Minutes of the
Climate Change Program Product Development
Advisory Committee (CPDAC) Meeting,
August 17-18, 2006,
American Geophysical Union, Washington, D.C

CPDAC members present:

David C. Bader
Antonio J. Busalacchi, Jr.
Curtis C. Covey
James A. Edmonds
Karen Fisher-Vanden (Thursday only)
Brian P. Flannery
William J. Gutowski
David G. Hawkins
Isaac M. Held
Henry D. Jacoby
David W. Keith (Friday only)
Kenneth E. Kunkel
Richard S. Lindzen
Linda O. Mearns
Ronald L. Miller
Edward A. Parson (Friday only)
Hugh M. Pitcher (Friday only)
William A. Pizer
Soroosh Sorooshian, Vice Chair
John M. Reilly
Richard G. Richels
Cynthia E. Rosenzweig (Friday only)
Robin T. Tokmakian
Virginia R. Van Sickle-Burkett (Friday only)
Mort D. Webster
Robert M. White, Chair
Julie A. Winkler
Gary W. Yohe
Minghua H. Zhang

CPDAC member absent:

Leon E. Clarke

Also participating:

Anjuli Bamzai, Climate Change Research Division, Office of Biological and Environmental Research, Office of Science, USDOE
Jerry Elwood, Acting Director, Office of Biological and Environmental Research, USDOE
Chuck Hakkarinen, Electric Power Research Institute (retired)
John Houghton, Life and Medical Sciences Division, Office of Biological and Environmental Research, Office of Science, USDOE
Margaret Lyday, Oak Ridge Institute for Science and Education
Frederick M. O'Hara, Jr., CPDAC Recording Secretary
Bruce Warford, Oak Ridge Institute for Science and Education

About a dozen others were also in attendance during the course of the two-day meeting including Francisco de La Chesnaye, Climate Economics Branch EPA, Eric Smith Climate Economics Branch EPA, Jiayu Zhou NOAA National Weather Service, Julian Wang NOAA Research Climate Program Office, Hassan Virji START Office.

Thursday, August 17, 2006
Morning Session

Before the meeting, DOE Human Resources personnel swore in the members of the Committee. DOE General Counsel gave a talk on ethics rules and regulations. **Anjuli Bamzai** called the meeting to order at 9:58 a.m. and introduced the Chairman, **Robert White**. He asked each of the members to introduce himself or herself. **Jerry Elwood** was asked to give an overview of the charge to the Committee. He thanked the Committee for its hard and important work.

The Climate Change Science Program Product Development Advisory Committee (CPDAC) is a federal advisory committee constituted under the Federal Advisory Committee Act (FACA). Its members are appointed as experts in fields pertinent to the Committee's responsibilities. Its duties are advisory and specified in the CPDAC charter. The reports developed by CPDAC are products of the entire committee and not just of the authors of each synthesis and assessment product (SAP). Reports will be delivered to the Under Secretary for Science, Raymond Orbach, and will become public documents after review by the National Science and Technology Council (NSTC).

Its charter specifies that CPDAC will draft three specific SAPs at DOE's request and in accordance with Climate Change Science Program (CCSP) guidelines for producing such products. It will update DOE on progress toward the completion of these reports and will agree on contents of the products before advising DOE to adopt the language. And it will comply with the Information Quality Act guidelines of DOE and the Office of Management and Budget (OMB) in the development of these products. The three reports are:

- SAP 2.1.a. Scenarios of Greenhouse-Gas Emissions and Atmospheric Concentrations
- SAP 2.1.b. Global-Change Scenarios: Their Development and Use
- SAP 3.1. Climate Models: An Assessment of Strengths and Limitations for User Applications

Independent scientific judgment will be used as the guiding force. As open a process as possible will be used to provide legitimacy. Analyses are to be structured around specific questions or issues detailed in the prospectus of each product. Early and continuing involvement of stakeholders inside and outside the scientific community has been and is continuing to be sought. The explicit treatment of uncertainties is essential. There will be transparent public review of analysis questions, methods, and draft results. There will also be an independent expert review of the draft product. A flexible approach will be taken, building on lessons learned (e.g., SAP 1.1's Executive Summary was far too technical; it must be understandable to an educated layman).

Each product will be prepared, peer reviewed, and revised in the light of any comments. The draft will be reviewed by the public and revised. The draft will then be submitted by CPDAC to DOE, which will submit it to the Interagency CCSP Committee for review to determine whether any further action is needed. DOE will then submit the product to the NSTC for approval; once cleared, it will be printed and released for dissemination as a CCSP product. This is one of three options for expert review. Review by the National Research Council (NRC) is another option and was used for SAP 1.1.

The third option is an alternative approach approved by OMB and the Office of Science and Technology Policy (OSTP).

One responsibility of this advisory committee is to ensure adherence to the guidelines, ensuring and maximizing the quality, objectivity, utility, and integrity of the information disseminated by federal agencies. This guarantee requires rigorous peer review of "highly influential scientific assessments" (including all CCSP SAPs).

