small islands, where there is high exposure of population and infrastructure to projected climate change impacts
- Asian and African megadeltas, due to large populations and high exposure to sea level rise, storm surges and river flooding.
- Within other areas, even those with high incomes, some people (such as the poor, young children and the elderly) can be particularly at risk, and also some areas and some activities.

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4. Adaptation and mitigation options

A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to climate change. There are barriers, limits and costs, which are not fully understood.

Societies have a long record of managing the impacts of weather- and climate-related events. Nevertheless, additional adaptation measures will be required to reduce the adverse impacts of projected climate change and variability, regardless of the scale of mitigation undertaken over the next two to three decades. Moreover, vulnerability to climate change can be exacerbated by other stresses. These arise from, for example, current climate hazards, poverty and unequal access to resources, food insecurity, trends in economic globalisation, conflict and incidence of diseases such as HIV/AIDS.

Some planned adaptation to climate change is already occurring on a limited basis. Adaptation can reduce vulnerability, especially when it is embedded within broader sectoral initiatives. There is high confidence that there are viable adaptation options that can be implemented in some sectors at low cost, and/or with high benefit-cost ratios. However, comprehensive estimates of global costs and benefits of adaptation are limited.

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Adaptive capacity is intimately connected to social and economic development but is unevenly distributed across and within societies.

A range of barriers limits both the implementation and effectiveness of adaptation measures. The capacity to adapt is dynamic and is influenced by a society's productive base, including natural and man-made capital assets, social networks and entitlements, human capital and institutions, governance, national income, health and technology. Even societies with high adaptive capacity remain vulnerable to climate change, variability and extremes.

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5. The long-term perspective

Determining what constitutes "dangerous anthropogenic interference with the climate system" in relation to Article 2 of the UNFCCC involves value judgements. Science can support informed decisions on this issue, including by providing criteria for judging which vulnerabilities might be labelled 'key'.

Key vulnerabilities may be associated with many climate-sensitive systems, including food supply, infrastructure, health, water resources, coastal systems, ecosystems, global biogeochemical cycles, ice sheets and modes of oceanic and atmospheric circulation.

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There is high confidence that neither adaptation nor mitigation alone can avoid all climate change impacts; however, they can complement each other and together can significantly reduce the risks of climate change.

Adaptation is necessary in the short and longer term to address impacts resulting from the warming that would occur even for the lowest stabilisation scenarios assessed. There are barriers, limits and costs, but these are not fully understood. Unmitigated climate change would, in the long term, be likely to exceed the capacity of natural, managed and human systems to adapt. The time at which such limits could be reached will vary between sectors and regions. Early mitigation actions would avoid further locking in carbon intensive infrastructure and reduce climate change and associated adaptation needs.

Many impacts can be reduced, delayed or avoided by mitigation. Mitigation efforts and investments over the next two to three decades will have a large impact on opportunities to achieve lower stabilisation levels. Delayed emission reductions significantly constrain the opportunities to achieve lower stabilisation levels and increase the risk of more severe climate change impacts.

In order to stabilise the concentration of GHGs in the atmosphere, emissions would need to peak and decline thereafter. The lower the stabilisation level, the more quickly this peak and decline would need to occur.

There is high agreement and much evidence that all stabilisation levels assessed can be achieved by deployment of a portfolio of technologies that are either currently available or expected to be commercialised in coming decades, assuming appropriate and effective incentives are in place for their development, acquisition, deployment and diffusion and addressing related barriers.

All assessed stabilisation scenarios indicate that 60 to 80% of the reductions would come from energy supply and use and industrial processes, with energy efficiency playing a key role in many scenarios. Including non-CO_2 and CO_2 land-use and forestry mitigation options provides greater flexibility and cost-effectiveness. Low stabilisation levels require early investments and substantially more rapid diffusion and commercialisation of advanced low-emissions technologies.

Without substantial investment flows and effective technology transfer, it may be difficult to achieve emission reduction at a significant scale. Mobilising financing of incremental costs of low-carbon technologies is important.

The macro-economic costs of mitigation generally rise with the stringency of the stabilisation target. For specific countries and sectors, costs vary considerably from the global average.

In 2050, global average macro-economic costs for mitigation towards stabilisation between 710 and 445ppm CO_2-eq are between a 1% gain and 5.5% decrease of global GDP. This corresponds to slowing average annual global GDP growth by less than 0.12 percentage points.

Responding to climate change involves an iterative risk management process that includes both adaptation and mitigation and takes into account climate change damages, co-benefits, sustainability, equity and attitudes to risk.

Impacts of climate change are very likely to impose net annual costs, which will increase over time as global temperatures increase. Peer-reviewed estimates of the social cost of carbon in 2005 average US$12 per tonne of CO_2, but the range from 100 estimates is large (-$3 to $95/t$CO_2$). This is due in large part to differences in assumptions regarding climate sensitivity, response lags, the treatment of risk and equity, economic and non-economic impacts, the inclusion of potentially catastrophic losses and discount rates. Aggregate estimates of costs mask significant differences in impacts across sectors, regions and populations and very likely underestimate damage costs because they cannot include many non-quantifiable impacts.

Limited and early analytical results from integrated analyses of the costs and benefits of mitigation indicate that they are broadly comparable in magnitude, but do not as yet permit an unambiguous determination of an emissions pathway or stabilisation level where benefits exceed costs.

Climate sensitivity is a key uncertainty for mitigation scenarios for specific temperature levels.

Choices about the scale and timing of GHG mitigation involve balancing the economic costs of more rapid emission reductions now against the corresponding medium-term and long-term climate risks of delay.

NOTES AND QUESTIONS

1. The synthesis report delineates areas of greater and lesser certainty. What are they and how does the language of the report differentiate among different levels of certainty? In your view, which certainties and uncertainties are most critical for law and policy?

2. The synthesis report captures an overwhelming mix of environmental and human interactions that both cause the problem of climate change and help to determine an appropriate response. How should policymakers respond to this overwhelming mix? More broadly, what is the role of law in addressing complex problems like climate change?

3. Issues of inequality emerge throughout the synthesis report. Beyond the economic differences between countries that impact their emissions levels and ability to adapt, the report highlights the systems, sectors, and regions most vulnerable to climate change. How do these inequalities impact the way in which law should be used as a tool in addressing climate change? Chapter 7 explores these problems of inequality in more depth.

4. The synthesis report makes clear that there are economic costs both to mitigating climate change and to failing to mitigate effectively. Which costs are more certain? When would these costs occur? How should these issues of competing costs and their different levels of certainty and timing affect climate change law and policy?

2. Barriers to Scientific Understanding

The public discussion over climate change science often focuses on polarized battles between those who believe in climate change science and skeptics. This discussion is important in framing the policy debates, and the next section will focus on controversies over climate change science. However, before focusing on those controversies, this section engages the certainties and uncertainties of climate change science in a more nuanced way than these debates often allow.

Climate change science is analyzing a very complex system with interactions in many places and at many physical (local, state, national, international) and temporal (past, present, future) scales. The level of scientific certainty is not uniform across this system. Rather it depends upon what aspect of the system is being discussed; some aspects have been studied more than others and some are easier to understand and predict than others.

Although a high level of certainty exists about the global-level processes of climate change, more uncertainty exists about some of the impacts taking place locally and regionally at specific points in time. This uncertainty, however, varies depending on the type of impact. For example, while climate change increases the risk of severe storms, it is difficult to say that it caused a particular hurricane or blizzard. On the other hand, strong scientific consensus exists about climate change causing sea level rise and heat waves, even at smaller scales.

At both an international level and at a national level one, there are efforts to address knowledge gaps where possible. The U.S. National Research Council’s 2007 assessment of the U.S. Climate Change Science Program helped to frame some of the most recent efforts in the United States through highlighting areas where progress was needed for more effective scientific understanding and policymaking. The following is an excerpt of that advice.

Committee on Strategic Advice on the U.S. Climate Change Science Program, National Research Council, *Evaluating Progress of the U.S. Climate Change Science Program: Methods and Preliminary Results* 1, 34–37 (2007), *available at* http://www.nap.edu/catalog/11934.html.

The U.S. Climate Change Science Program (CCSP) was created in February 2002 under a new cabinet-level management structure designed to improve government-wide management of climate and related environmental science. The CCSP integrated the then-existing U.S. Global Change Research Program (USGCRP) with the administration's Climate Change Research Initiative. The CCSP was formed with an ambitious, but practical, guiding vision: *a nation and the global community empowered with the science based knowledge to manage the risks and opportunities of change in the climate and related environmental systems.*

Although the U.S. government has sponsored research on climate and related environmental change through the CCSP or USGCRP for more than 15 years, the progress of either program has never been evaluated. Such evaluations are important for identifying strengths and weaknesses and determining what adjustments should be made to achieve program goals. At the request of Dr. James Mahoney, then director of the CCSP, the National Research Council (NRC) established the Committee on Strategic Advice on the U.S. Climate Science Program to carry out three tasks over a three-year period. The first task—an evaluation of program progress—is the subject of this report:

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OVERARCHING CONCLUSIONS

Discovery science and understanding of the climate system are proceeding well, but use of that knowledge to support decision making and to manage risks and opportunities of climate change is proceeding slowly.

Good progress has been made in documenting climate changes and their anthropogenic influences and in understanding many aspects of how the Earth system works (e.g., aerosol direct forcing, glacier melting). Coupled ocean-atmosphere-land climate models have also improved, although models that enable exploration of feedbacks, assessment of human driving forces, or trade-offs of different resource management and mitigation options are still relatively immature. The program has made a significant contribution to international climate research, particularly to Working Group 1 of the Intergovernmental Panel on Climate Change (IPCC). CCSP research and the temperature trends report have also played a role in the findings of the recently released IPCC (2007) report.

In contrast, inadequate progress has been made in synthesizing research results, assessing impacts on human systems, or providing knowledge to support decision making and risk analysis. Reports on temperature trends and scenarios of greenhouse gas emissions were the only CCSP synthesis and assessment products completed in the last four years; most synthesis activities have been small, focused, community efforts. A previous review of the CCSP strategic plan found that decision support activities were underdeveloped. The committee's preliminary assessment of progress (Chapters 4 and 5) shows that decision support has been incorporated into some aspects of the ecosystems research element (i.e., management strategies that consider the effect of climate variability on fisheries) and the human contributions and responses research element (e.g., Decision Making Under Uncertainty [DMUU] centers). However, these programs are small, and decision support is treated primarily as a service activity, rather than a topic that requires fundamental research. As a result, decisions about climate and associated environmental change have had to be made without the benefit of a strong scientific underpinning.

Progress in understanding and predicting climate change has improved more at global, continental, and ocean basin scales than at regional and local scales.

The disparity in progress is partly a result of the site-specific nature of impacts and vulnerabilities and the much greater natural variability on smaller scales. For example, the interannual variability of surface temperature is an order of magnitude greater on the scale of an individual town than the global average. It is these smaller spatial scales that are most relevant for state and local resource managers, policy makers, and the general public. Future projected land cover changes and changes in the distribution of continental water due to dams and irrigation, for example, are just beginning to be included in climate models. However, improving understanding of regional-scale climate processes and their impacts in North America would require improved integrated modeling, regional-scale observations, and the development of scenarios of climate change and impacts. Improved predictions of climate change at local levels should help the CCSP bridge the gap between science and decision making.

Our understanding of the impact of climate changes on human well-being and vulnerabilities is much less developed than our understanding of the natural climate system.

The greatest progress in the CCSP has been made on basic climate science associated with overarching goals 1, 2, and 3 (although human driving forces have lagged) and the least has been made on the interaction of climate change with human systems (overarching goals 4 and 5). Improved progress toward overarching goals 4 and 5 will require stronger connections with the social science community and a more comprehensive and balanced research program. Indeed, a review of the draft CCSP strategic plan recommended accelerating efforts in human dimensions, economics, adaptation, and mitigation by strengthening science plans and institutional support. Yet only a small percentage of the CCSP research and observations budget is devoted to the human contributions and responses research element, making it difficult to carry out even the limited research agenda outlined in the CCSP strategic plan. The bundling of human dimensions research and decision support tools further deemphasizes the importance of social science research and is detrimental to both parts of the program.

Another reason for inadequate progress is that no agency has a program focused on the human dimensions of climate. A consequence is that expertise in the human dimensions of climate change is in short supply in the participating agencies, which in turn makes it difficult for the CCSP to exert leadership and forge the necessary links between these agencies and the academic social science community. The connections that the National Science Foundation established for its DMUU centers may provide a model for other CCSP social science research. Finally, the human dimensions research community is small and unorganized and thus may be unable to advocate effectively for changing program priorities. However, the good quality of work achieved with the low level of investment to date suggests that the community is capable of supporting a more substantial program.

Science quality observation systems have fueled advances in climate change science and applications, but many existing and planned observing systems have been cancelled, delayed, or degraded, which threatens future progress.

Much of the progress in understanding the climate system has been fueled by the availability of a wide range of data. A rich resource of satellite and in situ observations has been collected, disseminated, and archived by agencies participating in the CCSP. However, the number and diversity of satellite observations are expected to diminish significantly with the cancellation or delay of several planned National Aeronautics and Space Administration (NASA) and National Oceanic and Atmospheric Administration (NOAA) satellite missions (e.g., Hydros, Global Precipitation Measurement mission, Landsat Data Continuity Mission, Geostationary Operational Environmental Satellite Series-R) and the elimination of climate instruments from NPOESS. By the end of the decade the number of operating sensors and instruments on board NASA platforms is expected to decrease by approximately 40 percent. In addition, a number of long-standing in situ networks (e.g., U.S. Geological Survey stream gauge network, U.S. Department of Agriculture Snowpack Telemetry snow observation system) are deteriorating, and planned carbon cycle field campaigns may be cancelled because of funding shortfalls. The anticipated decline in U.S. capability to monitor global- or regional-scale environmental changes and the degradation of climate data climate change research. Indeed, the reduction in remote sensing capability is perhaps the single greatest threat to the future progress of the CCSP. Yet the CCSP has no strategy for implementing, sustaining, and evolving an observing system to address crucial questions on climate and related environmental changes. It is also not clear what role the CCSP might play in cooperating with other countries to obtain necessary data. This is particularly worrisome, given the IPCC prediction that the large warming trend of the last two decades will continue for at least the next few decades.

Progress in communicating CCSP results and engaging stakeholders is inadequate.

One of the most important differences between the CCSP and the U.S. Global Change Research Program (USGCRP) is the increased emphasis on communicating research results to stakeholders and encouraging the use of science-based products to support decision makers. Indeed, using CCSP knowledge to manage risks and opportunities related to climate variability and change is an overarching goal of the program. However, a coherent communications strategy, informed by basic social science research, has not yet been developed. Most efforts to carry out the two-way dialogue envisioned in the CCSP strategic plan appear to be ad hoc and to rely more on communicating research results—especially to federal agencies and, to a lesser extent, the scientific community—than on hearing what others need from the program. NOAA’s Regional Integrated Sciences and Assessments program has been effective in communicating research results to stakeholders in particular sectors (e.g., impact of seasonal-to-interannual climate variability on water resources) or regions, but this program is small and has limited reach. Other efforts to identify and engage state and local officials, nongovernmental organizations, and the climate change technology community are still in the early stages. Building and maintaining relationships with stakeholders is not easy and requires more resources in the CCSP Office and participating agencies than are currently available. Yet a well-developed list of stakeholders, target audiences, and their needs is essential for educating the public and informing decision making with scientifically based CCSP products.

