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Prospects for Future Climate Change and the Reasons for Early Action

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Never before in human history has the global community collectively faced an environmental issue as complex as climate change. Left unchecked, the rapidly growing concentrations of greenhouse gases (GHGs) are projected to change the world we live in to one that is likely to have longer and more severe droughts and water shortages, more intense storms, flooding of coastal communities, worsening of air pollution, migration of forests, and loss of valuable ecosystems.[1] The scenario of this world presents a bleak future for our children and grandchildren.

These projected impacts are so frightening that many people question whether they could really happen. Are they just another media scare? And aren't climate changes part of the natural variability of the Earth? To answer these questions and many others raised by the public and by policy-makers, thousands of scientists who are part of the Intergovernmental Panel on Climate Change (IPCC), have spent years researching all aspects of Earth science and compiling their peer-reviewed findings into four comprehensive IPCC science assessments (published in 1990, 1995, 2001, and 2007).[2–5] Although some details of the projections remain uncertain, the scientific knowledge that is known with some confidence leads to the conclusions given by the IPCC in the latest assessment report. The Earth's climate is in for a significant warming that is likely to induce a number of adverse impacts. During nonglacial periods in the past, significant shifts in the Earth's climate generally occurred over tens to hundreds of thousands of years, whereas today's changes are occurring over mere decades. Will we have time to adapt?

Because the IPCC has conducted a number of comprehensive assessments of climate change, the 38th Annual A&WMA Critical Review by Dr. Michael MacCracken[6] could not—and does not—attempt to duplicate such an effort. Rather, in this review, Dr. MacCracken builds a bridge from a basic understanding of climate science, including climate change impacts, to his argument that there is an urgent need for aggressive action to stabilize the climate. He focuses on six overarching elements of climate science that are known with a high level of confidence, along with their supporting evidence. They are (1): Emissions from human activities, particularly combustion of fossil fuels, are changing atmospheric composition; (2) Enhancing the natural greenhouse effect will lead to long-term global warming; (3) Changes in the climate as a result of past activities are already evident, and these changes are consistent with a human influence; (4) Future warming is projected to be substantial; (5) The environment and society will both be impacted in significant ways; and (6) Slowing the ongoing change will require substantial reductions in emissions over coming decades to limit anthropogenic interference with the climate system. The final sections of the review are devoted to a discussion of what is needed to form the basis for an international agreement that will seek to avoid the very worst of the projected impacts. Dr. MacCracken notes that as a last resort, there may be a need for human geoengineering to mitigate the projected change.

In 2007, the Nobel Committee awarded the Nobel Peace Prize jointly to IPCC and to former Vice President Al Gore "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change." Dr. MacCracken was privileged to attend the ceremony, which he calls "very moving." The work of the IPCC has come to represent the most authoritative and complete review of the scientific literature on climate change, forming a basis for international policy development. With the projections of the scientific community becoming more confident with each IPCC assessment, and with the world's climate exhibiting more and more signs of warming, the political community worldwide is mobilizing to meet the challenge. Plans and strategies for mitigation of and adaptation to climate change are developing rapidly on many fronts. Most world leaders and many major multinational industries are taking climate change very seriously. However, there is much disagreement over the most effective approach to address climate change.

In 1992, the U.S. government negotiated and ratified the United Nations Framework Convention on Climate Change (UNFCCC), committing the United States to take voluntary steps to limit year 2000 emissions to their 1990 levels. A primary objective of the UNFCCC is to "prevent dangerous anthropogenic interference with the climate system," the definition of which has been intensely debated since the time of the UNFCCC inception. Follow-up negotiations under the UNFCCC led to an agreement on the Kyoto Protocol in 1997, which called for developed nations, on average, to reduce their emissions in the period 2008–2012 to approximately 5% below 1990 levels. Over the ensuing 5 yr, details were negotiated and, with the notable exception of the United States, the Kyoto Protocol was ratified and entered into force on February 16, 2005. Policies to implement it are currently being put in place in Europe and other developed nations.