The peer-review process has to be documented. Peer review is conducted by nominated reviewers who are cleared by the Chief Information Officer and for conflicts of interest. Comments from and responses to reviews are posted on the Web; they are not published in the reports. The peer-review report must either summarize the views of the reviewers as a whole or provide verbatim comments of individual reviewers. A written response to peer review is required and must indicate (1) whether the authors/advisory-committee members agree with the reviewers, (2) the actions taken to address reviewers' comments, and (3) the reasons why actions satisfy key concerns (if any) about the report.

The peer-review process will address a number of questions, primarily: Are the conclusions and recommendations in the SAP adequately supported by evidence, analysis, and arguments and are uncertainties or incompleteness in evidence explicitly recognized? In addition, the reviewers must determine whether the SAP is fair, whether its tone is impartial and devoid of special pleading, and whether it is balanced in scientific viewpoints. Also, does the SAP's Executive Summary concisely and accurately describe key findings and recommendations, and is it consistent with other sections of the SAP? Finally, what other significant improvements, if any, might be made?

Covey asked if including "in press" references is all right. Elwood replied. yes. Covey asked if graphics can be redeveloped and if new conclusions can be reached. Elwood responded that graphics can be redone, but new conclusions may not be developed. The writing team can do synthesis of existing data but not introduce new data.

John Houghton was asked to review the Climate Change Science Program's SAP 2.1.a and b. This work started in 2003 and took more effort than anticipated. The Prospectus was coordinated at the Climate Change Science Program level and with the Climate Change Technology Program Office. It was decided to write SAP 2.1.a on scenarios with carbon dioxide *and other greenhouse gases*. Three modeling teams were recruited to join the process with the potential to add other teams based on the public response to the SAP 2.1.a Prospectus. The results were brought together into a report.

For SAP 2.1.b, a writing team was put together to discuss scope. The Prospectus was developed, put on the Web, and commented on. That team wrote the SAP 2.1.b report.

Hawkins asked whether the Prospectus's timeline still held true. Houghton replied, no; it is just a guideline, and extra time has been granted. Hawkins asked who was responsible for taking the input from the discussions here and altering the report. White stated that O'Hara's notes will be used to ask the writing committees to take action.

Houghton noted that public comments have been received on SAP 2.1.a and b. This Committee needs to specify what and why further changes should be made.

Mearns noted that there is some overlap in the work on scenarios for SAP 2.1.a and b and asked if these two reports could be coordinated so they are not contradictory. Houghton replied that, in an ideal world, SAP 2.1.b would have been written before SAP 2.1.a, but there was not time to do them in that sequence. Both reports will contribute to

the knowledge of how to do scenarios. They were coordinated in a variety of ways, including overlap in the authorship of the two reports.

Anjuli Bamzai was introduced to review the status of SAP 3.1. Present-day climate models include the atmosphere; land surface; vegetation; ocean; sea ice; a coupled climate; sulfate aerosols; the carbon cycle; dust, sea-spray, and carbon aerosols; interactive vegetation; and biogeochemical cycles. They will soon also incorporate the ice sheet. Now is a propitious time for assessing the strengths and limitations of those models in meeting user needs and expectations.

The Prospectus for SAP 3.1 is to include an overview that describes the topic, audience, intended use, and questions to be addressed; contact information for responsible individuals at lead and supporting agencies; the lead authors; a proposed plan for drafting, reviewing, producing, and disseminating the product; a proposed approach for evaluating and communicating uncertainty and confidence levels of climate-model outputs; the relationship of the SAP to other national and international assessment processes; and a timeline for the production of the final document. The Prospectus poses six questions:

- What are the major components and processes of the climate system that are included in present state-of-the-science climate models, and how do climate models represent these aspects of the climate system?
- How are changes in the Earth's energy balance incorporated into climate models and how sensitive is that modeled Earth's climate to changes in the factors that affect the energy balance?
- How uncertain are climate-model results and in what ways have uncertainty and model-based simulations and prediction both increased and decreased over time with increased knowledge about the climate system? [This product will *not* deal with projections.]
- How well do climate models simulate global climate variability over the historical period (1873–2000)?
- How well do climate models simulate regional climate variability and change?
- What are the trade-offs to be made in further climate-model development (e.g., between increasing spatial/temporal resolution and representing additional physical/biological processes)?

All eight lead authors are members of the newly formed CPDAC, and each brings a different spectrum of expertise. The Prospectus is final as of February 2006 and, like all background material, is available on the web at http://www.science.doe.gov/informationtechnologymgmt .

The FACA committee charged with issuing this report was formed with this meeting. The lead authors will prepare a draft framework and will make writing assignments. That draft framework is reported on later in this meeting. DOE has committed itself to releasing an online version of the report in April 2007.

Covey asked if the term "draft" on the Prospectus was outdated. Bamzai replied, yes; it is the final Prospectus now.