The separation of leadership and budget authority presents a serious obstacle to progress in the CCSP.

A principle in *Thinking Strategically* is that a leader with authority to direct resources and/or research effort is essential if the program is to succeed. However, the CCSP is an interagency program in which responsibility for program management and budget allocation is shared among the participating agencies. As a result, effective coordination mechanisms are essential. Strong coordination at all levels of the program—within research questions, among closely related research elements and cross-cutting issues, and across the program as a whole—can create new avenues of investigation and should enable the CCSP to achieve more than its participating agencies could accomplish alone. Advances in characterizing the carbon budget, for example, have been attributed in part to an active IWG and scientific steering committee, community-established implementation plans, and a long history of interagency cooperation on carbon cycle research projects (see Chapter 4). Established coordination mechanisms exist at both the component level (IWGs for research elements and cross-cutting issues…) and the program level (CCSP principals and program office).

However, coordination of budgets has been less effective. In the early years of the USGCRP, the Office of Management and Budget worked closely with the program leadership to identify priorities and to communicate those priorities to the relevant agency heads. CCSP budget allocations are coordinated to a much lesser extent today. Budgets are reported for major components of the CCSP (e.g., overarching goals, research elements), although this is primary a post factum accounting exercise, not a true allocation of funds to carry out the program. The CCSP director and agency principals have only a small budget over which they have discretionary control, and they must rely on persuasion rather than authority to allocate or prioritize funding across the agencies. For example, the CCSP appears to have had little influence either on the decisions taken to cancel or delay satellite missions or on what resources should be allocated to expand or upgrade in situ networks, despite the importance of observing systems to achieving CCSP objectives. Instead, these decisions are made by the respective agencies. Similarly, the interagency working groups have few discretionary funds and little authority to implement the objectives that they define, unless these objectives coincide with their agency objectives. Even funding for the Climate Change Research Initiative is disbursed among agency programs. Such fragmented authority can only weaken coherent leadership and priority setting and slow progress in achieving the overall goals of the program.

NOTES AND QUESTIONS

1. Although greater focus on local and regional issues will increase scientific certainty, it still will be hard to know whether any particular weather event in a specific place at a point in time is caused by climate change. What is the appropriate way to deal with that uncertainty? Is it enough to know that climate change increases the risk of more frequent and severe weather events?

   One well-established approach to scientific uncertainty under international environmental law, known as the precautionary principle, is to act with caution in the face of risk. This principle has many different formulations, one of the most well-accepted of which is articulated in the 1992 Rio Declaration: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." Rio Declaration on Environment and Development, princ. 15, U.N. GAOR, 46th Sess., U.N. Doc. A/CONF. 151/5/Rev. 1, June 13, 1992, 31 I.L.M. 874 (1992), http://www.unep.org/Documents.Multilingual/Default.asp?documentid=78&articleid=1163.

Do you agree with taking a precautionary approach to the scientific uncertainties in climate change science? How would you translate such an approach into law and policy?

2. This report, like the IPCC synthesis report above, highlights the complexity of the science-law interface. While many issues might be able to be addressed by involving government officials more effectively, a key gap will likely remain. Namely, the scientists understand science better than law and the lawmakers understand law better than science. What is the best way of addressing this gap? How should the proposed "two-way communication" be operationalized?

3. This report also highlights the complexity of the human-science interface. Why is research at that interface critical to addressing the problem of climate change? Which types of human-science research seem most important to you based on what you know the problem thus far?

3. Controversies and Public Perceptions of Risk

Climate change science and scientists have been challenged over the past few years based on the release of information that showed procedural and substantive problems with both the IPCC and its underlying science. These scandals have formed part of a shift in public opinion in the United States, where public opinion polls show that people have become less certain about climate change science. This section discusses two of the most significant scandals to give clearer context for the controversies.

First, a paragraph of the 2007 IPCC synthesis report on the melting of Himalayan glaciers was shown to be inaccurate. Although it was a relatively limited error, the fact that it made it into the report undermined the IPCC's credibility and raised questions about its process. The IPCC has responded both directly and proactively to the problematic paragraph in the IPCC synthesis report and the following two excerpts describe that response.

The first excerpt is the IPCC's direct response to the error and its effect on the rest of the document.

Intergovermental Panel on Climate Change, IPCC Statement on the Melting of Himalayan Glaciers, Jan. 20, 2010, *available at* http://www.ipcc.ch/pdf/presentations/himalaya-statement-20january2010.pdf.

The Synthesis Report, the concluding document of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (page 49) stated: "Climate change is expected to exacerbate current stresses on water resources from population growth and economic and land-use change, including urbanisation. On a regional scale, mountain snow pack, glaciers and small ice caps play a crucial role in freshwater availability. Widespread mass losses from glaciers and reductions in snow cover over recent decades are projected to accelerate throughout the 21st century, reducing water availability, hydropower potential, and changing seasonality of flows in regions supplied by meltwater from major mountain ranges (e.g. Hindu-Kush, Himalaya, Andes), where more than one-sixth of the world population currently lives."

This conclusion is robust, appropriate, and entirely consistent with the underlying science and the broader IPCC assessment.

It has, however, recently come to our attention that a paragraph in the 938-page Working Group II contribution to the underlying assessment refers to poorly substantiated estimates of rate of recession and date for the disappearance of Himalayan glaciers. In drafting the paragraph in question, the clear and well-established standards of evidence, required by the IPCC procedures, were not applied properly.

The Chair, Vice-Chairs, and Co-chairs of the IPCC regret the poor application of well-established IPCC procedures in this instance. This episode demonstrates that the quality of the assessment depends on absolute adherence to the IPCC standards, including thorough review of "the quality and validity of each source before incorporating results from the source into an IPCC Report." We reaffirm our strong commitment to ensuring this level of performance.

In addition to addressing the problematic paragraph, the IPCC established an independent committee to review its procedures and prevent a recurrent of these types of problems. The following IPCC statement describes that decision.

Intergovernmental Panel on Climate Change, Statement of the IPCC Chairman on the Establishment of an Independent Committee to Review IPCC Procedures, Feb. 27, 2010, ***available at*** **http://www.ipcc.ch/pdf/press/PA_IPCC_Chairman_Statement_27Feb2010.pdf.**

The IPCC strives to ensure that its procedures for use of published material in the preparation of its assessment reports are followed in all respects. But we recognize the criticism that has been leveled at us and the need to respond. While embarking on the preparation of its Fifth Assessment Report it was the intention of the IPCC that an independent committee of distinguished experts evaluate means by which IPCC procedures must be implemented fully and that they should also examine any changes in procedure that may be required. The proposal to set up such an independent committee was conveyed to governments by the IPCC Secretariat in a communication dated Tuesday 16 February.

Further, during the 11th Session of the Governing Council/ Global Ministerial Environment Forum convened by the United Nations Environment Programme in Bali during February 24-26, IPCC pursued interaction with governments and the UN to establish an independent review of the IPCC procedures as proposed. The mechanism by which such an independent review will take place is under active consideration.

Meanwhile, we stand firmly behind the rigour and robustness of the 4th Assessment Report's conclusions, and are encouraged by the support demonstrated recently by scientists and governments around the world.

The 4th Assessment Report's key conclusions are based on an overwhelming body of evidence from thousands of peer-reviewed and independent scientific studies. Most significantly, they rest on multiple lines of analysis and datasets.

Second, an internet release of emails by climate change scientists at the University of East Anglia in the United Kingdom showed inappropriate behavior by them in the way in which they handled their data, approached peer review, and reported their results to the public. An independent investigation found that these emails did not undermine the accuracy of their scientific work, but the tone and content of these emails hurt their credibility.

The following excerpt summarizes the conclusions of the independent investigation. The report not only engages the impact of the scientists' behavior in the emails, but also the broader implications of this scandal for how climate change science should be conducted.

The Independent Climate Change Emails Review (July 2010), ***available at*** **http://www.cce-review.org/.**

1.1 Introduction

2. In November 2009, approximately 1000 e-mails from the Climatic Research Unit (CRU) of the University of East Anglia (UEA) were made public without authorisation.

3. CRU is a small research unit which over the last 30 years has played an important role in the development of climate science, in particular in their work on developing global temperature trends.

4. The e-mails fuelled challenges to the work of CRU, to the reliability of climate science generally, and to the conclusions of the Intergovernmental Panel on Climate Change (IPCC). All this happened shortly before the Copenhagen Summit, and was extensively referred to there.

5. In response, the UEA commissioned two inquiries. The first led by Lord Oxburgh, into the science being undertaken at CRU, has already reported. This document is the report of the second inquiry – The Independent Climate Change E-mails Review – which examines the conduct of the scientists involved and makes recommendations to the University of East Anglia. Our inquiry addresses a number of important allegations that were made following the e-mail release.

6. The allegations relate to aspects of the **behaviour** of the CRU scientists, such as their handling and release of data, their approach to peer review, and their role in the public presentation of results.

7. The allegations also include the assertion that actions were taken to promote a particular view of climate change by improperly influencing the process of advising policy makers. Therefore we have sought to understand the significance of the roles played by those involved from CRU and of the influence they had on the relevant outcomes.

8. The Review examines **the honesty, rigour and openness** with which the CRU scientists have acted. It is important to note that we offer no opinion on the validity of their scientific work. Such an outcome could only come through the normal processes of scientific debate and not from the examination of e-mails or from a series of interviews about conduct.

….

1.3 Findings

13. Climate science is a matter of such global importance, that the highest standards of honesty, rigour and openness are needed in its conduct. On the specific allegations made against the behaviour of CRU scientists, **we find that their rigour and honesty as scientists are not in doubt.**

14. In addition, we do not find that their behaviour has prejudiced the balance of advice given to policy makers. In particular, **we did not find any evidence of behaviour that might undermine the conclusions of the IPCC assessments.**

15. **But we do find that there has been a consistent pattern of failing to display the proper degree of openness**, both on the part of the CRU scientists and on the part of the UEA, who failed to recognise not only the significance of statutory requirements but also the risk to the reputation of the University and, indeed, to the credibility of UK climate science.

1.3.1 Land Station Temperatures

16. **On the allegation of withholding temperature data, we find that CRU was not in a position to withhold access to such data or tamper with it.** We demonstrated that any independent researcher can download station data directly from primary sources and undertake their own temperature trend analysis.

17. **On the allegation of biased station selection and analysis, we find no evidence of bias.** Our work indicates that analysis of global land temperature trends is robust to a range of station selections and to the use of adjusted or unadjusted data. The level of agreement between independent analyses is such that it is highly unlikely that CRU could have acted improperly to reach a predetermined outcome. Such action would have required collusion with multiple scientists in various independent organisations which we consider highly improbable.

18. **On the allegation of withholding station identifiers we find that CRU should have made available an unambiguous list of the stations used in each of the versions of the Climatic Research Unit Land Temperature Record (CRUTEM) at the time of publication. We find that CRU's responses to reasonable requests for information were unhelpful and defensive.**

19. **The overall implication of the allegations was to cast doubt on the extent to which CRU's work in this area could be trusted and should be relied upon and we find no evidence to support that implication.**

1.3.2 Temperature Reconstructions from Tree Ring Analysis

20. The central implication of the allegations here is that in carrying out their work, both in the choices they made of data and the way in which it was handled, CRU scientists intended to bias the scientific conclusions towards a specific result and to set aside inconvenient evidence. More specifically, it was implied in the allegations that this should reduce the confidence ascribed to the conclusions in Chapter 6 of the IPCC 4th Report, Working Group 1 (WG1).

21. **We do not find that the way that data derived from tree rings is described and presented in IPCC AR4 and shown in its Figure 6.10 is misleading.** In particular, on the question of the composition of temperature reconstructions, we found no evidence of exclusion of other published temperature reconstructions that would show a very different picture. The general discussion of sources ofuncertainty in the text is extensive, including reference to divergence. In this respect it represented a significant advance on the IPCC Third Assessment Report (TAR).

22. **On the allegation that the phenomenon of "divergence" may not have been properly taken into account when expressing the uncertainty associated with reconstructions, we are satisfied that it is not hidden and that the subject is openly and extensively discussed in the literature, including CRU papers.**

23. **On the allegation that the references in a specific e-mail to a "trick" and to "hide the decline" in respect of a 1999 WMO report figure show evidence of intent to paint a misleading picture, we find that, given its subsequent iconic significance (not least the use of a similar figure in the IPCC Third Assessment Report), the figure supplied for the WMO Report was misleading.** We do not find that it is misleading to curtail reconstructions at

some point *per se*, or to splice data, but we believe that both of these procedures should have been made plain – ideally in the figure but certainly clearly described in either the caption or the text.

24. **On the allegations in relation to withholding data, in particular concerning the small sample size of the tree ring data from the Yamal peninsula, CRU did not withhold the underlying raw data (having correctly directed the single request to the owners).** But it is evidently true that access to the raw data was not simple until it was archived in 2009 and that this delay can rightly be criticized on general principles. In the interests of transparency, we believe that CRU should have ensured that the data they did not own, but on which their publications relied, was archived in a more timely way.

1.3.3 Peer Review and Editorial Policy

25. **On the allegations that there was subversion of the peer review or editorial process we find no evidence to substantiate this in the three instances examined in detail.** On the basis of the independent work we commissioned (see Appendix 5) on the nature of peer review, we conclude that it is not uncommon for strongly opposed and robustly expressed positions to be taken up in heavily contested areas of science. We take the view that such behaviour does not in general threaten the integrity of peer review or publication.

1.3.4 Misuse of IPCC Process

26. **On the allegations that in two specific cases there had been a misuse by CRU scientists of the IPCC process, in presenting AR4 to the public and policy makers, we find that the allegations cannot be upheld.** In addition to taking evidence from them and checking the relevant records of the IPCC process, we have consulted the relevant IPCC review Editors. Both the CRU scientists were part of large groups of scientists taking joint responsibility for the relevant IPCC Working Group texts, and were not in a position to determine individually the final wording and content.

1.3.5 Compliance with the Freedom of Information Act (FoIA) and the Environmental Information Regulations (EIR)

27. **On the allegation that CRU does not appear to have acted in a way consistent with the spirit and intent of the FoIA or EIR, we find that there was unhelpfulness in responding to requests and evidence that e-mails might have been deleted in order to make them unavailable should a subsequent request be made for them.** University senior management should have accepted more responsibility for implementing the required processes for FoIA and EIR compliance.

1.3.6 Other Findings on Governance

28. **Given the significance of the work of CRU, UEA management failed to recognise in their risk management the potential for damage to the University's reputation fuelled by the controversy over data access.**

1.4 Recommendations

29. Our main recommendations for UEA are as follows:

Risk management processes should be directed to ensuring top management engagement in areas which have the potential to impact the reputation of the university. Compliance with FoIA/EIR is the responsibility of UEA faculty leadership and ultimately the Vice-Chancellor. Where there is an organisation and documented system in place to handle information requests, this needs to be owned, supported and reinforced by University leadership. CRU should make available sufficient information, concurrent with any publications, to enable others to replicate their results.

