# Prospectus for Synthesis and Assessment Product 2.1

## *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations and Review of Integrated Scenario Development and Application*

Lead Agency: DOE
Supporting Agencies: EPA, NOAA, NASA

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## 1. Overview

Scenario analysis is a widely used intellectual device for decisionmaking in complex and uncertain situations. Scenarios have been applied extensively in the climate change context. Examples include emissions scenarios, climate scenarios, and technology scenarios. Scenarios are 'what ifs'—sketches of future conditions (or alternative sets of future conditions), used as inputs to exercises of decisionmaking or analysis. Scenarios are not predictions.

This product has two components, in conformance with the requirements of the *Strategic Plan for the U.S. Climate Change Science Program (CCSP)*: updating scenarios of greenhouse gas emissions and atmospheric concentrations (Part A) and a review of integrated scenario development and application (Part B). Parts A and B will be coordinated with each other and with other CCSP synthesis and assessment products, especially 3.2 and 4.5. They will enhance ongoing international efforts to produce scenarios and conduct scenario analysis by such entities as the Intergovernmental Panel on Climate Change (IPCC) and the Climate Change Technology Program (CCTP). Part B will also help develop CCSP research agendas and guide the preparation of future scenarios.

### *1.1. Part A: Updated Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations*

Part A will use integrated assessment models as the foundation for a small group of new and updated global emissions scenarios leading to long-term stabilization of greenhouse gas concentrations. These updated scenarios will incorporate lessons from previous scenario efforts and will be based on the current state-of-the-art in integrated assessment modeling. The updated scenarios are intended for technology planners, such as the CCTP, who are interested in the role of technology in stabilization; other decisionmakers or analysts interested in the overall results and implications of the scenarios or requiring scenario data for further analysis; and climate modelers who might use emissions trajectories as input for climate modeling.

The final product for Part A will be: (1) a data set that includes pertinent numerical information for each scenario, including, for example, emissions trajectories, primary energy contributions over time, and population trajectories; (2) an accompanying technical report that provides documentation and discussion of the scenarios; and (3) a summary for interested non-specialists.

Stabilization in the scenarios will be defined in terms of the radiative forcing resulting from the long-term combined effects of, at a minimum, carbon dioxide ($CO_2$), nitrous oxide ($N_2O$), methane ($CH_4$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride ($SF_6$). Other gases and radiatively important substances may also be addressed and reported, as appropriate, but may not be used to define stabilization.

Four stabilization levels will be considered as a basis for the stabilization scenarios. The four levels will be constructed so that the $CO_2$ concentrations resulting from stabilization are roughly consistent with the range of commonly discussed $CO_2$-concentration stabilization levels (i.e., 450 ppm through 750 ppm). The precise specification of these levels will emerge through the scenario development process.

The scenarios in Part A will be constructed to represent meaningful and plausible futures that would be useful to decisionmakers and analysts. The scenarios will not be constructed and coordinated to span the full range of meaningful and plausible futures, and likelihoods will not be assigned to the scenarios. The scenarios will provide insights into questions such as the following:

- *Emissions Trajectories:* What emissions trajectories over time are consistent with meeting the four alternative stabilization levels? How might the relative contributions of different gases to radiative forcing transition over time?
- *Energy Systems:* What primary energy contributions are consistent with each of the alternative stabilization levels? Is convergence toward a single, or a small set of, dominant technologies or fuels consistent with stabilization at the four alternative levels? Is substantial primary energy heterogeneity consistent with stabilization at the four alternative levels?
- *Economic Implications:* What are the possible economic implications of meeting the four stabilization levels?

### *1.2. Part B: Review of Integrated Scenario Development and Application*

A variety of scenarios, including, for example, emissions scenarios, climate scenarios, and technology scenarios, have been created and used for global climate change planning and decisionmaking. Defining and creating scenarios is a complex challenge in both national and international assessment processes (e.g., the IPCC). It requires linking diverse users in a flow of information that stretches from modelers of emissions and land use, to climate modelers, to impacts researchers, and finally to national and regional decisionmakers. Meeting the analytic needs of different users and expediting the flow of information across the diverse fields involved requires careful planning.