A break was declared at 10:59 a.m. The meeting was reconvened at 11:20 a.m., and **David Bader** was asked to outline report SAP 3.1. The lead authors have not met formally yet. A good start was made in January 2004, and the Prospectus was sent to agencies in March 2004. The process to be followed was unclear until a FACA

committee was instituted in July 2006. Two lead authors dropped out, and five new ones were added. The Prospectus was approved.

The Subcommittee developed an outline that addresses all six questions in the Prospectus. It discussed what models to talk about and focused on those on the top end, identifying how they work, how they are validated, and how they are used. The current top-end models are atmospheric global circulation models (GCMs), ocean GCMs, land-surface models, and sea-ice models. The report is also going to talk about couplings, feedbacks, and the model-development process. It will discuss control runs, idealized forcing experiments (especially climate-sensitivity tests with a doubling of CO_2), and 20th-century time-dependent forcing simulations. Topics added in response to the reviewers' comments include (1) the added value of regional models (using North America as the focus), including the design of downscaling simulations, and (2) the strengths and limitations of regional models.

These models are describing the major climate features of mean climate and 20th-century trends by representing and analyzing processes, circulation, modes of variability, extreme events, and specific North American effects (such as the North American monsoon). Because the Intergovernmental Panel on Climate Change (IPCC) has already progressed, this Subcommittee benefits from its modeling efforts. About 20 participating modeling centers are contributing work with runs on a pre-industrial control, present-day control, climate of the 20th century, SRES [Special Report on Emissions Scenarios] A2, a 1%-per-year CO_2 increase to doubling, a 1%-per-year CO_2 increase to quadrupling, and the Atmospheric Model Intercomparison Project (AMIP). There is a lot of information to work with.

In the last section in the report is a discussion of models that may be added in the next 5 years. These models deal with clouds, biogeochemistry (the uptake and release of carbon), ecosystem dynamics and dynamic vegetation (moving populations of uptakers and releasers), and surface and subsurface hydrology.

Simulations of the global ocean heat content during the 20th century vary widely. Simulations of the outgoing longwave radiation of the atmosphere are in very good agreement, and the models are tuned to get good heat balance, not to get these great results.

This report will not follow the IPCC outline, although chapters 8 (Climate Models and Their Evaluation), 9 (Understanding and Attributing Climate Change), and 11 (Regional Climate Projections) in the IPCC report are relevant to this report. The IPCC Model Output Database of the Program for Climate Model Diagnosis and Intercomparison (PCMDI) contains 174 recent papers, which will be reviewed and used.

Currently, the outline needs to be finalized (at the current meeting). Then four to six months will be required for the first draft, which will put the Subcommittee behind the schedule in the Prospectus, so it needs to get started.

Mearns asked what product SAP 3.2 was on. Bader replied, climate projections. Mearns asked what the difference between SAP 3.1 and 3.2 would be. He replied that he did not know what the discussion of uncertainty in SAP 3.2 would be, but uncertainty for the historical period in current models will be looked at in SAP 3.1. Mearns suggested that there should be some agreement on how well models represent current climate. Bader replied that all of the models could be off, but their agreement lends confidence, and the ensemble mean model outperforms any single model.

Bamzai stated that the models that will be examined in SAP 3.1 are primarily the CCSM, NASA GISS, and NOAA GFDL , and it is recognized that uncertainty needs to be assessed for each model.

White noted that the development of this report is at an early stage, and this is an opportunity to shape the contents of the report.

Hawkins said that the strengths and implications referred to in the title of this report are specifically *for user applications*. Also, an explicit discussion is needed about what these models are being compared against. These models are better tools for decision making than those being used today. Bader agreed that the comments received made it clear that the previous version focused too much on scientists and not on users. Users' interests as well as scientific uncertainty need to be propagated through these discussions. Hawkins said that another thing that should be addressed is to what extent these models make assumptions about the climate system in the next 10 years. This is a disorganized set of models. One should ask if things are really going to be the same in the future as they have been in the past.

Covey asked if a seventh section should be added to ask how good the models are. Mearns suggested that this is a real opportunity to go beyond Chapter 8 of the IPCC report. Gutowski said that Covey's comment applies more to SAP 3.2 than to SAP 3.1. Mearns suggested that there needs to be a connection between SAP 3.1 and SAP 3.2. Flannery suggested that there should be a distinction between users for decision making and users for model development.

Hawkins pointed out that the title of SAP 3.2 is about projections, and that for SAP 3.1 is about strengths and limitations. Jacoby asked if SAP 3.2 is analysis or just a literature survey. Bamzai said that the authors of SAP 3.2 intend to make climate projection runs for long- and short-lived radiatively active trace gases and aerosols.

Flannery stated that the SAP 3.1 document should clarify and highlight how the models are calibrated.

Lindzen suggested that it would be good to define the "mean" of the ensemble.

Miller pointed out that, in Section 6, ice-sheet modeling is missing. Covey added that atmospheric chemistry was missing, also. Bader cautioned that the authors have to be careful to remain within the scope.