1.5 Broader Issues

30. Our work in conducting the Review has led us to identify a number of issues relevant not only to the climate science debate but also possibly more widely, on which we wish to comment briefly.

31. **The nature of scientific challenge.** We note that much of the challenge to CRU‘s work has not always followed the conventional scientific method of checking and seeking to falsify conclusions or offering alternative hypotheses for peer review and publication. We believe this is necessary if science is to move on, and we hope that all those involved on all sides of the climate science debate will adopt this approach.

32. **Handling Uncertainty – where policy meets science.** Climate science is an area that exemplifies the importance of ensuring that policy makers – particularly Governments and their advisers, Non-Governmental Organisations and other lobbyists – understand the limits on what scientists can say and with what degree of confidence. Statistical and other techniques for explaining uncertainty have developed greatly in recent years, and it is essential that they are properly deployed. But equally important is the need for alternative viewpoints to be recognized in policy presentations, with a robust assessment of their validity, and for the challenges to be rooted in science rather than rhetoric.

33. **Peer review - what it can/cannot deliver.** We believe that peer review is an essential part of the process of judging scientific work, but it should not be overrated as a guarantee of the validity of individual pieces of research, and the significance of challenge to individual publication decisions should be not exaggerated.

34. **Openness and FoIA.** We support the spirit of openness enshrined in the FoIA and the EIR. It is unfortunate that this was not embraced by UEA, and we make recommendations about that. A well thought through publication scheme would remove much potential for disruption by the submission of multiple requests for information. But at the level of public policy there is need for further thinking about the competing arguments for the timing of full disclosure of research data and associated computer codes etc, as against considerations of confidentiality during the conduct of research. There is much scope for unintended consequences that could hamper research: US experience is instructive. We recommend that the ICO should initiate a debate on these wider issues.

35. **Handling the blogosphere and non traditional scientific dialogue.** One of the most obvious features of the climate change debate is the influence of the blogosphere. This provides an opportunity for unmoderated comment to stand alongside peer reviewed publications; for presentations or lectures at learned conferences to be challenged without inhibition; and for highly personalized critiques of individuals and their work to be promulgated without hindrance. This is a fact of life, and it would be foolish to challenge its existence. The Review team would simply urge all scientists to learn to communicate their work in ways that the public can access and understand. That said, a key issue is how scientists should be supported to explain their position, and how a public space can be created where these debates can be conducted on appropriate terms, where what is and is not uncertain can be recognised.

36. **Openness and Reputation.** An important feature of the blogosphere is the extent to which it demands openness and access to data. A failure to recognize this and to act appropriately, can lead to immense reputational damage by feeding allegations of cover up. Being part of a like minded group may provide no defence. Like it or not, this indicates a transformation in the way science has to be conducted in this century.
37. **Role of Research Sponsors**. One of the issues facing the Review was the release of data. At various points in the report we have commented on the formal requirements for this. We consider that it would make for clarity for researchers if funders were to be completely clear upfront in their requirements for the release of data (as well as its archiving, curation etc).
38. **The IPCC.** We welcome the IPCC's decision to review its processes, and can only stress the importance of capturing the range of viewpoints and reflecting appropriately the statistical uncertainties surrounding the data it assesses. Our conclusions do not make a judgement on the work of IPCC, though we acknowledge the importance of its advice to policy makers.

NOTES AND QUESTIONS

1. How serious do you think these problems with the IPCC report and emails by climate scientists are? Do you agree with the conclusions of the IPCC statements and report based on their description of the problem?

2. Do you see these independent assessments as an appropriate response to the incidents? What are the benefits and limitations of such assessments?

3. Both the scandals and the conclusions of the independent report on the emails were widely reported in the press. What should be the role of the media in addressing these sorts of controversies? How effectively can the media communicate the technical issues involved in such scandals?

4. These scandals not only highlight specific problems, but the broader political context in which climate science takes place. Scientists make choices with awareness that their work might be used by those who support or oppose lawmaking efforts to address climate change. Moreover, the growth of the internet has made the spotlight on climate science even brighter. Do you agree with the independent report on the emails' conclusions about how scientists should operate in this environment?

C. Addressing Climate Change Through Law: Core Options and Critical Dilemmas

The previous section makes clear that climate change science issues are tremendously complex because of their intersection with human beings and their cultural, political, economic, and legal institutions and norms. This section connects these issues more directly to law, the focus of this book, to set the stage for the chapters that follow.

Although the initial focus of those concerned about human-caused climate change was *prevention*, the level of past emissions is already great enough to make some impacts certain. The focus has thus shifted to *mitigation*, reducing greenhouse gas emissions to limit the extent of the change, and *adaptation*, preparing for impacts and responding to them to minimize their harm. As we continue to mitigate inadequately, there also has been an increasing focus on *geoengineering*, using technology to reverse climate change or its effects, which will be discussed in depth in Chapter Seven.

This section introduces the primary strategies being discussed and debated regarding both mitigation and adaptation and the dilemmas of regulating a foundationally cross-cutting problem. Throughout its discussion, this section highlights three core challenges facing ongoing efforts to address the problem of climate change: (1) the need for law to evolve to engage scientific complexity; (2) the insufficiency of the current international climate change legal regime to address the problem; and (3) the multi-dimensional nature of the legal solutions needed.

1. Mitigation

Much of the public discourse over climate change focuses on mitigation. Policymakers, business executives, nongovernmental organizations, and individuals have diverse views about what type of action is appropriate to reduce greenhouse gas emissions. This section explores two sets of core questions that animate debates over appropriate mitigation strategies: technological ones and law and policy ones.

The first type of issues that arise regarding mitigation are technological. The underlying problem of climate change involves complex and evolving science, but reducing emissions also raises disputes at the interface of law and technology. Legal measures that effectively reduce greenhouse gas emissions should focus on using existing technology effectively and on fostering the development of needed new technology. However, crafting such measures requires answering difficult questions: What technology is needed to reduce greenhouse gas emissions? Could we reach reduction targets with existing technology and, if so, what would that look like? What types of technological breakthroughs would be most helpful in bringing emissions down without major economic impacts?

In 2004, Professors Stephen Pacala and Robert Socolow attempted to answer these questions. In an article that continued to inspire debate and discussion in the lead up to the Durban climate change negotiations in 2011, they argued that we have the technology necessary to address climate change and proposed a set of options that could be combined to do so. Specifically, they suggested that humanity needed to choose to employ seven wedges – where each wedge represented a technological approach that would reduce emissions by a particular amount – in order to put itself on a fifty year path through which stabilizing climate change is possible. The following excerpt from their article introduces their theory of wedges and the fifteen wedge options they set forth.

Stephen Pacala & Robert Socolow, *Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies*, 305 SCIENCE 368 (2004).

The debate in the current literature about stabilizing atmospheric CO2 at less than a doubling of the preindustrial concentration has led to needless confusion about current options for mitigation. On one side, the Intergovernmental Panel on Climate Change (IPCC) has claimed that "technologies that exist in operation or pilot stage today" are sufficient to follow a less-than doubling trajectory "over the next hundred years or more." On the other side, a recent review in *Science* asserts that the IPCC claim demonstrates "misperceptions of technological readiness" and calls for "revolutionary changes" in mitigation technology, such as fusion, space-based solar electricity, and artificial photosynthesis. We agree that fundamental research is vital to develop the revolutionary mitigation strategies needed in the second half of this century and beyond. But it is important not to become beguiled by the possibility of revolutionary technology. Humanity can solve the carbon and climate problem in the first half of this century simply by scaling up what we already know how to do.

What Do We Mean by "Solving the Carbon and Climate Problem for the Next Half-Century"?

Proposals to limit atmospheric CO2 to a concentration that would prevent most damaging climate change have focused on a goal of 500 +/- 50 parts per million (ppm), or less than double the preindustrial concentration of 280 ppm. The current concentration is 375 ppm. The CO2 emissions reductions necessary to achieve any such target depend on the emissions judged likely to occur in the absence of a focus on carbon [called a business-as-usual (BAU) trajectory], the quantitative details of the stabilization target, and the future behavior of natural sinks for atmospheric CO2 (i.e., the oceans and terrestrial biosphere). We focus exclusively on CO2, because it is the dominant anthropogenic greenhouse gas; industrial-scale mitigation options also exist for subordinate gases, such as methane and N2O.

Very roughly, stabilization at 500 ppm requires that emissions be held near the present level of 7 billion tons of carbon per year (GtC/year) for the next 50 years, even though they are currently on course to more than double (Fig. 1A). The next 50 years is a sensible horizon from several perspectives. It is the length of a career, the lifetime of a power plant, and an interval for which the technology is close enough to envision….

The Stabilization Triangle

We idealize the 50-year emissions reductions as a perfect triangle…. Stabilization is represented by a "flat" trajectory of fossil fuel emissions at 7 GtC/year, and BAU is represented by a straight-line "ramp" trajectory rising to 14 GtC/year in 2054. The "stabilization triangle," located between the flat trajectory and BAU, removes exactly one third of BAU emissions.

To keep the focus on technologies that have the potential to produce a material difference by 2054, we divide the stabilization triangle into seven equal "wedges." A wedge represents an activity that reduces emissions to the atmosphere that starts at zero today and increases linearly until it accounts for 1 GtC/year of reduced carbon emissions in 50 years. It thus represents a cumulative total of 25 GtC of reduced emissions over 50 years. In this paper, to "solve the carbon and climate problem over the next half-century" means to deploy the technologies and/or lifestyle changes necessary to fill all seven wedges of the stabilization triangle.

Stabilization at any level requires that net emissions do not simply remain constant, but eventually drop to zero. For example, in one simple model that begins with the stabilization triangle but looks beyond 2054, 500-ppm stabilization is achieved by 50 years of flat emissions, followed by a linear decline of about two-thirds in the following 50 years, and a very slow decline thereafter that matches the declining ocean sink. To develop the revolutionary technologies required for such large emissions reductions in the second half of the century, enhanced research and development would have to begin immediately.

Policies designed to stabilize at 500 ppm would inevitably be renegotiated periodically to take into account the results of research and development, experience with specific wedges, and revised estimates of the size of the stabilization triangle. But not filling the stabilization triangle will put 500-ppm stabilization out of reach. In that same simple model, 50 years of BAU emissions followed by 50 years of a flat trajectory at 14 GtC/year leads to more than a tripling of the preindustrial concentration.

It is important to understand that each of the seven wedges represents an effort beyond what would occur under BAU. Our BAU simply continues the 1.5% annual carbon emissions growth of the past 30 years. This historic trend in emissions has been accompanied by 2% growth in primary energy consumption and 3% growth in gross world product (GWP). If carbon emissions were to grow 2% per year, then 10 wedges would be needed instead of 7, and if carbon emissions were to grow at 3% per year, then 18 wedges would be required. Thus, a continuation of the historical rate of decarbonization of the fuel mix prevents the need for three additional wedges, and ongoing improvements in energy efficiency prevent the need for eight additional wedges. Most readers will reject at least one of the wedges listed here, believing that the corresponding deployment is certain to occur in BAU, but readers will disagree about which to reject on such grounds. On the other hand, our list of mitigation options is not exhaustive.

What Current Options Could Be Scaled Up to Produce at Least One Wedge?

Wedges can be achieved from energy efficiency, from the decarbonization of the supply of electricity and fuels (by means of fuel shifting, carbon capture and storage, nuclear energy, and renewable energy), and from biological storage in forests and agricultural soils.… Although several options could be scaled up to two or more wedges, we doubt that any could fill the stabilization triangle, or even half of it, alone. Because the same BAU carbon emissions cannot be displaced twice, achieving one wedge often interacts with achieving another. The more the electricity system becomes decarbonized, for example, the less the available savings from greater efficiency of electricity use, and vice versa….

Category I: Efficiency and Conservation

Improvements in efficiency and conservation probably offer the greatest potential to provide wedges. For example, in 2002, the United States announced the goal of decreasing its carbon intensity (carbon emissions per unit GDP) by 18% over the next decade, a decrease of 1.96% per year. An entire wedge would be created if the United States were to reset its carbon intensity goal to a decrease of 2.11% per year and extend it to 50 years, and if every country were to follow suit by adding the same 0.15% per year increment to its own carbon intensity goal. However, efficiency and conservation options are less tangible than those from the other categories. Improvements in energy efficiency will come from literally hundreds of innovations that range from new catalysts and chemical processes, to more efficient lighting and insulation for buildings, to the growth of the service economy and telecommuting. Here, we provide four of many possible comparisons of greater and less efficiency in 2054.

Option 1: Improved fuel economy. Suppose that in 2054, 2 billion cars (roughly four times as many as today) average 10,000 miles per year (as they do today). One wedge would be achieved if, instead of averaging 30 miles per gallon (mpg) on conventional fuel, cars in 2054 averaged 60 mpg, with fuel type and distance traveled unchanged.

Option 2: Reduced reliance on cars. A wedge would also be achieved if the average fuel economy of the 2 billion 2054 cars were 30 mpg, but the annual distance traveled were 5000 miles instead of 10,000 miles.

Option 3: More efficient buildings. According to a 1996 study by the IPCC, a wedge is the difference between pursuing and not pursuing "known and established approaches" to energy efficient space heating and cooling, water heating, lighting, and refrigeration in residential and commercial buildings. These approaches reduce midcentury emissions from buildings by about one-fourth. About half of potential savings are in the buildings in developing countries.

Option 4: Improved power plant efficiency. In 2000, coal power plants, operating on average at 32% efficiency, produced about one fourth of all carbon emissions: 1.7 GtC/year out of 6.2 GtC/year. A wedge would be created if twice today's quantity of coal-based electricity in 2054 were produced at 60% instead of 40% efficiency.

Category II: Decarbonization of Electricity and Fuels

Option 5: Substituting natural gas for coal. Carbon emissions per unit of electricity are about half as large from natural gas power plants as from coal plants. Assume that the capacity factor of the average baseload coal plant in 2054 has increased to 90% and that its efficiency has improved to 50%. Because 700 GW of such plants emit carbon at a rate of 1 GtC/year, a wedge would be achieved by displacing 1400GWof baseload coal with baseload gas by 2054. The power shifted to gas for this wedge is four times as large as the total current gas-based power.

Option 6: Storage of carbon captured in power plants. Carbon capture and storage (CCS) technology prevents about 90% of the fossil carbon from reaching the atmosphere, so a wedge would be provided by the installation of CCS at 800 GW of baseload coal plants by 2054 or 1600 GW of baseload natural gas plants. The most likely approach has two steps: (i) precombustion capture of CO2, in which hydrogen and CO2 are produced and the hydrogen is then burned to produce electricity, followed by (ii) geologic storage, in which the waste CO2 is injected into subsurface geologic reservoirs. Hydrogen production from fossil fuels is already a very large business. Globally, hydrogen plants consume about 2% of primary energy and emit 0.1 GtC/year of CO2. The capture part of a wedge of CCS electricity would thus require only a tenfold expansion of plants resembling today's large hydrogen plants over the next 50 years….A worldwide effort is under way to assess the capacity available for multicentury storage and to assess risks of leaks large enough to endanger human or environmental health.