Part B will review and evaluate how the science and stakeholder communities define, develop, implement, and communicate scenarios in the global climate change context, and how this process might be enhanced or improved. This will include a review of past scenario development and application efforts. The intent of the review is to inform preparation and application of future scenarios by the CCSP, the IPCC, the CCTP, and other global change research and assessment organizations. The intended audience includes all participants in the integrated scenario development and application process, including integrated assessment modelers, climate modelers, technology planners, impacts researchers, and decisionmakers. The final product of Part B will include (1) a scientific/technical report of findings as well as (2) a summary for interested non-specialists.

Part B will explore the following questions:

- *Applications:* What do different users of scenarios expect or need from those who develop those scenarios? What choices or decisions have scenarios been constructed to illuminate? How well have existing scenarios (e.g., IPCC IS92 and IPCC *Special Report on Emissions Scenarios*) explored the decisions or conditions they were designed to illuminate? What sorts of conditions should future scenarios be developed to explore?
- *Uncertainty and Scenario Drivers:* What approaches are used in scenario development to characterize uncertainties? How can the development and application of scenarios be improved to better incorporate evolving process knowledge of socio-economic, climate, and environmental conditions, and to better communicate to users and the public about uncertainties? Do existing scenarios, taken as a set, span the range necessary to encompass uncertainty about potential future conditions?
- *Process:* What are the individual components of the integrated scenario process (e.g., macroeconomic models, climate models)? What approaches are available for each component and for integrating the components? What specific methodological issues are associated with each scenario component (e.g., macroeconomic frameworks underpinning integrated assessment models)? Which approaches are appropriate for what purposes?
- *Recommendations:* What improvements can be made to the process of developing and using scenarios (e.g., should a broader range of experts and stakeholders be involved in developing scenario assumptions)? What are the most important next steps in scenario development and application? How can the flow of information and results from emissions scenarios, to climate scenarios, to effects research be improved?

## 2. Contact Information

DOE is the lead agency for this product. Agency contacts are presented in the following table:

| Member Agency | Agency Lead | Email | Phone |
|---|---|---|---|
| DOE | J. Houghton | john.houghton@science.doe.gov | (301) 903-8288 |
| EPA | F. de la Chesnaye | Delachesnaye.Francisco@epamail.epa.gov | (202) 343-9010 |
| NOAA | D. Goodrich | david.goodrich@noaa.gov | (301) 427-2089 |
| NASA | P. Decola | pdecola@hq.nasa.gov | (202) 358-0768 |

## 3. Lead Authors

For Part A, authors will primarily be drawn from the participating modeling teams. Authors for Part A must have records of successful development, evaluation, and/or use of integrated assessment models. Participating models must (1) be global in scale; (2) capable of producing global emissions totals for, at a minimum, $CO_2$, $N_2O$, $CH_4$, HFCs, PFCs, and $SF_6$, that may serve as inputs to global general circulation models (GCMs) such as the National Center for Atmospheric Research (NCAR) Community Climate System Model (CCSM) and the Geophysical Fluid Dynamics Laboratory (GFDL) climate model; (3) represent multiple regions; (4) be capable of simulating the radiative forcing from these greenhouse gases (GHGs) and substances; (5) have technological resolution capable of distinguishing between major sources of primary energy (e.g., renewable energy, nuclear energy, biomass, oil, coal, and natural gas) as well as between fossil fuel technologies with and without carbon capture and storage systems; (6) be economics-based and capable of simulating macroeconomic cost implications of stabilization; and (7) look forward to the end of the century or beyond. In addition, modeling teams should have a track record of publications in professional, refereed journals, specifically in the use of their models for the analysis of long-term GHG emission scenarios.

This product is the first in a series of CCSP efforts to conduct scenario analyses and explore the scenario process. To facilitate expeditious completion, participation in Part A will be limited to U.S. modeling teams that meet the criteria above. This will include the EPPA model [Massachusetts Institute of Technology (MIT)], the MiniCAM model [Pacific Northwest National Laboratory (PNNL)], and the MERGE model (Stanford University). A small number of additional models that meet the above criteria may be added. Associated authors include:

- Professor Henry Jacoby, Co-Director of the Joint Program on the Science and Policy of Global Change at MIT
- Dr. John Reilly, Associate Director for Research at the Joint Program on the Science and Policy of Global Change at MIT
- Dr. James Edmonds, Senior Staff Scientist and Technical Leader of Economic Programs at the Joint Global Change Research Institute, a collaboration between PNNL and the University of Maryland on the College Park
- Mr. Hugh Pitcher, Staff Scientist at the Joint Global Change Research Institute, a collaboration between PNNL and the University of Maryland on the College Park
- Dr. Richard Richels, director of global climate change research at the Electric Power Research Institute
- Dr. Leon Clarke, Senior Research Economist at the Joint Global Change Research Institute, a collaboration between PNNL and the University of Maryland on the College Park.