By December 2007, the UNFCCC was holding its 13th meeting of the Conference of the Parties (COP 13) of the Framework Convention (as the UNFCCC is referred to in short). This meeting, hosted by the government of

Indonesia, took place in Bali and brought together more than 10,000 participants, including representatives from over 180 countries, intergovernmental and nongovernmental organizations, and the media. The conference culminated in the adoption of the Bali Roadmap, which consists of a number of forward-looking decisions that represent various tracks toward reaching a secure climate future and charts the course for a new negotiating process designed to tackle climate change, with the aim of getting to an agreed outcome in Copenhagen in 2009.

In early April 2008, COP 14 met in Bangkok, Thailand, to flesh out the Bali Roadmap, putting together a program to craft a future international climate pact that will successfully halt the increase in global emissions within the next 10 to 15 yr and dramatically reduce emissions by mid-century. Yvo de Boer, executive secretary of the UNFCCC, said that the meeting would also involve "examining to what extent developing countries can take real, measurable, and verifiable action to combat climate change, providing that real, measurable, and verifiable money is on the table."[7] By the end of the week, de Boer was able to announce that a timetable had been agreed for the negotiating process leading up to a long-term international climate change agreement to be concluded in Copenhagen in 2009. "The train to Copenhagen has left the station," he said.[7]

Recognizing that the United States simply has to be a party to an international effort to limit GHG emissions and avoid the most serious impacts, the current U.S. administration has been participating in the negotiations and indicating that it wants to get to an agreement, but that agreement must include limits on emissions by the major developing nations (even though their per capita emissions are a fifth or less of those in the United States). Trying to get U.S. efforts going, the U.S. Congress has stepped in; there are currently no fewer than seven economy-wide cap-and-trade proposals pending in the 110th Congress.[8] (Note: ref 8 has an excellent comparison chart of these proposals.)

On April 16–18, 2008, a meeting of the 17 top national emitters of GHGs was held in Paris at which President Bush unveiled a plan to limit GHG emissions after 2012 (the end of the Kyoto Protocol time period). The major economies represented at the meeting account for 80% of world GHG emissions, topped by the United States and China. President Bush's plan proposed to halt the growth of GHG emissions in the United States by 2025. However, the proposal was generally not well received, as many delegates at the meeting felt that far faster action was needed to avert the worst effects of global warming.[9]

One concern by many in the U.S. government has been the need to include developing nations in the negotiations for emission reductions. Because rapidly developing countries, such as India, China, and Brazil, are emitting an increasingly large percentage of the overall global emissions, though per capita emissions remain well below those in the developed countries, it is important that a mechanism be developed to engage their governments in measures to reduce emissions, or at the very least, in the growth of emissions.

The World Bank is considering the development of a clean energy financing vehicle to provide the upfront capital costs of switching to low-carbon technologies, with an initial capitalization of US$10 billion.[10] This plan includes the development of a long-term, stable, regulatory framework to stimulate an international carbon market that could transfer tens of billions of dollars per year to developing countries in return for reducing their emissions. The framework establishes systems to reduce carbon dioxide (CO_2) emissions from power plants, increase renewable energy generation, track renewable energy credits, and establish baselines for carbon sequestration.

China and other key developing nations have adopted "unilateral actions" to cut emissions. China is reported to be taking significant action to reduce its GHG emissions and these efforts are expected to equal or surpass currently proposed U.S. climate policy through 2010.[11] GHG emissions in China are expected to be cut 7% below projected levels through 2020. Most of the reductions have been financed domestically, independent of the Kyoto Protocol's Clean Development Mechanism, under which developing countries can sell emission reductions achieved from approved projects to developed nations. In contrast to the reductions reported above, there is some evidence that Chinese emissions may be rising at a rate of between 11% and 14% per year, a rate far greater than that assumed in the IPCC model projections.[12]

In this critical review, Dr. MacCracken comments that even if GHG emissions from the industrialized nations went to zero tomorrow, the projected growth in developing nation emissions will still cause warming to exceed dangerous levels later this century. Because the developing nations are least able to cope with some of the climate change impacts, it is in their best interest to move toward a low carbon-emitting economy. He adds: "To the leaders of the developing nations, [you] need to move expeditiously, albeit in a differentiated way that allows for some growth in CO_2 emissions for a brief period to allow for the economic development needed to raise the standard-of-living of your people."