Option 7: Storage of carbon captured in hydrogen plants. The hydrogen resulting from precombustion capture of CO2 can be sent offsite to displace the consumption of conventional fuels rather than being consumed onsite to produce electricity. The capture part of a wedge would require the installation of CCS, by 2054, at coal plants producing 250 MtH2/year, or at natural gas plants producing 500 MtH2/year. The former is six times the current rate of hydrogen production. The storage part of this option is the same as in Option 6.

Option 8: Storage of carbon captured in synfuels plants. Looming over carbon management in 2054 is the possibility of large-scale production of synthetic fuel (synfuel) from coal. Carbon emissions, however, need not exceed those associated with fuel refined from crude oil if synfuels production is accompanied by CCS. Assuming that half of the carbon entering a 2054 synfuels plant leaves as fuel but the other half can be captured as CO2, the capture part of a wedge in 2054 would be the difference between capturing and venting the CO2 from coal synfuels plants producing 30 million barrels of synfuels per day….Currently, the Sasol plants in South Africa, the world's largest synfuels facility, produce 165,000 barrels per day from coal. Thus, a wedge requires 200 Sasol-scale coal-to-synfuels facilities with CCS in 2054. The storage part of this option is again the same as in Option 6.

Option 9: Nuclear fission. On the basis of the Option 5 estimates, a wedge of nuclear electricity would displace 700 GW of efficient baseload coal capacity in 2054. This would require 700 GW of nuclear power with the same 90% capacity factor assumed for the coal plants, or about twice the nuclear capacity currently deployed. The global pace of nuclear power plant construction from 1975 to 1990 would yield a wedge, if it continued for 50 years. Substantial expansion in nuclear power requires restoration of public confidence in safety and waste disposal, and international security agreements governing uranium enrichment and plutonium recycling.

Option 10: Wind electricity. We account for the intermittent output of windmills by equating 3 GW of nominal peak capacity (3 GWp) with 1 GW of baseload capacity. Thus, a wedge of wind electricity would require the deployment of 2000 GWp that displaces coal electricity in 2054 (or 2 million 1-MWp wind turbines). Installed wind capacity has been growing at about 30% per year for more than 10 years and is currently about 40 GWp. A wedge of wind electricity would thus require 50 times today's deployment. The wind turbines would "occupy" about 30 million hectares (about 3% of the area of the United States), some on land and some offshore. Because windmills are widely spaced, land with windmills can have multiple uses.

Option 11: Photovoltaic electricity. Similar to a wedge of wind electricity, a wedge from photovoltaic (PV) electricity would require 2000 GWp of installed capacity that displaces coal electricity in 2054. Although only 3 GWp of PV are currently installed, PV electricity has been growing at a rate of 30% per year. A wedge of PV electricity would require 700 times today's deployment, and about 2 million hectares of land in 2054, or 2 to 3 m2 per person.

Option 12: Renewable hydrogen. Renewable electricity can produce carbon-free hydrogen for vehicle fuel by the electrolysis of water. The hydrogen produced by 4 million 1-MWp windmills in 2054, if used in high-efficiency fuel-cell cars, would achieve a wedge of displaced gasoline or diesel fuel. Compared with Option 10, this is twice as many 1-MWp windmills as would be required to produce the electricity that achieves a wedge by displacing high-efficiency baseload coal. This interesting factor-of-two carbon-saving advantage of wind-electricity over wind-hydrogen is still larger if the coal plant is less efficient or the fuel-cell vehicle is less spectacular.

Option 13: Biofuels. Fossil-carbon fuels can also be replaced by biofuels such as ethanol. A wedge of biofuel would be achieved by the production of about 34 million barrels per day of ethanol in 2054 that could displace gasoline, provided the ethanol itself were fossil-carbon free. This ethanol production rate would be about 50 times larger than today's global production rate, almost all of which can be attributed to Brazilian sugarcane and United States corn. An ethanol wedge would require 250 million hectares committed to high-yield (15 dry tons/hectare) plantations by 2054, an area equal to about one-sixth of the world's cropland. An even larger area would be required to the extent that the biofuels require fossil-carbon inputs. Because land suitable for annually harvested biofuels crops is also often suitable for conventional agriculture, biofuels production could compromise agricultural productivity.

Category III: Natural Sinks
Although the literature on biological sequestration includes a diverse array of options and some very large estimates of the global potential, here we restrict our attention to the pair of options that are already implemented at large scale and that could be scaled up to a wedge or more without a lot of new research.

Option 14: Forest management. Conservative assumptions lead to the conclusion that at least one wedge would be available from reduced tropical deforestation and the management of temperate and tropical forests. At least one half-wedge would be created if the current rate of clear-cutting of primary tropical forest were reduced to zero over 50 years instead of being halved. A second half-wedge would be created by reforesting or afforesting approximately 250 million hectares in the tropics or 400 million hectares in the temperate zone (current areas of tropical and temperate forests are 1500 and 700 million hectares, respectively). A third half-wedge would be created by establishing approximately 300 million hectares of plantations on nonforested land.

Option 15: Agricultural soils management. When forest or natural grassland is converted to cropland, up to one-half of the soil carbon is lost, primarily because annual tilling increases the rate of decomposition by aerating undecomposed organic matter. About 55 GtC, or two wedges' worth, has been lost historically in this way. Practices such as conservation tillage (e.g., seeds are drilled into the soil without plowing), the use of cover crops, and erosion control can reverse the losses. By 1995, conservation tillage practices had been adopted on 110 million hectares of the world's 1600 million hectares of cropland. If conservation tillage could be extended to all cropland, accompanied by a verification program that enforces the adoption of soil conservation practices that actually work as advertised, a good case could be made for the IPCC's estimate that an additional half to one wedge could be stored in this way.

Conclusions
In confronting the problem of greenhouse warming, the choice today is between action and delay. Here, we presented a part of the case for action by identifying a set of options that have the capacity to provide the seven stabilization wedges and solve the climate problem for the next half-century. None of the options is a pipe dream or an unproven idea. Today, one can buy electricity from a wind turbine, PV array, gas turbine, or nuclear power plant. One can buy hydrogen produced with the chemistry of carbon capture, biofuel to power one's car, and hundreds of devices that improve energy efficiency. One can visit tropical forests where clear-cutting has ceased, farms practicing conservation tillage, and facilities that inject carbon into geologic reservoirs. Every one of these options is already implemented at an industrial scale and could be scaled up further over 50 years to provide at least one wedge.

Even if people could agree on technological options, difficult legal issues would remain. A range of different legal mechanisms could assist in reaching these mitigation goals. As with technology, deep disagreements exist over these options and countries, states, and localities have proceeded along divergent paths. These current choices and alternatives to them lead to this section's second set of questions: What types of mechanisms could incentivize individuals and companies to reduce their emissions? Which ones would be most effective and which ones would be most politically acceptable? What combination of mandatory and voluntary commitments at international, national, state, local, and individual levels would create the reductions that scientists say are needed to minimize impacts?

In 2008, the Canadian Library of Parliament published a document outlining three major policy options that governments have for mitigating greenhouse gas emissions: cap-and-trade systems, carbon taxes, and direct regulations. It explains that all of these options aim to set a price on carbon in a way that reduces its use in the market, but that each of them use a different mechanisms for doing so. It considers both the political viability and potential effectiveness of each approach, and how the approaches might be used together. Because it predates the 2010 failure of cap-and-trade legislation in the United States and Canada's 2011 decision not to recommit to the Kyoto Protocol, it particularly focuses on cap-and-trade. However, even in the current North American political environment, this document provides a helpful summary of policy options.

Frédéric Forge & Tim Williams, Science and Technology Division, Parliamentary Research and Information Service, Library of Parliament, Canada, PRB 08-19E: Policy Options to Reduce Greenhouse Gas Emissions (Oct. 7, 2008), http://www.parl.gc.ca/Content/LOP/researchpublications/prb0819-e.htm (last visited Dec. 22, 2011).

There are many policy tools available to the government to help induce greenhouse gas (GHG) emissions reductions, including voluntary actions and agreements, financial incentives and subsidies and information instruments. However, there is a growing consensus among economists, environmentalists, many politicians and business leaders that putting a price on greenhouse gases (GHG) is essential to reduce emissions.

Market-based approaches are thought to be most effective because they signal that GHG emissions have a monetary value, stimulating actions that will lead emitters to reduce their emissions. In effect, putting a price on GHG emissions would acknowledge that the atmosphere cannot be used as a free waste disposal site for these pollutants. Such a price would therefore take into account costs that are not reflected in the price of energy production and use, termed "external" costs. This would level the playing field with other, currently more expensive, lower carbon energy sources, making these sources more economically viable.

There are different ways of pricing carbon which can be used in combination with other mechanisms, such as regulation. While it is acknowledged that putting a price on carbon is an effective way to reduce emissions, the best market mechanism or combination of mechanisms for pricing carbon is much more difficult to establish. The following document gives a brief overview of market mechanisms and regulatory options for reducing GHG emissions.

Cap-and Trade Systems
A cap-and-trade system is a regulatory program under which government sets a cap on the quantity of GHG emissions, distributes permits for allowable emissions that add up to the cap, and enables firms to buy and sell the permits after the initial distribution. Regulated sources must pay allowances at the end of a given period equal to their emissions. The price for emission allowances (the carbon price) is determined by supply and demand for allowances in an emissions trading market.

A. Upstream and Downstream Systems
Cap-and-trade systems can be focussed either on "upstream" or on "downstream" facilities. An upstream cap-and-trade (UCT) system applies to fuel suppliers and requires them to surrender allowances equivalent to the carbon content of fossil fuels they distribute. A UCT system would cover almost all energy-related emissions. This option has the advantage of being relatively simple, and it covers the entire economy. Analyses have shown that it would be environmentally efficient, minimize economic costs to the economy, be manageable administratively, and link easily to domestic and international offset programs…. On the other hand, a UCT system would likely drive up the cost of gasoline and home heating fuels, and it is a system that has yet to be implemented in any country.

A downstream cap-and-trade (DCT) program applies to sources of GHG emissions and requires them to pay allowances equal to their emissions. An all-source-DCT system would imply the regulation of millions of individual GHG sources, including cars and homes. Because of the difficulty in monitoring emissions from small sources, as well as the potential transaction costs involved with emissions trading from small sources, a DCT system could most effectively apply to a subset of sources consisting of large emitters.
….

B. Carbon Offsets and Credits from the Kyoto Protocol
If a company does not have sufficient allowances to cover its emissions or if reducing actual emissions or purchasing credits within the cap-and-trade system is relatively expensive, the company may be permitted to supplement its allowances by purchasing emission reductions outside of the cap-and-trade system. This may include "carbon offsets" or credits associated with other emission reduction systems like those provided through the Kyoto Protocol.

Carbon offsets are certified emission reductions produced by individuals and businesses not regulated under the cap-and-trade system that regulated facilities can purchase. Carbon offsets can include such projects as those that produce renewable energy, energy efficiency, reforestation and GHG emission reductions resulting from changes in agricultural practices. Though only certified offsets would be allowable under any trading system, the NRTEE concluded that an offsets system would likely be ineffective because it would provide incentives to technology and behaviour that would likely have occurred in the absence of the program.
The Kyoto Protocol includes systems that allow the purchase of credits internationally. This will be done through the *emissions trading mechanism*, one of the three Kyoto mechanisms. The other two mechanisms are designed to create credits that then can be traded, if a country or industry so chooses:

• the *clean development mechanism* (CDM) allows developed countries to gain credit for projects with verifiable emission reductions in developing countries; and
• the *joint implementation* (JI) *mechanism* allows developed countries to gain credit through projects in another developed country, or in a country in transition to a market economy.

These credits may also be allowed to apply to a facility's target within a domestic cap-and-trade system. The price of international credits and carbon offsets, as well as the quantity of them that would be allowed for use against targets, will influence the price of credits within the cap-and-trade system. The credibility of the credits would influence the effectiveness of the scheme.

Emission (Carbon) Tax
A "carbon tax" or a tax on GHG emissions imposes a direct fee (the carbon price) on emission sources based on the amount of GHG they emit, but does not set a limit on GHG emissions. In a manner similar to cap-and-trade options, the tax could be imposed upstream or downstream. It could require importers, producers and distributors of fossil fuels to pay a fixed fee on the carbon dioxide contained in fuel sold and/or it could require emitters to pay based on their actual emissions.

In order to make a tax more politically acceptable, revenues generated by carbon taxes are typically recycled back to emitters and the general public, who may be paying higher prices for goods and services affected by the taxes. Revenue recycling could take many forms, including compensating adversely impacted firms and segments of society, proportionally returning revenue based on tax paid, reducing other labour or capital taxes, or investing in technology and innovation.

An emission tax program, unlike a cap-and-trade scheme, does not guarantee that a given emissions reduction target will be met, because emitters may choose either to pay the tax or to reduce emissions. As a result, the level of the tax will likely have to be adjusted over time to meet a given emission target. This system does, however, provide price certainty, because the tax level is set before the policy is implemented.

Analyses have shown that an emission tax is more likely to allow for adoption of the cheapest mitigation strategies, as well as easier administration, than a cap-and-trade scheme. How policy-makers distributed revenues from the tax would determine the economic impact and effectiveness of the tax. However, political acceptability is likely to be a major obstacle, since new taxes and fuel price increases would garner negative reaction. An emission tax may be more politically attractive as part of a larger tax reform program.

While the NRTEE analysis showed that an economy-wide carbon tax would result in significant GHG emission reductions, experience in various countries shows that the implementation of such a broad and effective tax is exceedingly difficult.

Generally speaking, existing carbon taxes are primarily aimed at fossil fuel use and related emissions, and have been mostly applied to the household sector and services sector. Industry typically benefits from various exemptions because of concerns about international competition….

Although some correlations have been found between carbon taxes and greenhouse gas reductions, it is difficult to specifically attribute emission reductions to a carbon tax for a number of reasons, including:

• the countries that have implemented forms of carbon taxation have done so as one part of a suite of other programs aimed at reducing emissions, many of which could have cross-sectoral impacts on emissions;

• no country has put in place a true economy-wide carbon tax, choosing rather to target some areas while exempting others, often exempting the sectors where the most impact is required for emission reductions; and

• carbon tax regimes that do exist have generally been weak as a result of worries about competitiveness, given that other countries have not put such taxes in place.

Direct Regulations

Economy-wide regulatory mechanisms to force GHG emission reductions have never been seriously considered without a trading mechanism (cap-and-trade). They could, however, be used for parts of the economy that may not respond well to a price signal. There may be no response because:

• market failures and other barriers may reduce the responsiveness of certain sectors to changes in emission costs – particularly in the transportation and building sectors and some consumer markets, such as those for vehicles, houses and appliances; and

• emissions from some sectors of the economy, including agriculture, forestry, and waste management, may not be covered by the broad price signal.