Authors for Part B must have records of successful development, evaluation, and/or use of the different components of the scenario development and application system. The set of authors for this product will cover a range of expertise commensurate with range of participants and users of the integrated scenario process, from integrated assessment modelers, to climate modelers, to impact modelers, to decisionmakers and technology planners. The proposed authors for Part B include:

- Professor Edward Parson, Professor of Law, Associate Professor of Natural Resources and Environment, University of Michigan
- Professor Karen Fisher-Vanden, Assistant Professor of Environmental Studies at Dartmouth College
- Dr. Virginia Burkett, chief of the Forest Ecology Branch at the National Wetlands Research Center of the U.S. Geological Survey, U.S. Department of the Interior
- Dr. Cynthia Rosenzweig, Senior Research Scientist at NASA Goddard Institute for Space Studies
- Professor Mort Webster, Assistant Professor of Public Policy at the University of North Carolina at Chapel Hill
- Mr. Hugh Pitcher, Staff Scientist at the Joint Global Change Research Institute, a collaboration between PNNL and the University of Maryland on the College Park
- Dr. Linda Mearns, Director of the Weather and Climate Impact Assessment Initiative, NCAR
- Professor David Keith, Professor of Economics, Professor of Chemical and Petroleum Engineering, and Canada Research Chair in Energy and the Environment at the University of Calgary, Alberta; and Adjunct Professor of Engineering and Public Policy at Carnegie-Mellon University.

## 4. Stakeholder Interactions

For both Parts A and B, stakeholder input will be solicited through the public comment period for this prospectus and the public comment period for the draft final reports. This input may be enhanced by direct requests for input, during the public comment periods, from a set of stakeholders identified by the lead and supporting agencies. In addition, individual authors for Parts A and B will participate in a range of scenario-relevant conferences, meetings, or other forums, at which the authors will solicit feedback, both formally and informally.

## 5. Drafting

### *5.1. Part A: Updated Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations*

Part A will be drafted based on new scenarios developed specifically for this product. The core of Part A will be a group of “scenario sets” developed by the participating modeling teams. Each scenario set will include four stabilization scenarios corresponding to the four stabilization levels, with each set based on model assumptions designed by the individual modeling team to represent plausible and meaningful values for critical drivers such as global population growth, technological change, and economic growth. Each modeling group will produce and document at least one scenario set, but each may generate additional scenarios if appropriate.

The scenarios will include some standardized elements. For example, the choice of alternative stabilization levels and GHGs considered for stabilization in the scenarios will be coordinated across models. Conversely, model assumptions (e.g., population growth, technological change, economic growth) will not be standardized across modeling teams. Differing assumptions among the models provide useful additional hypotheses about the future. In addition, many parameters are often not easily compared across models because they are defined and used in different ways.

A protocol or outline will be developed to ensure consistent documentation and data availability across scenarios. However, it is anticipated that different models will provide differing levels of detail. Each modeling team may also produce an independent background report, as a way of summarizing and documenting the analysis carried out in support of this effort.

Scenarios developed for Part A will address land use and land use change as both GHG sources and sinks. Because models have varying capabilities to explicitly consider land use and land use change, however, such consideration will vary across models.

### *5.2. Part B: Review of Integrated Scenario Development and Application*

Part B will be drafted based on a review of accumulated experience developing and using scenarios in past global-change analyses. This review of past experience will be supplemented by insights and concepts drawn from relevant scholarly and research literatures in integrated assessment, decisionmaking under uncertainty, strategic planning, and design of decision and assessment processes.