In the absence of aggressive action by the U.S. government, many private groups in the United States have stepped forward, including the Pew Center on Global Climate Change supported by the Pew Charitable Trusts.[13] The Pew Center is working with 42 major corporations that comprise the Business Environmental Leadership Council (BELC). These companies, ranging from high technology to diversified manufacturing, oil, and gas to transportation, utilities, and chemicals manufacturers with more than 3.8 million employees and representing US$2.8 trillion in market capitalization, joined the BELC with the belief that companies taking early action on climate strategies and policy will gain sustained competitive advantage over their peers.

There are a number of other private initiatives looking at ways to address climate change. For example, at the 2007 U.S. Conference of Mayors Climate Protection Summit, former President Bill Clinton announced a new partnership between the Clinton Climate Initiative and Wal-Mart Stores Inc.[14] One of the technologies the partnership will explore is energy-efficient, high-performance light-emitting diode lights for parking lots and street lamps. By switching to LEDs, Wal-Mart estimates that cities could save 50% on street lamp energy consumption and reduce maintenance costs by 80%. Wal-Mart has also made a commitment to

designing a store prototype that is 25–30% more efficient by 2009, and reducing GHG emissions in existing stores by 20% by 2012.[15]

Another private organization, the Climate Group, is dedicated to advancing business and government leadership on climate change and includes companies based in the United Kingdom, the United States, and Australia. One member of the group, DuPont, has made a significant investment in energy efficiency, allowing the company to hold energy use flat between 1990 and 2000, while increasing production 35% and saving the company US$2 billion. DuPont also helped to start up several external emissions trading programs, including the Chicago Climate Exchange and the UK Emissions Trading Scheme.[16]

There is also a tremendous amount of action to confront climate change going on at the state and local level. For example, the Regional Greenhouse Gas Initiative, established in December 2005, is the first mandatory U.S. cap-and-trade program for CO_2.[17] The initiative currently includes 10 Northeast and Mid-Atlantic states and sets a cap on emissions of CO_2 from power plants, allowing sources to trade emissions allowances. Major efforts to combat climate change are also under way in California and other western states, Florida, North Carolina, several other southeastern states, and the Midwest.

On April 18, at the 2008 Conference of Governors on Climate Change, 4 governors—along with representatives from another 14 states—signed a joint declaration on the future of climate change policy in the United States. The declaration recognized the leadership of state-based climate action plans and programs in paving the way for cost-effective reductions of GHGs, but acknowledged that a federal–state partnership is the only way to "get the job done."[18]

There is some frustration by the states that the U.S. Environmental Protection Agency (EPA) has not acted to regulate GHG emissions. In April 2007, the U.S. Supreme Court ruled, in the case of *State of Massachusetts et al. versus EPA*, that EPA is authorized to regulate GHGs under the federal Clean Air Act.[19] Dr. MacCracken wrote an affidavit in support of the plaintiffs gaining standing in the case by demonstrating that actual impacts were occurring; his affidavit was mentioned favorably in the resulting majority opinion. Among other defenses, EPA claimed that GHGs were not "pollutants" in the sense of the word that defined EPA's mandate and, therefore, they had no jurisdiction to regulate them. The court found that CO_2 was a pollutant and instructed EPA to proceed with regulations unless it could demonstrate that GHGs do not contribute to climate change that harms human health and welfare.

In late March 2008, the EPA administrator revealed plans to issue an advanced notice of proposed rulemaking on the endangerment posed by GHGs, requesting comment on both the science and the implications of regulation. However, to date, EPA has not issued any formal language toward establishing regulations for GHG emissions or documentation on the potential harm from GHG emissions. On April 2, 2008, 12 states, the District of Columbia, 2 cities, and several environmental groups sued EPA over its failure to regulate GHG emissions from motor vehicles.[20] They asked the U.S. Circuit Court of Appeals for the District of Columbia to force EPA to issue a formal determination within 60 days on the public health impacts from GHG emissions.