Bamzai asked if there was any discussion of climate change, which appears in SAP 3.2. Bader replied, yes, there is such a discussion.

Sorooshian suggested that such issues might be resolved by the writing group when it gets together. Elwood suggested that one approach would be to wait until the SAP 3.2 prospectus of 3.2 is available and then see where there are overlaps and gaps and to have the CCSP Office resolve them. Bader stated that that would have to happen soon. [Bamzai checked later that evening, and found that the Draft Prospectus for SAP 3.2 was still up for public comment at the CCSP website. The public comment period ended August 28.] Bader stated that he hoped to have the outline and schedule set by the end of this meeting.

Covey said that the target audience is everyone but scientists. A discussion of how good the models are should appear at the end of the report. Zhang noted that the criteria applied would be different for scientists and decision makers. One would have to be careful in assessing how users would use criteria. Richels stated that "strengths and weaknesses for what?" has to be clarified. Lindzen noted that the discussions in SAP

2.1.a and b will color the discussions in SAP 3.1. White pointed out that SAP 3.1 will have to explain complexity. Bader cautioned that scope creep should be avoided; there are six questions already. Gutowski said that the Prospectus says that the focus should be on temperature, precipitation, and sea-level rise and asked how much wider the scope should be. Pizer said that the report should end in a more user-friendly manner than it does now.

Richels stated that there should be statements on the order of "the model is useful because … ." Input should be gotten from specialists in the fields that use the model. Flannery said that the focus should be on how good the models are for making long-range decisions.

White asked if these comments were useful. Bader replied, yes. A major problem is defining the scope. The hope is that, if one gets 180 responses, one gets a better report. It is obvious that a lot of specific definitions are missing. White offered to leave those decisions to Bader's Subcommittee.

A break for lunch was declared at 12:20 p.m.

Thursday, August 17, 2006
Afternoon Session

The meeting was called back into session at 1:15 p.m., and **Henry Jacoby** was asked to give an introduction to SAP 2.1.a. A scenario is an internally consistent story about the future and is not a best-guess forecast. It is not a one-time thing, but part of a process because conditions and needs change and one learns from results that suggest an advantage of extensions. There is value in a study that applies diverse models. Three models are used in the present study: IGSM (Massachusetts Institute of Technology), MERGE (Electric Power Research Institute), and MiniCAM (Pacific Northwest National Laboratories), which were developed with different design criteria (so they have different strengths) and which have varying assumptions (and therefore explore different future outcomes). That statement underscores two issues that recur throughout this presentation: the specification of the policy assumption and the explanation of complex model structures.

The Subcommittee started with a Prospectus that went through public review and revision and response. The next step was to do the analysis and prepare the draft report. That draft went through peer review and revision and response. It is now undergoing public review and will undergo additional revision and response as a result of that public-review process.

The Prospectus adopted four stabilization levels with six gases and radiative forcing targets. The targets were set to 450, 550, 650, or 750 ppmv CO_2, and then the analysis was run to 2100 W/m^2. The policy assumptions made reflected existing measures only through 2012 and then equal marginal cost across regions and sectors. This is not a forecast but a scenario; meaningful and plausible assumptions were made.

The models had to be able to handle a global scale with multiple regions, six greenhouse gases, and forcing; have a technical resolution of the energy sector; be economics-based; be able to do macro cost analysis; simulate to 2100; and have a track record of publication and application. Early on, it was decided to consider only the United States models because of the tight timeline. Each research group was to develop

one scenario set. The objective was to give insight into emissions, energy, and economics and to prepare an analysis, a joint report, and a data set.

The public review pointed out

- several areas of unclarity and misunderstanding (corrections have been introduced);
- a need for full presentation of a reference case (the text has been changed to specify its inclusion);
- that it is too soon to do this analysis: the science uncertainties are not resolved, and SAP 2.1.b had not yet been prepared (the product will be useful regardless of uncertainties);
- the lack of a basis to project beyond 50 years (one needs 100 years to understand the dynamics);
- the need to be more specific about the policies assumed (equal marginal cost was adopted for modeling purposes);
- the desire to add 350-ppmv and 1000-ppmv cases to the four already considered (350 is outside the model range, and 1000 does not limit);
- the need to add an analysis of aerosols (not all models can do that, and doing so would add great uncertainty);
- the desirability of adding sensitivity tests (this is beyond the scope of this effort; the objective is to develop a new set of concentrations);
- the desirability of adding a special analysis of short-lived gases (the focus is long-term stabilization; modeling teams will impose different treatments); and
- the need to require explicit model intercomparison (the report will discuss the key drivers and assumptions).

After that public review, the Subcommittee held all-team meetings in Washington, D.C., and conference calls with U.S. government officials and SAP 2.1.b representatives, the objective of which was to interpret the Prospectus, clarify details, develop common reporting protocols, decide the results that were going to be presented, decide the report structure, consider the reviews, and help decide responses. Individual teams carried out simulations. Many sets of calculations were required over a period of months. In addition, each team may prepare a separate paper. The Subcommittee developed a database for managing results, preparing figures, and public use. The report is being prepared, and writing tasks are being shared.