## 6. Review

Parts A and Part B will be reviewed independently, and follow the process described in the *Guidelines for Producing CCSP Synthesis and Assessment Products*: (1) a first draft for expert peer review, (2) a second draft posted for public comment, and (3) a third draft for final review and approval through the CCSP interagency committee and the National Science and Technology Council (NSTC). The expert peer review process will consist of independent reviews from five to ten expert peer reviewers for Part A and five to ten expert peer reviewers for Part B. Expert peer reviewers will be selected by the lead and supporting agencies. Separate expert peer reviewers will be selected for Part A and Part B, although there may be overlap. Nominations for expert peer reviewers can be provided to representatives of the lead and supporting agencies on or before 1 September 2005. The expert peer review process will be 45 days long.

## 7. Related Activities

Both nationally and internationally, the process of scenario development and application is ongoing and iterative, with each new effort endeavoring to more clearly understand and explain specific issues raised by previous efforts, and moving forward to raise new issues and build upon and expand the applicable base of tools. Part A represents one step in this ongoing process. It will incorporate lessons gleaned from previous scenario efforts, including those of the IPCC and the CCTP; it will be based on the current state-of-the-art in integrated assessment modeling (e.g., the inclusion of multiple GHGs); and it represents a first step in a longer CCSP scenario analysis process that includes Synthesis and Assessment Products 3.2 (climate projections for research and assessment based on emissions scenarios) and 4.5 (scenario-based analysis of the climatological, environmental, resource, technological, and economic implications of different atmospheric concentrations of greenhouse gases). Part B will serve to enhance this longer term CCSP scenario process as well as scenario processes by other entities. To the extent possible, any interactions between Part A and Part B will be exploited.

## 8. Communication

Hardcopies of the product will be published using the standard format for all CCSP synthesis and assessment products. The final product and the comments received during the expert review and the public comment period will be posted on the CCSP web site. The number of hardcopies and the process for their dissemination will be determined as part of the development of this product.

## 9. Timeline

The following schedule is proposed for the completion of this product. Unless otherwise noted, deadlines refer to both Part A and Part B. Because this product will require substantial new modeling, the final deadline is contingent on approval of the prospectus on the schedule shown as well as completion of review deadlines following completion of the draft products.

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| Jan 05 | Prospectus posted on CCSP web site for public comment (30 days) |
| Feb 05 | Final prospectus posted on the CCSP web site |
| Dec 05 | Draft #1 provided to peer reviewers (45 days) |
| Mar 06 | Draft #2 made available for public comment (45 days) |
| Jun 06 | Draft #3 submitted to CCSP interagency committee for review and processing through NSTC |
| Aug 06 | Final product posted on CCSP web site |

## Appendix. Biographical Information for Authors

**James Edmonds:** Dr. Edmonds is a Chief Scientist and Laboratory Fellow at the Pacific Northwest National Laboratory's (PNNL's) Joint Global Change Research Institute, a collaboration with the University of Maryland at College Park. Dr. Edmonds research has contributed to the development of scenarios and the integrated assessment of climate change since 1978. He has published two books, numerous scientific papers and made countless presentations on topics relating to climate change. He has served as lead author for all three major assessments of the Intergovernmental Panel on Climate Change (IPCC) and numerous interim assessment reports. Dr. Edmonds has also served since 1998 as the principal investigator for the Global Energy Technology Strategy Program, an international, public-private research collaboration that explores the role of technology in managing the long-term risks of climate change. Dr. Edmonds received his B.A. from Kalamazoo College in economics (1969) and his M.A. and Ph.D. in economics from Duke University (1972, 1974).

**Hugh Pitcher:** Mr. Pitcher is a Staff Scientist at Pacific Northwest National Laboratory's (PNNL's) Joint Global Change Research Institute, a collaboration the University of Maryland at College Park. Over the last decade, Mr. Pitcher worked extensively on integrated assessment model development and use, including a wide range of scenario or scenario-related efforts. He is a member of IPCC Task Group on Scenarios for Impact and Climate Assessment, TGICA, participating since its founding. He has been a lead author of Chapter 2, Working Group III, TAR on stabilization scenarios, a lead author of the Special Report on Emissions Scenarios as part of which he prepared the scenarios from PNNL's MiniCAM model, and a lead author of the Summary for Policy Makers of the Special Report on Emissions Scenarios. His scenario interests include demographics, economic growth including PPP/MER issues, and simple analytic frameworks for uncertainty analysis. Mr. Pitcher holds degrees in economics and mathematics from Oberlin College.