There is a general recognition by all that developing a strategy to stabilize the climate at a level that will minimize damages is an extremely difficult and potentially costly issue. Economic models predict up to two orders of magnitude difference in the costs of reducing the same amount of GHG emissions. Costs for stabilizing the climate range from somewhere between 0.1% and 10% of the world's total economic output per year,[21] depending on which model is used and what assumptions are made. Economic models, although unable to provide accurate cost estimates, can be used to provide insights into ways to reduce costs. For example, the many models deployed to evaluate the costs of stabilizing the climate have suggested that overall costs can be reduced by allowing a certain amount of flexibility in methods for reducing GHGs, by announcing policies well in advance of implementation to allow for thoughtful planning, and by allocating allowances to make up for differences in the costs to be borne by various states, industrial sectors, and households.[21]

The authors of a recent paper in *Nature*[22] argue that the IPCC gives a mistaken impression of the extent of the technological challenges we face to reduce CO_2 emissions to an acceptable level. They argue that if the IPCC were to run the models out to 2100, assuming that energy technologies stayed the same, the results would be totally unrealistic. The IPCC used scenarios with an already assumed rate of technology improvement equalized across regions and countries, masking the need for a more accelerated path forward. In a personal communication during an interview, one of the authors stated that the IPCC assumption that technological innovations will occur spontaneously threatens to "blind us to reality and could potentially distort our ability to develop effective policies."[23] Because climate models require projecting changes out 50–100 yr in the future, assumptions must be made on the types of technological developments that will be made over that period. One can understand the challenge in making these assumptions because 100 yr ago no one could have imagined today's transportation systems and information technologies.

It is evident that it will be necessary to have both a program on mitigation and one on adaptation to enable humanity to lead healthy lives in a changing climate. The authors of a recent paper published in *Science*[24] suggest some new ways to help promote regional adaptation to climate change. To identify the most critical aspects, they suggest assessing the vulnerability of natural and human systems to climate change as a function of the magnitude of global warming and then, to indicate the level of policy action needed, identifying the scenarios of greenhouse gas emissions that avoid the most damaging impacts of climate change. Their system provides data-constrained estimates of the range of possible future climate changes on decadal to century time scales that can be updated on the basis of new results, providing a narrower range of possible futures for use in adaptive planning. Although this approach does not attempt to manage the climate system itself, it does provide ideas for different regions to develop their own roadmap to climate adaptation.

Finally, the often-quoted Stern report[25] lays out the issue clearly: "Our actions now and over the coming decades could create risks of major disruption to economic and social activity, on a scale similar to those associated with the great wars and the economic depression of the first half of the twentieth century. And it will be difficult or impossible to reverse these changes. So prompt and strong action is clearly warranted." Dr. MacCracken agrees with this comment and his critical review elaborates the reasons why.

Given the complexity of the problem and the potential cost of action, it may be that effective policies are being developed as quickly as humanly possible. In this review, Dr. MacCracken comments that "The industrialized nations need to get on a path that reduces their collective [GHG] emissions by approximately 80% by 2050, and that heads to essentially zero emissions in the few decades thereafter." That scenario is a hard one to imagine. Dr. MacCracken reminds us that because of the long lifetime of CO_2 and the large capacity of the ocean to store CO_2 for long periods, "Even if [GHG] emissions are halted completely and the concentrations of relatively short-lived gases (like methane) start to drop, there will be some future warming as the deep ocean warms (thus reducing the cooling influence of upwelling waters) and as the aerosol loading simultaneously drops."

Why is it taking so long for us to get moving to address the problem? The National Research Council (NRC) of the National Academy of Sciences[26] was recently asked to review the U.S. Climate Change Science Program. The NRC report includes the comment: "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."

Clearly what is needed most is some fresh and creative thinking on the issue. Dr. MacCracken has outlined a path forward that brings in the developing countries and suggests that by using a well-designed combination of increases in energy efficiency, switching to renewables, fission, and fusion, and the development of other new technologies that the climate might be stabilized at levels ranging from 445 to 710 ppmv of CO_2 equivalent. Dr. MacCracken urges government negotiators to agree on a combination of national and international regulations, taxes, permits, and incentives to make this happen. He calls for immediate action and comments, "Strong leadership and a firm commitment to move away from carbon emitting technologies are needed to convince businesses and the public to act."