The predictive results are

- Radiative forcings from 2000 to 2100 are uniform across the scenarios.
- The carbon prices assumed by the different scenarios vary widely and imply that vastly different policies would have to be imposed to stabilize carbon releases, according to these three programs.
- Predicted abatement performance predicted by the models is very different after 2050.
- The models have different underlying behaviors, reflecting different understandings of the abatement technology that will be available after 2050. This difference is well within the current level of ignorance.

These results went to the peer reviewers. They requested a lot of improvements in the writing (e.g., clarification, terminology, tightened text, better descriptions of land-use components, better descriptions of electricity-sector differences, and individual model

details). In response, the text was enhanced at many points. The reviewers also requested a better description of technology cost, innovation, and technical change. The report covers the essential points of model structure, but full intercomparison is beyond the study scope. The reviewers requested the addition of a concluding chapter. This chapter was added with a summary of insights and limitations. Several reviewers requested that results on economic costs be added. Gross domestic product (GDP) results were added. The addition of a comparison with the SRES scenarios was requested. An emissions comparison was added. A sensitivity test to the key assumptions (growth, technologies, barriers to nuclear power, etc.), an uncertainty analysis, and a discussion of the role of aerosols were requested. Sensitivity testing, uncertainty analysis, and the role of aerosols are beyond the Prospectus scope. The reviewers questioned the use of forcing rather than temperature change as the stabilization metric. Forcing was specified in the Prospectus and is a good compromise.

Edmonds asked if there were any analysis of climate costs and feedback loops. Jacoby replied, no. There were things the group studied but did not report. Richel added that the group was not looking at effects on the economy; only vegetation response and feedback and CO_2 uptake by the oceans were included. Covey suggested putting in an explicit statement that this was not analyzed.

The reviewers raised a question about a policy assumption (participation and equal marginal cost) and requested sensitivity tests. A common assumption was specified in the Prospectus, but text was added on the implications of alternatives. Reviewers questioned the mitigation paths. A discussion of alternatives was added to Chapter 4. The reviewers called for a better, stand-alone Executive Summary, one oriented to the public and policymakers. A rewrite is planned, including two or three figures. A request was made for a more complete description of technology structure and cost across the models. A model intercomparison study is beyond the scope, and the requested details are in cited papers; a better summary of the key differences will be added. The reviewers suggested the addition of a comparison with other literature. This is another, major, new task, which would require detailed analysis of structure and assumptions if it were to be of value.

There is one aspect of the public review that has not been discussed by the writing teams. The Edison Electric Institute (EEI) had a number of objections to the Prospectus, including the preparation of SAP 2.1.b ahead of SAP 2.1.a and the lack of coordination between the two. It also opposed the “international” aspect of the objective, questioned the FACA role, and criticized the lack of a second stage of public review. A number of points raised by EEI were covered earlier, such as the need for agreed-upon policy assumptions and procedures, the lack of an explicit uncertainty analysis, and the technology description. Statements about the FCCC [Framework Convention on Climate Change] and U.S. policy development are being clarified and corrected.

A number of recurring issues have been raised. Among them are the policy-case assumptions. The Prospectus specifies the full participation and equal marginal cost across sectors and regions. Similar path assumptions were made by the teams with the emissions price rising over time. The modeling teams and reviewers were both concerned that results were far from any likely path, and departures will, in general, bring higher price and welfare costs. However, the model designs also omit factors that will yield lower costs (e.g., ancillary benefits and double dividends). The solution is to conduct well-structured sensitivity tests.

On the issue of technology description, there is a desire for transparent technology costing (e.g., what the cost is for a megawatt hour for an electricity source and what the cost is per ton of CO_2 saved by capture and storage). There is no simple answer in a general-equilibrium model (as opposed to a partial equilibrium over a given time and specific variability with fixed prices). A general-equilibrium model is dynamic and reactive and has feedback loops. Costs depend on model structure and endogenous and dynamic input prices. The structure differs among the three models. The challenge is that one also has a technology structure, price of coal, price of capital and labor, price of materials, place in the merit order, pace of deployment, limits on storage, and technical progress (pace of funding). All of these influences are changing with time and with developments elsewhere in the economy. The answer to a simple question is very complex. This technology-description issue could be resolved by improving the current text and cited documentation, by conducting the inter-model comparison studies or sensitivity tests (both of which are beyond the study scope), by adding a technical appendix, or by adding a box to explain the difficulty. An important point that should be made is to base more detailed description on sound scientific investigation. Casual analysis can be misleading.

The Subcommittee was pleased with the response of the reviewers. They were responsive to the Prospectus, their comments lead to a useful product, and their comments were well presented. Many helpful corrections and suggestions were received. Mainly, they expressed a desire for more explanation. Some lessons were learned along the way: The ease of communication and familiarity with other models is a great help. A central coordinator/manager is essential. A well-designed, common database is of great value; it speeds the process of comparison and presentation, helps identify errors, and provides a basis for a public data archive.