**Richard Richels:** Dr. Richels directs global climate change research at EPRI in Palo Alto, California. Dr. Richels has served as a lead author for the Intergovernmental Panel on Climate Change's (IPCC) Second and Third Scientific Assessments and served on the Synthesis Team for the U.S. National Assessment of Climate Change Impacts on the United States. He currently serves on the Scientific Steering Committee for the U.S. Carbon Cycle Program and the Advisory Committee for Princeton University Carbon Mitigation Initiative. Dr. Richels is a coauthor of "Buying Greenhouse Insurance – the Economic Costs of CO2 Emission Limits", and has written numerous papers on the economics of climate change. Dr. Richels has served on a number of national and international advisory panels, including committees of the Department of Energy, the Environmental Protection Agency and the National Research Council. He has served as an expert witness at the Department of Energy's hearings on the National Energy Strategy and testified at Congressional hearings on priorities in global climate change research. Dr. Richels received a B.S. degree in Physics from the College of William and Mary (1968) and an M.S. (1973) and a Ph.D. (1976) from Harvard University's Division of Applied Sciences.

**Henry Jacoby:** Dr. Jacoby is Professor of Management in the M.I.T. Sloan School of Management and Co-Director of the M.I.T. Joint Program on the Science and Policy of Global Change. Dr. Jacoby was formerly Director of the Harvard Environmental Systems Program, Director of the MIT Center for Energy and Environmental Policy Research, Associate Director of the MIT Energy Laboratory, and Chair of the MIT Faculty. Professor Jacoby has made contributions to the study of policy and management in the areas of energy, natural resources and environment—writing widely on these topics, including five books. Public involvement has included Chairmanship of the Massachusetts Governor's Emergency Energy Technical Advisory Committee (1973-74); and service on the National Petroleum Council (1975-83), the Climatic Impact Committee of the National Academy of Sciences (1973-75), the AAAS Panel on Climate and Water Resources (1986-89), the NAS/NAE Committee on Alternative Energy R&D Strategies (1989-90), a study by the U.S. Office of Technology Assessment of "Systems at Risk from Climate Change” (1992-93), and an NRC Panel on Metrics for Global Change Research (2004). In 1998-99 he was Environmental Fellow of the American Council on Capital Formation. Dr. Jacoby was an undergraduate mechanical engineer at the University of Texas at Austin, and he holds a Ph.D. in Economics from Harvard University.

**John Reilly:** Dr. Reilly is the Associate Director for Research in the Joint Program on the Science and Policy of Global Change and a Senior Research Scientist in the Laboratory for Energy and Environment at MIT. Much of his 24-year research career has focused on the economics of climate change, including modeling of energy use and greenhouse gas emissions and the impacts of climate change on agriculture as well as consideration of agriculture and forestry sinks. He has published numerous articles on the economics of climate change and on other issues related to natural resources, technology, and energy use and supply. He was a principal author for the IPCC Second Assessment Report and has served on a variety of U.S. Federal government and international committees. He was the Co-Chair of the recent U.S. National Agricultural Assessment on Climate Change. Prior to joining MIT in 1998, he spent 12 years with the Economic Research Service of USDA, most recently as the Acting Director and Deputy Director for Research of the Resource Economics Division. He has been a scientist with Battelle's Pacific Northwest National Laboratory and with the Institute for Energy Analysis, Oak Ridge Associated Universities. He received his Ph.D. in economics from (1983) from the University of Pennsylvania and holds a B.S. in economics and political science from the University of Wisconsin.

**Leon Clarke:** Dr. Clarke is a Senior Research Economist at Pacific Northwest National Laboratory’s (PNNL’s) Joint Global Change Research Institute, a collaboration the University of Maryland at College Park. Dr. Clarke conducts research on the treatment of technological change in integrated assessment models and other large-scale energy and environmental models, and on R&D strategy for climate change. Recent work includes scenario-based analyses for climate change technology planning; the impact of climate uncertainty on optimal R&D; the sources of technological advance and their incorporation into formal models; and investment decision-making under uncertainty. Dr. Clarke is a contributing author on the Working Group III contribution to the IPCC’s Fourth Assessment Report. Prior to joining PNNL, Dr. Clarke worked at Lawrence Livermore National Laboratory and as a research assistant at the Energy Modeling Forum as Stanford University. He has also worked on energy efficiency issues as an energy consultant and at Pacific Gas & Electric Company. Dr. Clarke holds a B.S. (1988) and M.S. (1990) in mechanical engineering from the University of California at Berkeley, and a M.S. (1999) and Ph.D. (2002) in Engineering-Economic Systems and Operations Research from Stanford University.