Dr. MacCracken is currently chief scientist for climate change programs at The Climate Institute in Washington, DC, a nonprofit organization founded in 1986, and possibly the oldest single-issue group focused on climate change. Dr. MacCracken holds a bachelor's of science degree from Princeton University and a Ph.D. from the University of California Davis/Livermore; his dissertation focused on exploring the viability of different hypotheses for explaining glacial cycling. He went to work at Lawrence Livermore National Laboratory (LLNL), developing an air quality model for the San Francisco Bay Area that helped in the region's development of an air quality maintenance plan. Most of his research, however, focused on modeling the effects on climate of natural forcings and human-activities, including the proposed fleet of supersonic aircraft, a possible nuclear war, soot aerosols, and emissions of GHGs. From 1987 to 1993, he served as division leader for atmospheric and geophysical sciences, having served from 1974 as deputy division leader. From 1993 to 2002, Dr. MacCracken was on assignment from LLNL to the Interagency Office of the U.S. Global Change Research Program, where he served as the founding executive director of the office (1993–1997) and then as executive director of the National Assessment Coordination Office (1997–2001). His responsibilities included coordinating the U.S. government's review of draft IPCC assessments and advising the administration on the science of global warming. Dr. MacCracken retired from LLNL when his assignment with the Global Change Office ended in 2002. Since then, in addition to his position at The Climate Institute, he has served as president of the International Association of Meteorology and Atmospheric Sciences (2003–2007) and as a member of the integration team for the Arctic Climate Impact Assessment and a range of other panels.

A&WMA members and interested parties are invited to read, attend, and comment on the 38th Annual Critical Review at A&WMA's 101st Annual Conference & Exhibition in Portland, OR, on Wednesday, June 25, 2008, 8:00 a.m. to 11:30 a.m. As always, the review presentation will be followed by comments from invited discussants: (1) Mark Trexlor, managing director of global consulting services, EcoSecurities; (2) Bart Croes, chief of the Research Division for the California Air Resources Board; (3) Carol Whitman, senior legislative principal of environmental policy for the National Rural Electric Cooperative Association; and (4) Mark Jacobson, director of the Atmosphere and Energy Program and professor of civil and environmental engineering at Stanford University. The discussants will provide different perspectives on the climate change issue and extend the discussion to aspects of the issue not being addressed by the review author. Comments also will be accepted from the floor and from written submissions to the Critical Review Committee Chair. The Chair will condense and summarize these points for publication in the October issue of the *Journal*. Members are encouraged to suggest topics and authors for future critical reviews and to apply for membership on the Critical Review Committee to assist with the process.

Critical Review Committee Chair (2008–2009)
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REFERENCES

1. Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2007: Impacts, Adaptation and Vulnerability*; Parry, M., Canziani, O., Palutikof, J., van der Linden, P., Hanson, C., Eds.; Cambridge University Press: Cambridge, U.K., 2007.
2. Intergovernmental Panel on Climate Change (IPCC). *The IPCC Scientific Assessment*; Houghton, J.T., Jenkins, G.J., Ephraums, J.J., Eds.; Cambridge University Press: Cambridge, U.K., 1990.