Bader pointed out the importance of aerosols in radiative forcing and asked why the models were apparently not taking these aerosol effects into consideration. Jacoby responded that some models can handle aerosols, and others cannot. There are huge uncertainties in dealing with the aerosols. This study is not the end of the process; one could take this analysis and add some aerosol effects. Reilly noted that one problem is the time mismatch. The effects of aerosols in the atmosphere can be “turned on” or “shut off” in a matter of weeks, whereas the effects of greenhouse gases are cumulative and long-lived. How to include the control of aerosols in the terms of long-term stabilization is the question. All the models have representations of short-lived gases. A clarification here is that the stabilization targets identified are only that part of forcing derived from the long-lived greenhouse gases. There are further elements of the models that deal with aerosols that the Committee did not look at. The full database can be made available. Richels said that this is the beginning of the process, not the end. Aerosols are in there. The aerosols are more important in determining temperature than in radiative forcing. Reilly stated that aerosols are more important at the top of the atmosphere; they are not as important for surface climate.

Miller suggested that it should be stated why keeping aerosols out of the discussion is useful. Scenarios are being used that are not well understood. It is hard to know why models are acting differently. The writing group should say why it went down the path that it did.

Flannery asked how one puts a price on aerosols. There are a number of challenges with aerosols, important as they are. Lindzen said that the statement that aerosols are crucial is an assumption. It is not known what they are in nature. He asked where Jacoby got his radiative forcing numbers. Jacoby replied that the radiative forcing numbers come out of the radiative code and that the Subcommittee should stick with the calculations that it has done and insert a box on aerosols to clarify the issue.

Flannery said that using only a harmonized universal carbon tax is no better than using a bifurcated one [for OECD (Organisation for Economic Cooperation and Development) vs. non-OECD]. If possible, a different assumption should be looked at, and more-recent information should be cited. It is also important to cite an indicator of difference among the models (e.g., the price of transportation fuel) at some interval(s). Jacoby noted that this is an issue that the Subcommittee has thought about a lot. It needs to find a feasible solution. If it could find three to five indicators for some specific year (that could be drawn from the existing runs), that would be important. Richels said that one does not want to use a model with unreasonable assumptions. He noted that 21 studies are going on now and asked if there was a goal to go forward in a more integrated manner. Edmonds said there is a long literature on the solution to this model-intercomparison issue. The effort was not trivial. To give the reader a notion of what is different among the models comes down to a problem of different roots and different representations of technology. That actually strengthens the study by adding a robustness to the results. The Subcommittee will continue to struggle with it.

Hawkins said that the Executive Summary needs to explain the reasons why there are different results from the three models (in terms of cost to achieve stabilization). One table (4.7) uses 1990 energy costs and a $100 carbon cost, but it is not very useful. Pizer said that some sort of assessment of the substitution of technologies is needed or made more obvious. Marginal costs versus percent abatement need to be made clearer as to why they are similar in one graph and different in the other.

Gutowski observed that the Executive Summary has a broader meaning [than does the text it summarizes] with a negative tone that needs to be corrected.

Mearns asked what is meant by “uncertainty analysis.” She asked if there had been any discussion of a probabilistic definition of stabilization. Jacoby replied that, for uncertainty analysis, one looks at the model and sees what factors affect the results. One can then develop the likelihood of different scenarios. Webster noted that there are different types of scenario exercises.

Mearns pointed out that scenarios are used for different purposes. Jacoby responded that the Subcommittee did a single case and looked at uncertainties. It could have done high, low, and medium cases. Then there would have been an elaborate uncertainty analysis required. Mearns stated that she understood that an uncertainty analysis is different from a sensitivity analysis. Richels said that what is wanted is to know the uncertainty in the long term: What are the outcomes of decisions that are made today?

Reilly said that multiple scenarios should not be used to set a probability of outcome. That would be a mistake.

A break was declared at 2:52 p.m. The meeting was reconvened at 3:08 p.m. to continue the discussion of SAP 2.1.a.

Yohe returned to the cost estimates in Graph 26. There is no reduction in climate damages cited. The numbers are therefore very dangerous. They imply there are no

damages. Jacoby replied that the Subcommittee needs to make that much clearer, especially in the Executive Summary. Yohe said that the Subcommittee has to delineate what those numbers portray. It has to be made clear that this is not a cost-benefit analysis.

Winkler said that she had read SAP 2.1.b before a, and noted that referencing back and forth might be helpful.

Sorooshian asked if there were models that *do* handle the aerosols. Jacoby replied that the models handle aerosols, but uncertainty ranges widely from model to model. Richels added that the sulfate aerosols are included in the radiative forcing calculations through concentrations.

Hawkins asked if the cases for what happens to sulfates were varied by the scenarios. Richels answered that they only vary because of other things that happen in the scenarios. It is assumed that the United States will impose constraints on aerosols and that other countries will also impose such constraints as they can. Reilly added that certain aerosol sources (e.g., open-air biomass burning) are not included. Three specific types of aerosols are in the model.