Examples of this type of regulation might include energy efficiency standards and building codes or requirements to use alternative energy sources in buildings, equipment and transportation. Such actions would be relatively easy to take since they would simply involve modifying existing regulations. They would also avoid the politically difficult step of attaching a carbon cost to the price of gasoline and home heating.…Improving product efficiency standards yields limited results, [however,] because the incentive to reduce the use of inefficient products and to replace such products with more efficient ones is weak; indeed, the incentives may lead to greater use of energy-consuming products, since energy savings may allow consumers to buy more of these products, including some with elevated consumption levels. Energy use reduction through efficiency also effectively increases supply relative to demand, which could decrease energy prices, spurring greater demand.

There is a consensus that direct regulatory instruments would not lead to large reductions in GHG emissions but could be used as complementary policy tools to a market-based approach like an emission tax or a cap-and-trade scheme. For example, only by putting a significant price on carbon emissions would carbon capture and storage become economically attractive.

Conclusion

There is general agreement that putting a price on carbon through an emissions tax and/or a cap-and-trade approach is the most effective way to achieve GHG emission reductions. Taxes are generally seen as the most cost effective method, but they are not easy to couple with reduction targets and are politically very difficult to implement. Cap-and-trade systems are more complex to implement, must be very carefully planned (the compliance mechanisms and the volume and distribution of permits, in particular, must be well-thought-out) and do not provide cost assurance. In addition, companies may pass on to consumers the costs incurred by a cap-and-trade system in a way that is less transparent than a tax. Experience with these policies has delivered mixed results that are difficult to analyze.

Scandinavian countries pioneered the use of carbon taxes in the early 1990s. While a few other jurisdictions, most recently British Columbia, have since followed suit, carbon taxes have not been widely adopted. Rather, the cap-and-trade system has emerged as the internationally preferred market mechanism for mitigating GHG emissions. The European Union (EU) has operated a cap-and-trade system since January 2005. Despite some initial problems, the system is growing both in scope and in importance. Various legislative initiatives in the United States Congress also indicate that a cap-and-trade scheme is likely to become the dominant market mechanism for mitigating GHG emissions in the United States, particularly given the political difficulties involved with introducing a new tax.

NOTES AND QUESTIONS

1. In a September 2011 essay, *Wedges Reaffirmed*, Professor Socolow reflects upon how they could have been more effective in motivating change and what updating their 2004 paper would entail:

> Today, *nine* wedges are required to fill the stabilization triangle, instead of seven. A two-segment global carbon-dioxide emissions trajectory that starts now instead of seven years ago – flat for 50 years, then falling nearly to zero over the following 50 years – adds another 50 parts per million to the equilibrium concentration. The delayed trajectory produces nearly half a degree Celsius (three-quarters of a degree Fahrenheit) of extra rise in the average surface temperature of the earth….
>
> Worldwide, policymakers are scuttling away from commitments to regulations and market mechanisms that are tough enough to produce the necessary streams of investments. Given that delay brings the potential for much additional damage, what is standing in the way of action?
>
> Familiar answers include the recent recession, the political influence of the fossil fuel industries, and economic development imperatives in countries undergoing industrialization. But, I submit, advocates for prompt action, of whom I am one, also bear responsibility for the poor quality of the discussion and the lack of momentum. Over the past seven years, I wish we had been more forthcoming with three messages: We should have conceded, prominently, that the news about climate change is unwelcome, that today's climate science is incomplete, and that every "solution" carries risk. I don't know for sure that such candor would have produced a less polarized public discourse. But I bet it would have. Our audiences would have been reassured that we and they are on the same team – that we are not holding anything back and have the same hopes and fears.

> It is not too late to bring these messages forward.
> ….
> I believe the messages of the wedges paper are as important as ever. The global greenhouse-gas emissions rate in 2061 is a better focus of attention than targets a century or more in the future. Achieving an emissions rate in 2061 no higher than today's is a goal that can be achieved by scaling up already deployed technologies. Given present knowledge, that goal is probably ambitious enough; pursuing tougher goals could lead us to opt for cures that are worse than the disease. And an iterative process for resetting goals is essential, in order to take into account both new science and newly revealed shortcomings of "solutions."
>
> To motivate prompt action today, seven years later, our wedges paper needs supplements: insights from psychology and history about how unwelcome news is received, probing reports about the limitations of current climate science, and sober assessments of unsafe braking.
> Robert Socolow, *Wedges Reaffirmed*, BULL. ATOMIC SCIENTISTS, Sept. 27, 2011, *available at* http://www.thebulletin.org/web-edition/features/wedges-reaffirmed (last visited Dec. 22, 2011).

Ten leading commentators, advocates, and policymakers provided solicited comments in response to *Wedges Reaffirmed*, which can be found at http://www.thebulletin.org/web-edition/features/wedges-reaffirmed for those interested in further exploration. These comments are largely complementary of the wedges approach, but provide a diversity of views on how to move climate change policy forward in the aftermath of cap-and-trade's failure in the United States and the limited progress since the original 2004 article.

As you reflect upon the original paper, Socolow's recent essay, and the commentaries, consider the following questions: What are the benefits and limitations of thinking about climate change mitigation in terms of wedges? Do you agree with Socolow's assessment that a different approach by advocates to the public discourse about climate change science is likely to result in more progress? If so, how might such a conversation be begun most effectively?

2. As noted above, the Canadian Library of Parliament report's focus on cap-and-trade predates developments in 2010 and 2011 that make a fuller North-American adoption of this approach less likely. However, Australia, as part of meetings its obligations under the Kyoto Protocol's first commitment period, passed legislation establishing a carbon price in 2011 which relies on cap-and-trade mechanisms. For the Australian government's updates on its progress on implementing its climate change and clean energy plans, see Australian Government, Clean Energy Future, http://www.cleanenergyfuture.gov.au/ (last visited Dec. 22, 2011). At the 2011 Durban climate change negotiations, Australia remained open to a second Kyoto Protocol commitment period which would rely on these national-level developments even as Canada, Japan, and Russia refused to commit to additional targets and timetables. *See* Draft Decision -/CMP.7, Outcome of the work of the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol at Its Sixteenth

Session, Dec. 2011 (advance unedited version), *available at* http://unfccc.int/files/meetings/durban_nov_2011/decisions/application/pdf/awgkp_outcome.pdf (last visited Dec. 22, 2011). Given these developments, how do you view the three policy options presented in the Canadian report? In the absence of effective national-level commitments in North America to climate change mitigation, how might those concerned about climate change proceed towards implementing strategies like those proposed by Pacala and Socolow?

2. Adaptation

As it has become clearer that some climate change will happen regardless of our mitigation choices moving forward, policymakers and academics have increasingly begun to examine strategies for adapting to climate change. Like mitigation, adaptation has a complex relationship with law because it involves so many different aspects of peoples' choices. But in many ways, it is even more difficult to regulate because it involves evolving ecosystems and the uncertainties of how climate change will affect them. This section explores both the big picture of what adaptation would entail and the nuances of addressing through often-too-rigid law this complicated interface between people and the natural environment.

The following excerpt from a brief that is part of a series that the Pew Center on Global Climate Change and the Pew Center on the States have jointly prepared on *Climate Change 101: Understanding and Responding to Global Climate Change* provides an introduction to adaptation issues. It makes the case for why adaptation planning is needed and proposes some strategies for effective policymaking.

Pew Center on Global Climate Change & the Pew Center on the States, Adaptation (2008), *available at* http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Reports/Global_warming/Adaptation_0.pdf (last visited Dec. 22, 2011).

The Case for Adaptation Planning

Limits on emissions will not be enough, or happen soon enough, to avoid all impacts of climate change. Reducing emissions will decrease the magnitude of global warming and its related impacts. But carbon dioxide and other greenhouse gases can remain in the atmosphere for decades or centuries after they are produced. This means that today's emissions will affect the climate for years to come, just as the warming we are experiencing now is the result of emissions produced in the past. Because of this time lag, the Earth is committed to some additional warming no matter what happens now to reduce emissions. As a result, there are unavoidable impacts already built into the climate system. With worldwide emissions continuing to rise, adaptation efforts are necessary to reduce both the cost and severity of both mitigation and climate change impacts for decades to come.

Current model projections underestimated actual rates of climatic changes and impacts. Recent scientific research demonstrates that many aspects of climate change are happening earlier or more rapidly than climate models and experts projected. The rate of change projected for global surface temperatures, and related impacts such as ice melt and sea-level rise, is unprecedented in modern human history. We now have nearly two decades of observations that overlap with model projections. Comparing the model projections to the observations shows the models underestimated the amount of change that has actually occurred. For instance, sea-level rise has occurred 50 percent faster than the projected rate, and the area of summer Arctic sea ice has decreased at three times the projected rate, while several other aspects of climate change have also been underestimated. Adapting to climate change will become that much harder, and that much more expensive, to the extent that the changes happen faster, or on a larger scale, than we expect going forward.

Acting now to limit the potential damage from climate change is often smarter—and costs less in the long run—than acting later. There is a human tendency to address current or near-term climate impacts in a just-in-time fashion (for example, water conservation measures to prevent droughts in some southeastern U.S. cities were started only after a severe shortage was evident). This approach may work when: the impacts are predictable or slow in developing; solutions are available and can be implemented in time to save lives, property, or natural resources; and there is low risk of irreparable harm. Even under these conditions, however, people often overlook or delay solutions that reduce the ultimate risk of harm. “Proactive adaptation” requires assessing the vulnerability of natural and man-made systems, as well as the costs and benefits of action versus inaction, and planning alternatives accordingly. This approach recognizes the need to factor climate change into decisions that affect the long-term susceptibility of systems to the impacts of climate change. From the methods for building or repairing bridges, dams, and other infrastructure, to the rules and regulations governing coastal development and wetland protection, the decision whether to consider climate change now will have implications down the line.

Some systems and societies are more vulnerable to the impacts of climate change than others. Climate change will affect a wide array of systems including coastal settlements, agriculture, wetlands, crops, forests, water supply and treatment systems, and roads and bridges. The vulnerability of different systems varies widely. For example, the ability of natural systems to adapt to increasing rates of climate change is generally more limited than built systems. Similarly, some countries or regions, such as the United States, may be better able to adapt to climate change, or have a greater “adaptive capacity,” than others. By contrast, the adaptive capacity of many developing countries is often limited by a number of vital factors, such as economic or technological resources. Even within developed countries such as the United States, some areas have lower adaptive capacity than others. Smart planning ensures that governments and communities are paying attention to those systems that are most vulnerable, while laying the groundwork for actions to reduce the risk to human life, ecosystems, infrastructure, and the economy.

Successful Approaches to Adaptation

Adaptation services are emerging as governments, businesses, and communities worldwide are recognizing the need to address current and potential climate change impacts. Common elements in terms of methodology, or processes, for confronting climate change impacts include, but are not limited to:

Recognize that adaptation must happen at local and regional levels. Climate changes and their associated impacts vary greatly from location to location. Although national and international action is essential, many important decisions about how best to manage systems affected by climate change are made at local and regional levels. For example, states and localities have authority over land use planning decisions, including zoning and building codes, as well as transportation infrastructure. In some cases, state authority is extending to provide insurance coverage where the private market is retreating, exposing these states to larger financial risks. In exercising these authorities, managers, planners, and policy makers need to account for the potential outcomes of climate change. Yet systems such as water resources and species span city, county, and state lines. As a result, adaptation also requires planners from government, the private sector, and others to coordinate their activities across jurisdictions. Those engaged in planning need to share information, plan together, and collaboratively modify existing policies and procedures to ensure efficient and effective solutions. The exchange of information, resources, best practices, and lessons learned across jurisdictional lines and among different groups of stakeholders is a key element of successful adaptation planning.

Identify key vulnerabilities. Adaptation planning requires an understanding of those systems that are most at risk—and why. That means finding answers to questions in three key areas:

- **Exposure:** What types of climate changes and impacts can we expect, and which systems will be exposed? What is the plausible range of severity of exposure, including the duration, frequency, and magnitude of changes in average climate and extremes?
- **Sensitivity:** To what extent is the system (or systems) likely to be affected as a result of projected climate changes? For instance, will the impacts be irreversible (such as death, species extinction or ecosystem loss)? What other substantial impacts can be expected (such as extensive property damage or food or water shortages)?
- **Adaptive Capacity:** To what extent can the system adapt to plausible scenarios of climate change and/or cope with projected impacts? What is feasible in terms of repair, relocation, or restoration of the system? Can the system be made less vulnerable or more resilient?

Involve all key stakeholders. Successful adaptation planning relies on input from, and the alignment of, all key stakeholders. This means broadening the participants involved in identifying problems and solutions. Because the impacts of climate change span entire regions, adaptation planning should involve representatives from federal, state, and local government; science and academia; the private sector; and local communities. Successful planning will require creativity, compromise, and collaboration across agencies, sectors, and traditional geographic and jurisdictional boundaries. It also requires the involvement of experts who can help participants understand historical and current climate and other trends affecting various sectors, and who can provide completed impact assessments for other locations with similar sectors and/or projected impacts.

Set priorities for action based on projected and observed impacts.
For vulnerable systems, prioritizing adaptive measures based on the nature of the projected or observed impacts is vital. The Intergovernmental Panel on Climate Change published a list of criteria to aid in identifying key vulnerabilities. Some of these criteria include:

• **Magnitude:** Impacts are of large scale (high number of people or species affected) and/or high-intensity (catastrophic degree of damage caused such as loss of life, loss of biodiversity).
• **Timing:** Impacts are expected in the short term and/or are unavoidable in the long term if not addressed. Consider also those impacts with variable and unpredictable timing.
• **Persistence/Reversibility:** Impacts result in persistent damage (e.g., near permanent water shortage) or irreversible damage (e.g., disintegration of major ice sheets, species extinction).
• **Likelihood/Certainty:** Projected impacts or outcomes are likely, with a high degree of confidence (e.g., damage or harm that is clearly caused by rising temperatures or sealevel). The higher the likelihood, the more urgent the need for adaptation.
• **Importance:** Systems at risk are of great importance or value to society, such as a city or a major cultural or natural resource.
• **Equity:** The poor and vulnerable will likely be hurt the most by climate change, and are the least likely to be able to adapt. Pay special attention to those systems that lack the capacity and resources to adapt.

Choose adaptation options based on a careful assessment of efficacy, risks, and costs. Due to uncertainties in projected climate changes and in how systems will respond to those changes, adaptation options carry varying degrees of uncertainty, or risk, as well. Timing, priority setting, economic and political costs, availability of resources and skills, and the efficacy of various solutions all should be a part of the discussion. The range of options includes but is not limited to:

• **No-regret:** Actions that make sense or are worthwhile regardless of additional or exacerbated impacts from climate change. Example: protecting/restoring systems that are already vulnerable or of urgent concern for other reasons.
• **Profit/opportunity:** Actions that capitalize on observed or projected climatic changes. Example: a farmer is able to shift to different crops that are better suited to changing climatic conditions.
• **"Win-win":** Actions that provide adaptation benefits while meeting other social, environmental, or economic objectives, including climate change mitigation. Example: improving the cooling capacity of buildings through improved shading or other low-energy cooling solutions.
• **Low-regret:** Measures with relatively low costs for which benefits under climate change scenarios are high. Example: incorporating climate change into forestry, water, and other public land management practices and policies, or long-term capital investment planning.
• **Avoiding unsustainable investments:** Policies or other measures that prevent new investment in areas already at high risk from current climatic events, where climate change is projected to exacerbate the impacts. Example: prohibiting new development in flood-prone areas where sea-level rise is increasing and protective measures are not cost effective.
• **Averting catastrophic risk:** Policies or measures intended to avert potential or eventual catastrophic events—i.e., events so severe or intolerable that they require action in advance based on available risk assessment information. Example: relocating Alaskan villages in areas at or near sea-level with projected sea-level rise and increasing severe weather events.