**Edward Parson:** Dr. Parson is Professor of Law and Associate Professor of Natural Resources and Environment at the University of Michigan. He conducts research on environmental policy, particularly its international dimensions; the political economy of regulation; the role of science and technology in public issues; and the analysis of negotiations, collective decisions, and conflicts. Recent projects have examined scientific and technical assessment in international policy-making; the policy implications of carbon-cycle management; the design of international market-based policy instruments; and development of policy exercises, simulation-gaming, and related novel methods for assessment and policy analysis. His recent articles have appeared in *Science*, *Climatic Change*, *Policy Sciences*, *Issues in Science and Technology*, *the Annual Review of Energy and the Environment*, and *Scientific American*. Dr. Parson served as leader of the "Environmental Trends" Project for the Government of Canada and as editor of the resulting book, Governing the Environment: Persistent Challenges, Uncertain Innovations (University of Toronto Press, tr. les Presses de l'Université de Montréal, 2001). His most recent book, Protecting the Ozone Layer: Science and Strategy was published by Oxford University Press in 2003. Dr. Parson holds a B.S. in Physics from the University of Toronto (1975), a M.S. in Management Science from the University of British Columbia (1981), and a Ph.D. in Public Policy from Harvard University (1992).

**Cynthia Rosenzweig:** Dr. Rosenzweig is a Senior Research Scientist at NASA Goddard Institute for Space Studies where she heads the Climate Impacts Group. She has organized and led large-scale interdisciplinary regional, national, and international studies of climate change impacts and adaptation. She co-led the Metropolitan East Coast Regional Assessment of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change, sponsored by the U.S. Global Change Research Program. She is a Convening Lead Author of the chapter on observed changes for the IPCC Working Group II Fourth Assessment Report, and served on the IPCC Task Group on Data and Scenarios for Impact and Climate Assessment (TGICA). Dr. Rosenzweig's research involves the development of interdisciplinary methodologies by which to assess the potential impacts of and adaptations to global environmental change. She has joined impact models with global climate models (GCMs) to predict future outcomes of both land-based and urban systems under altered climate conditions. Dr. Rosenzweig holds a B.S. degree in Agricultural Sciences from Cook College (1980); a M.S. degree in Soils and Crops from Rutgers University (1983); and a Ph.D. in Plant and Soil Sciences from the University of Massachusetts (1991).

**Virginia Burkett:** Dr. Burkett is chief of the Forest Ecology Branch at the National Wetlands Research Center of the U.S. Geological Survey, U.S. Department of Interior. She also serves as an Associate Regional Chief Biologist for the USGS Central Region. Prior to her work for the USGS, she served as Secretary/Director of the Louisiana Department of Wildlife and Fisheries (1988-90), having previously served as Deputy Director (1984-85). Dr. Burkett has published extensively on the topics of global change and low-lying coastal zones. Nominated by the U.S. Government, she was a Lead Author on the United Nation's IPCC Third Assessment Report (2001) of global climate change and its impacts on coastal and marine ecosystems and she was recently appointed as a lead author of the IPCC's Fourth Assessment report that will be published in 2007. She was a lead author of U.S. National Assessment of Climate Change and Impacts in 2001. During 2002-2004 she served as a member of the National Research Council's

Panel on River Basin and Coastal Systems Planning. In 2004, she co-authored a report published by The Wildlife Society entitled "Global Climate Change and Wildlife in North America". She is presently co-leading the CCSP assessment of potential impacts of climate change on the transportation sector in the Gulf Coast region. Dr. Burkett received her master's degree in botany from Northwestern State University (1975) and her doctoral degree in forestry from Stephen F. Austin State University (1996).