Bamzai asked if all the models ran on the same data set. Richels said that there is a misunderstanding; the different models did not operate off a single database. The *results* are in a single database. Jacoby pointed out that the output is massive. The data set will contain all the information needed and is summarized in the figures.

White asked if, in the view of the Committee, the authors did a good job writing SAP 2.1.a and responding to the two sets of reviews to date. The vote was unanimously positive. There were two abstentions. Those Committee members would like more details added to the report.

White said that the next meeting will likely be in November to look at final approval of SAP 2.1.a and b. Houghton pointed out that that task might be accomplished by telephone or e-mail. Also, if the reports were ready earlier, one would not want to wait until November to forward them to the Department of Energy (DOE). Jacoby noted that there are three groups working on these reports. Also, IPCC meetings are coming up. More time is needed to do a quality job. Early December would be a better date. Bamzai suggested putting a version on the Web and having a teleconference during the last week of November or the first week of December.

Richels asked what steps were needed to finish up. Bamzai replied that the Advisory Committee has to reach consensus that the report is acceptable, then the draft goes to DOE, and then to the NSTC for acceptance and publication. This Committee is responsible for the FACA report. The next draft should be received by the Committee members several weeks before the teleconference.

White called for other comments. He noted that the minutes of this meeting will be circulated and posted on the Web. The meeting was adjourned for the day at 3:42 p.m.

Friday, August 18, 2006
Morning Session

The meeting was called to order by Chairman White at 8:30 a.m. He had the members who were joining the Committee for the first time introduce themselves.

Bader said that the SAP 3.1 writing team had decided to add a new section. It will highlight a dozen or so applications with a paragraph each plus illustrations, to tell what

climate data those applications use, and to describe how well they do with current models.

Jacoby said that his group had decided to include added information on how aerosols develop and the roles they play.

Lindzen said that some of these models calculate temperature, and it would be good to include the effects of temperature.

Edward Parson was asked to present an introduction to SAP 2.1.b.

The Subcommittee responsible for producing SAP 2.1.b is not tasked with a review of the body of *literature* but of a body of *scenarios* and those scenarios' assumptions about inputs. Scenarios are needed to consider any long-term change. There is little scholarly research on this topic or systematic knowledge or general principles. The Subcommittee members have talked with people, have participated in exercises, and are relying on accounts of scenario use and analysis.

According to the Prospectus, SAP 2.1.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. It will also include a review of past scenario development and application efforts. It will inform the preparation and application of future scenarios by such entities as the CCSP, IPCC, Climate Change Technology Program (CCTP), and other global-change research and assessment organizations. Its intended audience includes everyone in the world having anything to do with scenarios.

The first draft was submitted for expert review on March 28, 2006. The review comments were received in May 2006. The public-comment draft was posted on June 30, 2006. The expert-review comments and author-team responses were posted on August 11, 2006. The public comment period ended on August 14, 2006.

The following definition was adopted: A scenario is a description of potential future conditions, which is developed to inform decision making under uncertainty. Two classes of activities must be distinguished from scenarios: (1) assessments, models, and decision-support activities that may use scenarios and (2) types of statements about future conditions [e.g., models or assessments or decision criteria (i.e., decision-support tools that use scenarios)], predictions, forecasts, and projections (which are often used synonymously with "scenarios" but are subtly different). Scenarios come in groups. Multiple scenarios are used to reduce uncertainty. Scenarios are conditioned and uncertain. They tend to be exogenous, the label for conditions that are needed but are not known.

The report talks about the need to identify the main focus, framing, users, and questions to be addressed. It also discusses the process of modeling, the key uncertainties to explore, and the richness and complexity of scenarios. There are four major types of scenarios in global-change applications:

- emissions scenarios, which are required for climate-model inputs and for exploring energy/economic/technology futures;
- climate scenarios (direct impacts of climate change);
- scenarios of first-order biophysical impacts; and
- multivariate scenarios for impacts, adaptation, and vulnerability assessment (these are much more challenging).

The bulk of the report is taken up by a review of major global-change scenario exercises. The first exercise was that of the IPCC. It went through three rounds and focused on SRES. It looked at 40 new scenarios of which 6 were called out. This exercise was widely praised and criticized. SRES brought with it certain challenges and controversies, such as the debate over assigning probabilities, exchange rates (market exchange rates versus purchasing power), the underdevelopment of narrative scenarios, the pitfalls associated with the risks of harmonizing scenarios and in interpreting results. It is difficult to be clear and explicit about intended uses and the involvement of users. The second exercise was the U.S. National Assessment. It had climate scenarios and socio-economic scenarios, but it failed badly. The third exercise was the Millennium Ecosystem Assessment, which had richly developed story lines with thin modeling and weak integration of qualitative and quantitative components. It ran the risk of circularity because response assumptions were embedded in the scenarios.