Effectively addressing climate change, both in the context of mitigation and adaptation, requires legal institutions and rules that have the flexibility to engage the changes that are needed. Unfortunately, our law and legal institutions often lack such flexibility because of the ways in which they are constituted to create stability. The following excerpt by from an article by Professor Robin Craig argues that adapting to climate change impacts requires a fundamental rethinking of legal approaches to environmental and natural resources problems.

Robin Kundis Craig, *"Stationarity is Dead"—Long Live Transformation: Five Principles for Climate Change Adaptation Law*, 8 HARV. ENVTL. L. REV. 9 (2010).

On Halloween, 2008, PBS's nightly news program The NewsHour reported the plight of Montana's $300 million recreational fishing industry and $2.4 billion agricultural industry, both of which depend on Montana's rivers and streams. Trout fishing makes up a substantial component of the fishing industry, but the trout begin to die when water temperatures reach 78°F or higher. Unfortunately for the trout, average spring air temperatures have been rising since the 1950s, at a pace consistent with projected climate change impacts, and will continue to increase. Higher temperatures mean earlier snowmelt and hence less and slower-moving water in the summer, which in turn allows instream temperatures to rise above the trout's tolerance --and temperatures are expected only to keep increasing. As for agriculture, the decrease in the total volume of water available during the summer makes irrigation increasingly difficult. Thus, climate change appears to be simultaneously putting at risk Montana's trout, fishing industry, agriculture industry, and the human communities dependent on all three.

As Montana's trout streams demonstrate, climate change is already altering the base conditions of ecosystems in the United States and hence is beginning to impact the human economies that depend on those ecosystems' services. To list three additional recent examples:

• Climate change is altering hydrological regimes, creating new and exacerbating existing conflicts between species' and humans' needs for water. In May 2007, the U.S. District Court for the Eastern District of California noted that the Delta smelt, "a small, slender bodied fish endemic to" the Sacramento-San Joaquin Delta and already at risk from the joint operations of the federally managed Central Valley Project and California's State Water Project ("CVP/SWP"), would likely be put further at risk by climate change-driven decreases in water volume and increases in water temperature in the Delta. Because the U.S. Fish and Wildlife Service ("FWS") failed to consider the effects of these changing hydrological conditions on the smelt, its Biological Opinion issued pursuant to the federal Endangered Species Act ("ESA") was arbitrary and capricious. The resulting injunction threatened to shut down water delivery to millions of southern Californians --indeed, delivery of water to southern California in summer 2009 (the start of the dry season) was only forty percent of users' expectations, a result of both continued drought and species considerations. To complicate the water delivery problem still further, in June 2009 the National Marine Fisheries Service ("NMFS") concluded that CVP/SWP operations are likely to jeopardize five other species protected under the ESA--the endangered Sacramento River winter-run Chinook salmon, the threatened Central Valley spring-run Chinook salmon, the threatened Central Valley steelhead, the threatened southern distinct population segment of North American green sturgeon, and Southern Resident killer whales--especially considering shifting ecological baselines for these species as a result of climate change.

• Climate change is already allowing destructive pest species to invade new territory, threatening both ecosystems and commercial interests. As is true of most insects, "[e]very aspect of [the mountain pine beetle's] lifecycle is dependent upon temperature." This pest invades pines, particularly lodgepole pines, and kills them. The beetle's territory is normally limited by cold winters, but since the 1970s, warming temperatures have expanded the beetle's potential range by more than seventy-five percent. Mountain pine beetles have been taking advantage of this new habitat in British Columbia, Canada, and the northern Rockies in the United States (especially Colorado and Wyoming), and the expansion of the species can only be explained by changes in climate. By the end of 2006, the beetle had infested 130,000 square kilometers of British Columbia and western Canada, an invasion that is an order of magnitude larger than any previous invasion. Moreover, between 1997 and 2007, the beetle destroyed thirteen million hectares of pine in this part of Canada, many areas of which are considered critical timber supply areas. To deal with the economic disruption that the infestation and its effects on the Canadian logging industry have caused, the Canadian government "invest[ed] over $33 million in projects that support economic growth, job creation and future sustainability of communities adversely affected by the widespread beetle infestation."

• Climate change is creating positive feedback loops that may irreversibly push ecosystems over ecological thresholds, destroying coupled socio-ecological systems. In January 2009, the U.S. Climate Change Science Program ("USCCSP") reported that the Arctic tundra represents a "clear example" of climate change pushing an ecosystem beyond an ecological threshold. Warmer temperatures in the Arctic reduces the duration of snow cover, which in turn reduces the tundra's ability to reflect the sun's energy, leading to an "amplified, positive feedback effect." The result has been "a relatively sudden, domino-like chain of events that result in conversion of the arctic tundra to shrubland, triggered by a relatively slight increase in temperature," and the consequences for people living in these areas have been severe. For example, the Inupiat Eskimo village of Kivalina, Alaska, is suing for the costs of moving elsewhere, in response to the steady erosion of the village itself. Similarly, most Canadian Inuit live near the coast, on lands that exist only because of permafrost. Warming Arctic conditions threaten to deprive them of their homelands.

Thus, a variety of natural systems and the humans who depend on them--what are termed socio-ecological systems --are vulnerable to climate change impacts.

While developing and implementing successful mitigation strategies clearly remains critical in the quest to avoid worst-case climate change scenarios, we have passed the point where mitigation efforts alone can deal with the problems that climate change is creating. Because of "committed" warming-- climate change that will occur regardless of the world's success in implementing mitigation measures, a result of the already accumulated greenhouse gases ("GHGs") in the atmosphere --what happens to socio-ecological systems over the next decades, and most likely over the next few centuries, will largely be beyond human control. The time to start preparing for these changes is now, by making adaptation part of a national climate change policy.

Nevertheless, American environmental law and policy are not keeping up with climate change impacts and the need for adaptation. To be sure, adjustments to existing analysis requirements are relatively easy, as when the Eastern District of California ordered the FWS to consider the impacts of climate change in its Biological Opinion under the ESA. Agencies and courts have also already incorporated similar climate change analyses into the National Environmental Policy Act's ("NEPA") Environmental Impact Statement ("EIS") requirement and similar requirements in other statutes.

Even so, adapting law to a world of continuing climate change impacts will be a far more complicated task than addressing mitigation. When the law moves beyond analysis requirements to actual environmental regulation and natural resource management, it will find itself in the increasingly uncomfortable world of changing complex systems and complex adaptive management--a world of unpredictability, poorly understood and changing feedback mechanisms, nonlinear changes, and ecological thresholds. As noted, climate change alters baseline ecosystem conditions in ways that are currently beyond immediate human control, regardless of mitigation efforts. These baseline conditions include air, water, and land temperatures; hydrological conditions, including the form, timing, quality, and amount of precipitation, runoff, and groundwater flow; soil conditions; and air quality. Alterations in these basic ecological elements, in turn, are prompting shifts and rearrangements of species, food webs, ecosystem functions, and ecosystem services. Climate change thus complicates and even obliterates familiar ecologies, with regulatory and management consequences.

Nor are these regulatory and management consequences an as-yet-still-hypothetical problem. In February 2008, a group of researchers noted in *Science* that current water resource management in the developed world is grounded in the concept of stationarity--"the idea that natural systems fluctuate within an unchanging envelope of variability." However, because of climate change, "stationarity is dead." These researchers emphasized that impacts to water supplies from climate change are now projected to occur "during the multidecade lifetime of major water infrastructure projects" and are likely to be wide-ranging and pervasive, affecting every aspect of water supply. As a result, the researchers concluded that stationarity "should no longer serve as a central, default assumption in water-resource risk assessment and planning. Finding a suitable successor is crucial for human adaptation to changing climate."

Further, these authors realized the critical question is what a successor regime to stationarity should look like. With the onset of climate change impacts, humans have decisively lost the capability--to the extent that we ever had it--to dictate the status of ecosystems and their services. As a result, and perhaps heretically, this Article argues that, for adaptation purposes, we are better off treating climate change impacts as a long-term natural disaster rather than as anthropogenic disturbances, with a consequent shift in regulatory focus: we cannot prevent all of climate change's impacts, but we can certainly improve the efficiency and effectiveness of our responses to them. As this slow-moving tsunami bears down on us, some loss is inevitable--but loss of everything is not. Climate change is creating a world of triage, best guesses, and shifting sands, and the sooner we start adapting legal regimes to these new regulatory and management realities, the sooner we can marshal energy and resources into actions that will help humans, species, and ecosystems cope with the changes that are coming.

The problem is, in this brave new world of climate change adaptation, there will be no panaceas--"one size fits all" solutions to environmental problems --particularly in the realm of natural resource management. We need new ways of thinking about law, and a new legal framework that will allow a multiplicity of techniques to be brought to bear in crafting adaptation responses to particular local impacts while still promoting actions consistent with overall ecological and social goals.

Specifically, in formulating the law that will govern adaptation to ecological and socio-ecological impacts ("climate change adaptation law"), two issues are of most immediate consequence. First, existing environmental and natural resources laws are preservationist, grounded in the old stationarity framework that no longer reflects ecological realities. In contrast, the new climate change adaptation law needs to incorporate a far more flexible view of the natural world, because both the identity of the regulatory objects--the things such as rivers that such statutes are trying to protect-- and the regulatory objectives will themselves be continually transforming, especially at the ecosystem level.

Second, legal flexibility in the past has occasionally operated as the means for avoiding tough decisions and needed actions, as the Environmental Protection Agency's ("EPA") attempted ducking of carbon dioxide regulation under the Clean Air Act ("CAA") demonstrates. Given the societal importance of climate change adaptation, however, increased legal flexibility should not become a mechanism for avoiding effective environmental regulation and natural resource management. To deal effectively with adaptation and climate change impacts, the law will need to differentiate aspects of flexibility and discretion. Specifically, the law will have to embrace flexibility and adaptive management in the implementation of specific adaptation measures. However, it will simultaneously need to limit actors' discretion to do nothing or to deviate materially from general regulatory and management precepts and goals. That is, the specific means of adaptation can reflect local circumstances and needs, but the fact of adaptation and the general goals and policies climate change adaptation law seeks to effectuate should not be subject to local veto or avoidance.

In other words, climate change adaptation law should be based on principled flexibility. As used in this Article, principled flexibility means that both the law and regulators (1) distinguish in legally significant ways uncontrollable climate change impacts from controllable anthropogenic impacts on species, resources, and ecosystems that can and should be actively managed and regulated, and (2) implement consistent principles for an overall climate change adaptation strategy, even though the application of those principles in particular locations in response to specific climate change impacts will necessarily encompass a broad and creative range of adaptation decisions and actions.

This Article takes a first step toward a new climate change adaptation regime for environmental regulation and natural resource management in the United States by suggesting an across-the-board shift in legal objectives, from preservation and restoration to the improvement of resilience and adaptive capacity.

NOTES AND QUESTIONS

1. Although mitigation and adaptation are being treated in separate sections, they interact with one another in many ways. Roger N. Jones, Paul Dettmann, Geoff Park, Maureen Rogers, and Terry White have explored the complexity of this relationship in their scholarship. They argue:

> The complementarity between adaptation and mitigation is critical. Exercising adaptive capacity (adapting) allows an activity to cope with successively larger changes produced by successively higher levels of global warming. Exercising mitigative capacity (mitigating) reduces the risk of climate hazards from the upper end of the projected range of change.
> ….
> However, there is a discontinuity between the local and global scale that can be expressed as the difference between mitigative capacity and the demand for mitigation for a particular activity at a given time and place. The capacity to

> mitigate is not related to the mitigative demand for each activity, instead being related to its adaptive capacity and whether exercising this capacity is sufficient to cope with serious impacts likely to be encountered at a given level of change. Where adaptive capacity can be exercised locally, the benefits are also felt locally. Demand for mitigation will be highest when and where adaptive capacity is exceeded. The supply of mitigative capacity is local, as is the demand, but that demand is for a global good. This is the largest hurdle facing the institutions of north central Victoria. While it makes good sense to exercise both adaptive and mitigative capacity … mitigation needs to be integrated within a global market to meet a host of demands at the local scale.
>
> Roger N. Jones, Paul Dettmann, Geoff Park, Maureen Rogers & Terry White, *The Relationship between Adaptation and Mitigation in Managing Climate Change Risks: A Regional Response from North Central Victoria, Australia*, 12 MITIG. ADAPT. STRAT. GLOB. CHANGE 685 (2007).

How should policymakers approach mitigation and adaptation efforts given these dynamics?

2. To what extent are you persuaded by the *Adaptation* brief's arguments for acting now? Can you think of any additional arguments for turning to adaptation? Which of the proposed strategies seem easiest to implement and which seem like they would face political and legal barriers?

3. What are the benefits and limitations of introducing greater regulatory flexibility to address the problem of climate change? How could that flexibility be used as a tool in greater implementation of adaptive management techniques, and how could it be used as a tool to prevent needed action? What are the downsides of legal flexibility?

   These questions over legal flexibility are made more complex by the interaction between law and science. If solutions need to be situation-specific but also take place in an environment of some level of scientific uncertainty, how should lawmakers and regulators craft appropriate responses? To what extent are flexibility and evaluating risk in the face of uncertainty compatible, and when might tensions arise?

4. The need for lawyers to engage science with respect to climate change and other problems raises questions about our current approach to legal education in the United States. To what extent should the legal curriculum mandate exposure to other disciplines? What are the benefits and limitations of having a more interdisciplinary curriculum? How, if at all, would you alter the law school curriculum to incorporate this interdisciplinary education?

3. Complexities of Cross-Cutting Regulatory Strategies

The previous sections have explored numerous complexities regarding the underlying climate change science and using law as an effective tool in both mitigation and adaptation. However, what makes climate change so hard to address through law is that each of these challenges is only one piece of the regulatory puzzle. This section considers the big picture, focusing on what the problem looks like when these pieces are put together and the difficulties of interacting with multiple levels of government and numerous substantive areas of law.

The following excerpt from Professor Richard Lazarus provides such a big picture view. It explains why climate change is even more difficult to regulate than the types of public policy problems that scholars have termed "wicked," making it "super wicked."

Richard J. Lazarus, *Super Wicked Problems and Climate Change: Restraining the Present to Liberate the Future,* 94 CORNELL L. REV. 1153, 1159–61 (2009).