3. Intergovernmental Panel on Climate Change (IPCC). *Climate Change 1995: the Science of Climate Change*; Houghton, J.T., Meira Filho L.G., Callender, B.A., Harris, N., Kattenberg, A., Maskell, K., Eds.; Cambridge University Press: Cambridge, U.K., 1995.
4. Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2001: The Scientific Basis*; Houghton, J., Ding, Y., Griggs, D.J., Nouger, M., van der Linden, P.J., Dai, X., Maskell, K., Johnson, C.A., Eds.; Cambridge University Press: Cambridge, U.K., 2001.
5. Intergovernmental Panel on Climate Change (IPCC). *Climate Change 2007: the Physical Science Basis*; Solomon, S., Qin, D., Manning, M., Marquis, M., Averyt, K., Tignor, M.M.B., Miller, H.L., Jr., Chen, Z., Eds.; Cambridge University Press, Cambridge, U.K., 2007.
6. MacCracken, M.C. Prospects for Future Climate Change and the Reasons for Early Action; *J. Air & Waste Manage. Assoc.* **2008**, *58*, 735-786.
7. United Nations Framework Convention on Climate Change, 2008. *Bangkok Climate Change Talks, 31 March to 4 April 2008*; available at *http://unfccc.int/meetings/intersessional/awg-lca_1_and_awg-kp_5/items/4288.php* (accessed April 24, 2008).
8. Pew Climate Center. Economy-Wide Cap-and-Trade Proposals in the 110th Congress, 2008; available at *http://www.pewclimate.org/docUploads/110-Congress-Cap-Trade-01-30-2008.pdf* (accessed April 24, 2008).
9. Bush Climate Plan under Fire. *International Herald Tribune*, April 17, 2008.
10. World Bank. *Clean Energy and Development: Towards an Investment Framework*; 2006-02; Prepared for the Development Committee (Joint Ministerial Committee of the Boards of Governors of the Bank and the Fund on the Transfer of Real Resources to Developing Countries): Washington, DC, 2006.
11. Center for Clean Air Policy (CCAP). *Greenhouse Gas Mitigation in Brazil, China and India: Scenarios and Opportunities through 2025*. CCAP: Washington, DC, November 2006.
12. Auffhammer, M.; Carson, R.T.J. Forecasting the Path of China's CO_2 Emissions Using Province-Level Information. *Environ. Econ. Manage.*, in press; also available online at *www.sciencedirect.com*.
13. Pew Climate Center; available at *http://www.pewclimate.org/business* (accessed April 24, 2008).
14. Wal-Mart & Clinton Climate Initiative Announce Partnership, 2007; available at *http://walmartstores.com/Sustainability/7789.aspx?p=8141* (accessed April 24, 2008).
15. Wal-Mart Sustainability Program, 2007; available at *http://walmartstores.com/sustainability* (accessed April 24, 2008).
16. The Climate Group and DuPont Corporate Case Study, 2007; available at *http://www.theclimategroup.org/* and *http://theclimategroup.org/index.php/reducing_emissions/case_study/dupont/* (accessed April 24, 2008).
17. Regional Greenhouse Gas Initiative (RGGI): an Initiative of the Northeast and Mid-Atlantic States of the U.S., 2008; available at *http://www.rggi.org/* (accessed April 24, 2008).
18. Governors' Declaration on Climate Change. Quote from press release on meeting held at Yale University, April 18, 2008; available at *http://yale.edu/opa/media/pdf/Gov-Declaration-20080418* (accessed April 24, 2008).
19. Supreme Court of the United States No. 05-1120. *Massachusetts, et al., Petitioners v. Environmental Protection Agency et al. on Writ of Certiorari to the United States Court of Appeals for the District of Columbia Circuit*; Opinion of the Court delivered by Justice Stevens, April 2, 2007.
20. United States Court of Appeals for the District of Columbia. *Circuit Petition for Writ of Mandamus to Compel Compliance with Mandate, Docket No. 03-1361 (and consolidated cases) Commonwealth of Massachusetts, et al. Petitioners, v. U.S. Environmental Protection Agency*; April 2, 2008.
21. Peace, J.; Weyant, J. *Insights Not Numbers: the Appropriate Use of Economic Models*; available at *http://www.pewclimate.org* (accessed 2008).
22. Pielke, R.; Wigley, T.M.; Green, C. Dangerous Assumptions; *Nature* **2008**, *452*, 508-509.
23. Pielke, R. Carbon Dioxide Emission Reduction Assumptions Overly Optimistic, Study Says; April 3, 2008; available at *http://www.sciencedaily.com/releases/2008/04/080402131140.htm* (accessed 2008).
24. Cox, P.; Stephenson, D. Climate Change: a Changing Climate for Prediction; *Science* **2007**, *317*, 13.
25. Stern, N. *Stern Review: the Economics of Climate Change*; Cambridge University Press: London, U.K., 2006.
26. National Research Council. *Evaluating Progress of the U.S. Climate Change Science Program: Methods and Preliminary Results*; Committee on Strategic Advice on the U.S. Climate Change Science Program, Division of Behavioral and Social Sciences and Education, National Academies Press, Washington, DC, 2007.