**Karen Fisher-Vanden:** Dr. Fisher-Vanden is Assistant Professor of Environmental Studies at Dartmouth College. She has held positions as a Senior Research Scientist in the Global Climate Change Group at Battelle, Pacific Northwest National Laboratories in Washington, D.C. and as an Air Quality Specialist at the South Coast Air Quality Management District (SCAQMD) in Los Angeles. Professor Fisher-Vanden is an environmental economist who has worked in the areas of economic instruments for pollution control, economic and integrated assessment modeling for climate change policy analysis, and the diffusion of efficient technologies in developing and transition economies. Currently, she is studying the effects of market reforms on structural change and technological diffusion in China and implications for energy use and greenhouse gas emissions. Professor Fisher-Vanden holds a B.S in Mathematics and a B.A in Economics both from UC Davis, a M.S. in Management Science from the Anderson Graduate School of Management at UCLA, and a Ph.D. in Public Policy from Harvard University.

**Mort Webster:** Dr. Webster is Assistant Professor of Public Policy at the University of North Carolina at Chapel Hill. His research focuses on the role of uncertainty (scientific or otherwise) in policy decisions and in the design of effective environmental policy, with a broad focus on exploring the interface between formal quantitative models and the policy process. His current focus is on two main areas within environmental policy: global climate change and local/regional air quality. His global climate change research explores methodologies for analyzing uncertainty in assessment models of global climate change so as to produce insights that are useful to the policy community, including addressing the role of learning in the future on today's decision, the effect of uncertainty on multi-stakeholder negotiations, and better means of communicating results to non-experts. Dr. Webster received a Ph.D. (2000) in Technology, Management and Policy from MIT and a B.S.E. (1988) in Computer Science and Engineering from the University of Pennsylvania.

**Linda Mearns:** Dr. Mearns is a Senior Scientist at the National Center for Atmospheric Research, Boulder, Colorado and Deputy Director of the Environmental and Societal Impacts Group (ESIG). She has performed research and published in the areas of crop-climate interactions, climate change scenario formation, climate change impacts on agro-ecosystems, and analysis of climate variability and extreme climate events in both observations and climate models. She has contributed to the Intergovernmental Panel on Climate Change (IPCC) 1992, 1995, and 2001 Reports on the subjects of climate variability in general circulation models, regional climate change, and climate scenario formation. She is a member of the IPCC Task Group on Scenarios for Climate Impact Assessment, and was co-convening Lead Author for the chapter on Climate Scenario Development in IPCC Working Group I for the IPCC Third Assessment Report (2001), and a Lead Author on two other chapters in Working Groups I and II. She served on the National Academy Panel on Climate, Ecosystems, Infectious Diseases, and Human Health, March 1999-June 2001 and currently serves on the Institute of Medicine Panel on Emerging Infectious Diseases of the 21st Century. She also leads the NCAR Weather and Climate Impacts Assessment Science Initiative. Dr. Mearns holds a M.A. and a Ph.D. in Geography from UCLA (1982, 1988), and B.A. in Philosophy from the University of Wisconsin at Madison (1971).

**David Keith:** Dr. Keith is Professor of Economics, Professor of Chemical and Petroleum Engineering, and Canada Research Chair in Energy and the Environment at the University of Calgary, Alberta; and Adjunct Professor of Engineering and Public Policy at Carnegie-Mellon University. Dr. Keith's work addresses the uncertainty in climate change predictions, geoengineering and carbon management. For more than a decade he has worked near the interface between climate science, energy technology and public policy. He has been a collaborator in research on climate related public policy at Carnegie Mellon University since 1991, and an investigator in the Center for the Integrated Study of the Human Dimensions of Global Change since its inception. Dr. Keith's current research aims to understand the economic and regulatory implications of current technologies, and to explore the technical potential of advanced technologies for managing carbon. This includes an economic analysis of carbon capture and storage in electric markets, an assessment of the risk and regulation of geological storage of $CO_2$, and engineering studies of systems that would capture $CO_2$ from the air. Dr. Keith's work also addresses hydrogen in transportation systems, wind power, biomass, and geoengineering. Dr. Keith holds a B.S. in Physics from the University of Toronto (1986) and a Ph.D. in Experimental Physics from the Massachusetts Institute of Technology (1991).