Even once one accepts the current scientific consensus that significant global climate change is happening, human activities are a significant contributing cause of that change, and the associated public health and welfare impacts are sufficiently serious to warrant climate change legislation, crafting that legislation is extraordinarily difficult. Scholars long ago characterized a public-policy problem with the kinds of features presented by climate change as a "wicked problem" that defies resolution because of the enormous interdependencies, uncertainties, circularities, and conflicting stakeholders implicated by any effort to develop a solution. Sometimes described as "social messes," classic wicked problems include AIDS, healthcare, and terrorism.

Climate change, however, has been fairly described as a "super wicked problem" because of its even further exacerbating features. These features include the fact that time is not costless, so the longer it takes to address the problem, the harder it will be to do so. As greenhouse gas emissions continue to increase, exponentially larger, and potentially more economically disruptive, emissions reductions will be necessary in the future to bring atmospheric concentrations down to desired levels. Future technological advances, therefore, would likewise have to be able to achieve those exponentially greater reductions to make up for lost time. The climate change that happens in the interim may itself cause sufficient economic disruption, for instance, by slowing growth rates, so as to make it much harder to accomplish the necessary technological innovation.

Another problematic characteristic of climate change is that those who are in the best position to address the problem are not only those who caused it, but also those with the least immediate incentive to act within that necessary shorter timeframe. The major sources of greenhouse gas emissions include many of the world's most powerful nations, such as the United States, which are not only reluctant to embrace restrictions on their own economies but are least susceptible to demands by other nations that they do so. In addition, by a perverse irony, they are also the nations least likely to suffer the most from climate change that will unavoidably happen in the nearer term.

A third feature is the absence of an existing institutional framework of government with the ability to develop, implement, and maintain the laws necessary to address a problem of climate change's tremendous spatial and temporal scope. Climate change is ultimately a global problem. But there is an absence of any global lawmaking institution with a jurisdictional reach and legal authority that match the scope of the problem.

As Professor Lazarus explains, climate change has global dimensions but is not being addressed effectively at a global scale; these failures have to do with the limits of international institutions, vagaries of international negotiations, and political will. However, even with more functional international regulatory mechanisms, climate change would still arguably be challenging because both mitigation and adaptation interact with multiple levels of government in ways that would pose challenges for a top-down approach driven by treaties. The following excerpt from an article by Professor Osofsky explores this dilemma by analyzing the ways in which climate change poses a multi-level regulatory problem.

Hari M. Osofsky, *Is Climate Change "International"?: Litigation's Diagonal Regulatory Role,* 49 VA. J. INT'L L. 585 (2009).

I. The Need for Multiscalar Climate Regulation

The structure of law poses a fundamental difficulty for effective regulation of multiscalar [involving multiple levels of government] problems like climate change. Namely, law's scales are sticky despite the fluid scalar nature of greenhouse gas emissions and impacts. In other words, we have subdivided law into levels of governance--a sensible idea for creating order and administrability--and formal regulation tends to happen within the fixed frames of those structures. As a result, we generally approach regulation as choosing or coordinating among those levels.

The current dilemmas over climate regulation reflect those constraints. This Part analyzes climate change as an example of a multiscalar problem that law struggles to address effectively. It begins by examining the multiscalar nature of emissions and impacts, and then turns to the barriers to an effective regulatory regime.

A. The Nature of the Problem

Much has been written about the problem of anthropogenic climate change. The purpose of this Section is not to summarize that literature, but rather to look at it through a scalar lens. This Section argues that the scientific consensus over climate change reveals not only near certainty that anthropogenic contributions matter, but also that emissions and impacts intersect with decision making from the smallest to the largest levels. Using the United States and its states and localities as examples, the Section explores this interaction.

1. Emissions

Greenhouse gas emissions result from individual, local, state, national, regional, and international decisions. At an individual level, each person, within parameters, makes choices about what his or her carbon footprint will be. Regarding transportation, for example, people decide whether to walk or to rely upon a bike or motor vehicle; if a motor vehicle, whether to use public, carpool, or individual options; and, if individual options, whether to use high or low emissions cars. Although each individual's choices have a minor impact on total greenhouse gas emissions, trends in personal decisions add up, even at the global scale.

Those individual choices occur not simply in a sociocultural context--the past couple of years, for instance, have seen a significant shift in public opinion about climate change --but also in a multiscalar legal one. As explored in recently settled litigation between California and San Bernardino County, urban growth plans significantly impact emissions trajectories. Many studies have shown, for example, the ways in which suburban zoning and planning--with large individual lots, separation between residential and commercial uses, and limited public transportation--increase vehicle miles traveled and, as a result, overall emissions from that locality. Moreover, although little of this research has been disaggregated for gender, it appears from the few studies that have taken place that this variable may matter for what types of urban planning will be most effective; for example, women in developed countries tend to make different transportation choices than men.

State-level decision making further impacts those individual transportation choices. Following California's lead, a number of states have attempted to exceed federal limitations on motor vehicle emissions by enacting more stringent regulations. As cases challenging and supporting these efforts wind their way through state and federal courts and interact with the Bush administration Environmental Protection Agency's (EPA) decision to deny California's waiver request and the Obama administration EPA's reconsideration of it, the future of these regulations remains uncertain. It appears likely, however, that the Obama administration EPA, upon completing its reconsideration, will take steps to allow California and other states to move forward. Whether and when these state regulations go into effect will have a significant impact on which cars consumers will be allowed to drive in those states --the reason for the auto industry's concern--and, as a result, on individual transportation choices.

As the disputes over these state laws make clear, the federal government also regulates individual transportation decisions through each of its three branches. Congress has passed several statutes impacting vehicle emissions--which the executive branch then implements--and is considering additional legislation targeted at climate change. The judicial branch evaluates agency choices about whether and how those statutes should be used to regulate vehicle emissions. These standards drive what options consumers have and how expensive they will be.

In the globalized economy and its web of legal interconnections, these interactions do not stop at U.S. borders. Regional and international trade agreements determine which vehicles we import and export and how expensive they will be, again impacting what options are available to consumers. U.S. participation in international negotiations--as well as formal and informal agreements--regarding climate change puts pressure on our national policies, which influence the price and availability of high and low emissions vehicles.

This type of analysis does not simply apply to vehicles, of course, but to the broad panoply of emissions decisions that individuals and governmental and nongovernmental entities make. From the multiscalar energy industry to the emergence of complex transnational coalitions on climate change, current and future emissions are shaped through multiscalar regulatory dynamics.

The Fourth IPCC Report's volume on mitigation reinforces this point; it relies on a mix of what it calls bottom-up and top-down economic studies to assess emissions reduction scenarios. The bottom-up studies consider specific options, generally with an unchanged macroeconomy, whereas the top-down studies engage economy-wide options. The IPCC summary for policymakers reports:

Bottom-up and top-down models have become more similar since the TAR [Third Assessment Report] as top-down models have incorporated more technological mitigation options and bottom-up models have incorporated more macroeconomic and market feedbacks as well as adopting barrier analysis into their model structures. Bottom-up studies in particular are useful for the assessment of specific policy options at [the] sectoral level, e.g. options for improving energy efficiency, while top-down studies are useful for assessing cross-sectoral and economy-wide climate change policies, such as carbon taxes and stabilization policies. However, current bottom-up and top-down studies of economic potential have limitations in considering life-style choices, and in including all externalities such as local air pollution. They have limited representation of some regions, countries, sectors, gases, and barriers. The projected mitigation costs do not take into account potential benefits of avoided climate change.

This consensus analysis suggests that in order to regulate emissions most efficiently, we must consider strategies at multiple levels, as well as find ways of incorporating cultural questions into economic models.

In addition, the mitigation volume makes clear how difficult the multiple geographic and time scales make this project. For example, the chapter entitled "Transport and Its Infrastructure" covers transportation issues in mostly sweeping terms and does not have the space to delve into the nuances of how its approach can be applied within specific contexts. More generally, the introduction to the volume explains that inertia in both climate and socioeconomic systems, combined with the multiple time scales involved regarding the problem and responses to it, pose serious challenges. Not only will many measures need to be taken in the short term in order to prevent medium and long term issues, but policymakers also will have to navigate the fact that the same radiative forcing may cause the atmosphere to respond in decades as the ocean changes over centuries. Effective legal regulation somehow must bridge these complexities of how emissions and their interaction with the physical environment are scaled and of the greater scientific uncertainty that currently exists at smaller scales.

2. Impacts and Adaptation

These complexities of scale are not limited to emissions, but also span issues of mitigation and adaptation. The Fourth IPCC Report makes clear that we have passed the point at which prevention of impacts is possible. Rather, a host of impacts already have been felt, and scientific consensus suggests that they will only get worse as time passes. The explosion of climate change litigation over the past few years, and its increasing viability in courts around the world, reflects this reality.

Just as the extent of emissions interacts with multiscalar regulatory behavior, mitigation and adaptation present quandaries at every level of governance. As a physical matter, climate change manifests uniquely in each specific place, and the likelihood of severe impacts are not distributed equally. Unfortunately, current predictions suggest that the places with the least economic and political resources often will bear the brunt of these physical changes.

At an individual level, people must make hard choices in response to the changes in their physical environment. As glacial lakes loom above them or risks from coastal storms grow more severe, should individuals leave their communities? Are they able to do so? What steps are realistic options to limit the damages that they will suffer from the changing climate where they live? These are not just decisions facing the very poor; European ski resorts have begun wrapping their glaciers, and wine growers try to take climate change into account when planting new grapes. But the choices are often more fundamental for those who have few resources and live in close connection with the land.

As with emissions, these individual choices occur within a multiscalar regulatory framework. Localities, states, and national governments decide what their plans will be in response to these changes and the extent to which they want to and are able to support the individuals making those hard decisions. From the details of land use planning to the availability of federal disaster relief, governmental decision makers help to structure how palatable life will be in particular places as climates change.

Moreover, these policy decisions have impacts at multiple time scales. As time passes, impacts evolve and, in many places, according to consistent scientific data, likely will worsen. In addition, as we load the atmosphere with more and more greenhouse gases, the risks of a sudden catastrophic event--such as ice sheet collapse--increase. Decision making on impacts thus has to grapple with current and predicted future issues.

Together, the multiscalar dimensions of both emissions and impacts suggest that climate change will be very difficult to regulate effectively at any one scale. Local action must be tied to larger-scale decision making, whereas international action must make room for the nuances of smaller-scale variation. Moreover, because the substances being regulated are so deeply embedded in economies and cultures, political complexities abound that likely will manifest differently at each level of governance.

B. Current Regulatory Failures

This need to cross cut levels of governance is, of course, not lost on those attempting to address climate change at any particular level. The major treaties on climate change build in flexibility mechanisms to allow for the nation-state parties to address emissions in ways that work for their particular contexts. Local efforts often use international standards as a benchmark, such as in cities' pledges to comply with the Kyoto Protocol's emissions reductions. Moreover, a wide range of actors at different levels of governance--including governmental entities, nongovernmental and quasigovernmental organizations, corporations, and individuals--are working collaboratively on crafting better regulatory strategies.

But even with this recognition, multiscalar efforts on climate change at this point are falling short. The international legal regime suffers from both a lack of political will and the complexities of national implementation. Although the United States agreed under great pressure to rejoin negotiations over the post-2012 regime at the December 2007 climate meetings in Bali and President Obama has pledged to “re-engage with the U.N. Framework Convention on Climate Change,” there are few signals that international consensus can be reached on the major reductions that scientists say are needed to avoid the most serious dangers. Moreover, many parties to the Kyoto Protocol are likely to miss its not very ambitious targets. In some countries, such as Canada, the implementation problem has stemmed in part from the fact that important subnational governmental entities are not prepared to make the needed reductions and the national government cannot force that change.

Once one gets below the international level, however, policy efforts on climate change become more piecemeal, which is a persistent issue in discussions of the appropriate role of smaller-scale regulation and the difficulties of leakage at the subnational level. The national and international coalitions of cities, for example, continue to grow--and at this point these cities represent fifteen percent of global emissions--but they do not yet come close to including all cities around the world. Those that join these coalitions also tend to be more amenable to taking needed regulatory steps than those that do not join. Moreover, many cities still face major internal political battles as they try to navigate the practical effect of meeting those obligations on their other goals.

Furthermore, as a formal matter, multiscalar regulatory approaches not only have to deal with specific barriers at each level of governance, but also have to bridge the way in which we categorize and cabin law. For example, treaties and customary international law--the bulwarks of international legal regulation--are based on the nation-state as the key decision maker. Under current legal models, international law can only be created through the consent of sovereign and equal nation-states. With such an approach, the ability of subnational governments to interact with international law is limited; even if their participatory role increases, the structure of how formal international law is created prevents entities other than nation-states from being treated as full subjects and objects of international law.

Formal barriers occur at the other end of the scale spectrum as well. Localities are constituted through a combination of state and local law and entities. When localities choose to make Kyoto Protocol commitments, they are not binding themselves to the treaty but rather incorporating its terms into local law. In fact, if they tried to do more, national and state governments might attempt to intervene on the basis that the localities are overstepping their boundaries. Similarly, their freedom to revise their greenhouse gas policies and commitments over time stems from the fact that international entities have no binding authority over them….[S]ome of the primary efforts to push localities on emissions policies that have showed some teeth are those undertaken by states in the context of direct litigation, such as the suit by the State of California against San Bernardino County, which resulted in a settlement agreement.

The combination of regulatory barriers at each level of governance and structural constraints on meaningful multiscalar regulation poses a formidable obstacle to addressing climate change. Despite determined advocacy by numerous committed entities, the world is still far from adequately addressing emissions and their looming impacts at any level of governance. Although particular localities certainly have shown leadership, even those at the forefront of emissions control are not reducing them at the rate scientists say are needed, and regulatory failures elsewhere are dwarfing their efforts.

The complexities of cross-cutting governance do not end with the challenge of bringing together different levels of government. Climate change also implicates many different areas of law, most fundamentally energy and environmental law. Many legal systems, including that of the United States, treat each substantive area of law under a separate statutory regime with its own regulatory apparatus. The result is that climate change governance must overcome simultaneous overlap and fragmentation, where more than one area of law with distinct mechanisms applies to mitigation and adaptation initiatives.

The following excerpt by Lincoln Davies explores this dilemma in the context of the United States. It explains why the disconnect between energy and environmental law makes effective approaches to alternative energy difficult and proposes ways to overcome this divide.

Lincoln L. Davies, *Alternative Energy and the Energy-Environment Disconnect*, 46 IDAHO L. REV. 473 (2010).

It is one of the most important--and unspoken--paradoxes of the modern American regulatory state: Energy law and environmental law rarely, if ever, merge. The fact that energy and environmental law do not work together has massive implications for the nation's future, particularly if we aim to curb our addiction to oil. Suggestions for how to change our energy trajectory are not in short supply. We need a smarter grid, and more of it. We need new transmission rules, and better ways of resolving siting conflicts. We need different transportation technologies, and better incentives for transitioning to them. We need to halt climate change, and move to electricity production that helps us do so. We need to reduce energy demand, and change our behavior to shift that curve. We need more efficiency, and fast.

All of these suggestions have merit. Taken together, they undoubtedly would propel us to a much different--and superior--future than the place to which our present energy policies have delivered us. Yet such specific policy reforms, as necessary as they are, do not take into account an overarching problem, a problem that may be their undoing if left unaddressed. Until the disjunction between energy and environmental law is repaired, one of the most fundamental barriers to a new and different energy future remains. Changing our course requires admitting our problem: Separating discussions of energy and environment works only to help us live the lie, to enable our addiction.

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II. THE HISTORICAL DIVORCE OF ENERGY AND ENVIRONMENTAL LAW

That energy law and environmental law have been so historically disconnected may not grab newspaper headlines, but the reasons for this odd result are hardly secret. The fields trace to disparate traditions. Energy law was born largely from public utility and antitrust law, which emphasize economic analysis, monopolistic presumptions, and market preferences. Environmental law, on the other hand, arose not from the world of economics but from a melding of risk assessment and policy, a search for regulatory tools to prevent mass tort-like harms, the erosion of ecosystems and deterioration of public health, the “tragedy of the commons,” and overexploitation of natural resources. Moreover, while the fields crystallized at roughly the same time--in the 1970s--environmental law has captured the public conscious far more readily than its energy law counterpart. “Even though energy policy had a prime role during [the 1970s and 1980s], environmental policy was the new star.”

The irony is that while energy and environmental law derive from different places, they increasingly look more and more alike. Where energy law once placed faith in the judgment of expert agency regulators, it now has found religion in the verdicts of markets. Likewise for environmental law, the dominance of the 1970s technocratic command-and-control directives continue to give way to market- and information-based policy mechanisms. Where energy law once drew bright lines between federal and state jurisdiction, it progressively blurs those distinctions by relying on federal-state cooperation for, among other things, market restructuring, transmission siting, and reliability governance. The same is true for environmental law. The field's primacy once lay in the states; the 1970s “statutory big bang” shifted that center toward the federal government; and the emerging sense now is that cooperative, or “dynamic,” federalism may have the best chance at regulatory success.

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III. MANIFESTATIONS OF THE DIVORCE

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That energy and environmental law generally seek to achieve different goals-- for energy law, economic development; for environmental law, conservation of resources and protection of public health--should already be clear. This is perhaps the most important distinction between energy law and environmental law. The fields' core thrusts differ because their ultimate aims differ.

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IV. IMPLICATIONS OF THE DIVORCE

Although there certainly are exceptions, the general trajectory of energy and environmental law should thus be clear. The fields work in separate spheres. They promote different objectives and, even where they share commonalities, such as the trend toward market-based regulation, fail to regulate in a coordinated, holistic manner.

On its face, this disconnect would seem problematic. Laws that address problems completely, rather than piecemeal, make for better regulation. Still, the question of whether connecting energy and environmental law would lead to better governance remains. That is, once the fields' disjunction is clear, are its implications really that problematic? Given that both fields have helped promote social welfare, the question is a fair one. Abundant energy is the lifeblood of our modern economy, and environmental protection helps guarantee the very basis of life.

This Part takes up the question by briefly assessing what deficiencies the disconnect between energy and environmental law might create for energy governance in general. It then applies those factors to the question of alternative energy development. Finally, on this foundation, it asks whether combining energy and environmental law may help forge a path to a new energy future.

A. For Energy Governance

Despite energy and environmental regulation's substantial accomplishments, a new approach could garner important improvements. Sufficient governance is not optimal governance, and there is a strong argument that the way we have been regulating energy questions is not sufficient: climate change looms, peak oil is either already here or just around the corner, and yet the profile of our national energy supply looks strikingly like it did when John F. Kennedy took office. All law is evolutionary. To account for the deficiencies that the disconnect between energy and environmental law creates, it may be time for these fields to evolve again--toward each other.

There are at least four deficiencies that disconnecting energy law and environmental law may produce. They are the risks of (1) inefficaciousness, (2) inefficiency, (3) foregone synergies, and (4) incompleteness….

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B. For Alternative Energy Development

Certainly the problems created by the energy-environmental law disconnect arise in many areas, but they may be most acute for alternative energy development. The disconnect exerts a subtle, if inexorable, force pushing against a transition from traditional fuels to a more sustainable energy future.

The problem is clearest from an efficacy perspective. To the extent that alternative energy is seen as promoting environmental objectives--less pollution, more conservation--the fact that energy law and environmental law promote different goals clearly has restrained the adoption of more renewables. Both energy law's focus on reliability and its emphasis on cost temper any incentive that environmental law might create for alternative energy production. Clean Air Act limits on pollution emissions, for instance, should at least indirectly promote use of fewer traditional coal plants and more emission-free facilities such as wind and solar farms, but energy law pushes the other way. Generation resources such as solar and wind are intermittent (not always available) and have comparably high capital costs, even if their operating costs are low. As Warren Kotzmann has observed, "[a]t some point, if a significant percentage of resource need is based on wind, then back up power plants must be built to supplement when the wind resources are not available. Obviously, this would result in a cost prohibitive duplication of facilities." Thus, the environmental benefits achievable by switching to such power sources have been slow to come, at least in part, because energy and environmental law stand at cross purposes.

The flipside is also true. The United States would be full of more dams, more nuclear power plants, and the lower electrical bills that come with them were it not for environmental regulation. True, were these two fields more closely coordinated, one could argue that where we stand today is actually a careful legislative balance of competing, yet equally valid, economic and environmental considerations. Given how separately the two fields operate, however, that case is a hard one to make. Instead, it looks much more like inefficaciousness.

The other problems created by the energy-environmental law disconnect also manifest in alternative energy development. Consider inefficiency. If promoting alternative energy were a goal of both fields, the most efficient solution for carrying it out would be a coordinated effort between their administrators. The least expensive and most reliable energy sources could be sought based on economic and scientific criteria nationwide: a synthesized, consistent national energy plan. Instead, the picture today is much different. Some states have adopted laws requiring renewable electricity development--the aforementioned renewable portfolio standards--while many have not. The result is a crazy-quilt patchwork of laws and regulations that frustrate efficiency instead of promoting it. Over two dozen national RPS proposals have been introduced in Congress, but none have gained enough traction to pass--in no small part because energy and environmental law remain at war.

The story is just as troublesome for alternative transportation fuels. In that context, "agribusiness and their political allies have foisted [a] snake oil [biofuels program that mandates the use of ethanol and biodiesel] on the American consumer in a successful effort to transfer billions of dollars from the public to corn farmers, and ethanol and biodiesel producers." The result is not a transition to sustainability but a short-sighted, inefficient energy strategy based on special interests. In short, at least partially because energy and environmental laws remain separate, whatever incremental moves the nation has made away from archetype fuels have been fractured and inefficient, not coordinated and economical.

Likewise, the fields' divorce frustrates regulatory synergies. Take again alternative energy in electricity generation. One set of agencies--state public service commissions and FERC--exercises authority over the energy side of this sector, while an entirely different group of agencies--EPA and state environmental quality divisions--regulates the industry's environmental effects. This is the "heart of the problem" with energy-environmental regulation: "[T]he division of authority among several separate agencies, each of which is almost wholly oblivious to the technological alternatives that lie outside its own particular area of expertise .... [means that] systematic intertechnology comparisons are impossible."

Were regulatory authority structured differently, such that pollution control technologies and clean energy technologies could be compared side by side, for instance, energy and environmental regulation might look much different. By bringing agencies together, a more deliberate alternative energy strategy could be crafted. Regulation might not only be more successful and less costly, it could be better too. This is not just because coordination would promote cooperation on alternative energy. It is also because agencies could learn from each other how to best achieve it.

Finally, the example of alternative energy development shows just how incomplete energy and environmental law are. If a sustainable energy future were a shared goal of both energy and environmental law, then the fields' targets would likely change in two ways. First, they both would likely focus more on transitioning to a more renewable-heavy electricity and transportation profile. Second, they would target areas for sustainable energy they now largely ignore. They might, for instance, aggressively chase efficiency gains in electricity, transportation, the built environment, and consumption generally. They would seek to fundamentally change the way energy is priced and used. They would target everyday consumers and the vast portion of energy use they comprise. They would target culture, and the "ossified" path of fossil fuel dependence we are now on. They would, in other words, extend their grasp to precisely the areas that energy and environmental law do not now reach.

C. Marrying Energy and Environmental Law--Toward a New Energy Future?

How do we move energy and environmental law closer together? Assessing with detailed precision what a merged body of energy-environmental law would look like is beyond this article's scope. Nevertheless, it should be clear that the marriage must happen. The disconnect between energy and environmental law hardly is alone as a roadblock to a more sustainable energy future, but the reality of this barrier is plain. Whether it is the need for new transmission capacity, or the lack of a comprehensive climate change regulatory scheme, or the on-again, off-again nature of alternative energy production tax credits that stands immediately in the way of moving to renewable energy, a key reason these barriers exist at all is because energy and environmental law continue to work in different worlds, promoting conflicting objectives. Changing that even incrementally would be a step in the right direction--a step toward removing barriers to alternative energy development. While finding the specific contours for merging energy and environmental law thus calls for further reflection, some initial outlines of the merger's architecture are apparent.

To begin, any marriage of environmental law must be more holistic than the fields are today. The combined field must "look at the essential characteristics of the energy system as a whole, to think how they are intertwined, and to use that knowledge as a basis for deriving a more effective environmental policy." As Gary Bryner has explained, "[a] cautious, conservative, ethically defensible, and balanced energy policy" must be centered "in the idea of ecological sustainability." The idea is that for regulation to be effective, it must not separate root causes from core effects. The idea is that to better promote alternative energy, all issues must be considered. The idea is that environmental and energy law must be remade to work together as a unified whole.

One way to begin making energy-environmental regulation more holistic is to find areas where the two fields' objectives can be reconciled. To a degree, this has already started. Renewable portfolio standards, federal fuel efficiency standards for cars, and even climate change legislation, can all be seen as simultaneously promoting both energy and environmental aims: cleaner energy use, but reliable and abundant energy supplies nevertheless. Still, much work remains. From an economic perspective, it is true that any environmental law which makes energy markets more accurately reflect social costs does not conflict with the goals of energy regulation. But law is not evaluated under economic theory alone, and any increase in energy costs is often seen as anathema.

Part of how energy and environmental law must move together, then, is by crafting a common metric that melds both fields' goals. There is much promise on this front in the concept of sustainability, because sustainability values both economic development and environmental protection. It also measures these values over a long-term frame, so that short-term losses lose some of their current overemphasis. Sustainability as a legal concept, however, is still largely nascent. Getting it off the ground unquestionably will take much time and effort, and merging energy and environmental law may be part of that broader campaign. Clearly, though, regulation centered in the notion that economics and environmental protection must be balanced, rather than left at war, would do much for a transition to alternative energy development.

The good news is that at least some groundwork for merging energy and environmental law already has been laid. Because both fields increasingly rely on the same regulatory tools, finding a way to coordinate them should be less difficult than it once might have been. They already speak much of the same language, or at least close dialects. Certainly this is not to say that the task will be easy. Environmental regulators use markets for much different purposes than energy administrators, but from this common ground, both might be able to find areas where the fields can most easily become symbiotic. In the alternative energy context, this is precisely what it means to make inter-technology comparisons. The merging of energy and environmental law will allow regulators to evaluate a much broader array of possible solutions, because the merger should help break down regulatory silos.

Moreover, because energy and environmental law both excise large, and similar, swaths of activity from their regulatory grasps, the promise of merging the fields should be significant. That is, fertile ground for blending the two fields rests in the areas where neither currently regulates at all: for instance, small individual actions that have large cumulative effects, such as household electricity use or personal motor vehicle gasoline consumption--in short, realms ripe for work in alternative energy. In these areas, because regulation is currently light or non-existent, there may be room for a new approach altogether. Writing on a blank slate should be simpler than revamping an entire book, especially a tome as complex as energy and environmental law.

Law, of course, has limits. Apart from its symbolic and moral-setting properties, law can only really control behavior on the margins. That may well be why energy and environmental law currently do not regulate many of the areas they leave unrestrained. Nevertheless, to the extent that a merged energy-environmental field begins to extend into areas such as nonpoint source pollution or household energy consumption, a prime opportunity for coordinating energy and environmental law may be available. One way of thinking of the challenge of sustainability is that we must transform both our infrastructure and our culture. Present moves to alternative energy address primarily the former. For the latter, room for a newly wedded field of energy and environmental law to experiment should be vast indeed.

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NOTES AND QUESTIONS

1. How can law most effectively address the challenges described by Lazarus? What kinds of legal structures are likely to be most able to engage the "wicked" aspects of climate change and the additional "super wicked" challenges that it poses?

2. As discussed in more depth in Chapter Five's discussion of state and local government efforts, Nobel Prize winner Elinor Ostrom has argued for the important role that a multi-level, polycentric approach (one based on many key stakeholders taking action at different

levels simultaneously) could play in addressing the collective action problem posed by climate change. She concludes:

> Given the complexity and changing nature of the problems involved in coping with climate change, there are no "optimal" solutions that can be used to make substantial reductions in the level of greenhouse gases emitted into the atmosphere. A major reduction in emissions is, however, needed. The advantage of a polycentric approach is that it encourages experimental efforts at multiple levels, as well as the development of methods for assessing the benefits and costs of particular strategies adopted in one type of ecosystem and comparing these with results obtained in other ecosystems. A strong commitment to finding ways of reducing individual emissions is an important element for coping with climate change. Building such a commitment, and the trust that others are also taking responsibility, can be more effectively undertaken in small- to medium-scale governance units that are linked through information networks and monitoring at all levels.
>
> Elinor Ostrom, *A Polycentric Approach for Coping with Climate Change*, Background Paper, World Bank's *World Development Report 2010: Development in a Changing Climate* (2009).

Does thinking about climate change as a multiscalar and/or polycentric regulatory problem require a legal paradigm shift in the way in which international negotiations are treated? How might multiscalar solutions vary in the context of mitigation and of adaption?

Could an effective multiscalar approach be crafted through viewing the smaller-scale activity as simply part of a nation's compliance with an international regime as a legal matter, or would this be inadequately polycentric in its focus? If one considers legal approaches within a nation-state in addition to international ones, how might solutions look different within a country and at an international level?

As discussed in more depth in chapters two and five, state, provincial, and local governments have increasingly become involved in climate change. Beyond their individual efforts and the use of local land use planning law to address climate change, these smaller-scale governments have been collaborating transnationally. How should these efforts fit into a multiscalar approach to climate change governance?

3. To the extent that Davies is correct that energy and environmental law need to be brought together, how should that be done in the short-term and long-term? Piecemeal efforts focused on a particular issue can sometimes move forward, but comprehensive reform of the statutory regime will likely be politically difficult to accomplish. Chapter Three considers an example of the Obama Administration bringing energy and environmental law together to address motor vehicle emissions' contribution to climate change; its "National Program" merges "energy law" fuel efficiency standards and "environmental law" tailpipe emissions standards through collaborative agency rulemaking.

4. What other areas of law besides those addressing energy and environment interact with the problem of climate change? How might all these different areas of law be integrated or harmonized?