The Subcommittee also looked at eight other scenario activities, the most interesting of which was the Global Business Network abrupt-climate-change scenario. This model constituted the outer bound of plausibility. It was a worst-case scenario to assess security, but it was a creative piece of work.

The Subcommittee found that climate-change scenarios are principally used in assessments and policy debates and to support further modeling and assessment. Scenarios are used to frame policy and generate unforeseen uses. Scenarios in pluralistic political settings come under pressure in production and subsequent use in controversial political public debates. Scenarios are not “scientific” or “objective” activities; they must blend expert knowledge (speculation) and judgment. One can only employee the maximal transparency in regard to the process about the reasoning and assumptions, including difficulties and disagreements and weaknesses. Much analysis of scenarios has focused on scenario use in single-organization applications that tend to be very small, homogeneous, and controlled situations.

Scenarios about climate change are used primarily to support decisions. But scenarios have a big gap between applications and explicit, informed use. Many decisions are not using scenarios. The Subcommittee tried to identify who might use climate-change scenarios. It found three types of potential users:

- Impact and adaptation managers (public or private water managers, coastal-zone managers, and health officials);
- Energy-resource and technology managers; and
- National officials.

Adaptation managers must anticipate, prepare for, and respond to a threat. Their responsibilities are generally relatively narrow in time and space. Their detailed needs are highly specific but rely on a common core of emissions and global-climate-change scenarios. Their mix of needs suggests a cross-scale structure. Such decision making is the area in which scenarios are most advanced and useful for the decision makers. One problem is that socio-economic scenarios, cross-scale linkages, and multiple stresses are not just marginal effects of climate change alone.

Energy resource and technology managers are mostly in the private sector. Their decisions powerfully shape societal response. On the other hand, the major climate-related threats and opportunities they deal with are not climate change, but climate-change *policies*. Current scenario activities do not serve these decision makers at all.

Maybe it is not their job to serve these decision makers; these decision makers are competitive and in adversarial relationships and have an interest in secrecy.

National officials have the broadest responsibilities, including national mitigation, international negotiations, adaptation, and everything else. Therefore, they have the broadest information needs about the risk of climate change and impacts. The key challenge here is what social scientists call reflexivity, representing decisions in scenarios to inform decisions. In constructing scenarios, one must avoid the risks of circularity and contradiction. A basic principle is that others' decisions are treated as exogenous uncertainties; one's own decisions are explicit alternatives to analyze. In climate-change scenarios, the principal concern is mitigation assumptions. For impacts, one should incorporate a judged range of likely mitigation efforts into emission and climate-change scenarios (e.g., how high coastal defenses should be). For mitigation, the analysis should consider a wide range of baseline emission assumptions. One should not prejudge likely mitigation efforts; that would introduce circularity. The hardest problem is dealing with assumptions about mitigation by others in dealing with current decisions. One alternative is to use target-driven scenarios to support back-casting. Backward reasoning also depends on decisions by others and decisions in the future.

The greatest need is for a core set of emissions and climate-change scenarios. Present scenario capacity is limited, under-resourced, and ad hoc. An expanded capacity to produce, simulate, analyze, disseminate, evaluate, and update scenarios is necessary and merits support. Various institutional models are possible, but must have

- adequate, sustained resources;
- strong connections to outside expertise, analysis, and models;
- insulation from political control;
- maximum feasible transparency;
- a mandate to support the development of methods and models rather than just employing existing methods and models; and
- the authority to maintain effective coordination and quality control.

The core scenarios of emissions and climate change should be global in scale and have a century time horizon. They should have alternative emission baselines, alternative levels of explicit mitigation effort, and analysis of specified future targets to support back-casting and feasibility analysis. They should be based on a wide range of socio-economic futures. Some should be intercomparisons. They should include and link qualitative and quantitative components to alternative models and structures. They should connect alternative narratives to model structures, not just to parameter values. A connection between users and modelers is needed at all stages. Scenarios need internal consistency, and multiple models need to be harmonized on inputs, not outputs.

Uncertainty is represented in multiple scenarios, and model users must decide how many uncertainties to employ, what range of uncertainty to accept, and how those uncertainties are described. Scenarios should give more attention to extreme cases. The key controversy is what to do about explicit statements of probability or likelihood. This question is unresolved. Should one maintain noble science or assign probability density functions or something in between?

The main arguments *against* explicit likelihood statements include: the need to remain "equally sound," judging the validity of the reasoning only and not the likelihood; rich narratives are drawn from too complex a space to assign probabilities; probabilities

do not solve the problem, and it is better to pursue robust decisions; reflexivity; probabilities cannot be "objective"; probabilities are not of much use and just confuse users; the setting of probabilities obtrudes on the responsibilities of decision makers; and technical problems make likelihood statements too hard to integrate across sources and experts.

The main arguments *for* likelihood statements include: scenario developers must be making these judgments, and concealing them is nontransparent and irresponsible; if developers refuse to make likelihood statements, others will substitute their own less-informed probability judgments; and (a key argument) users are numerous and diverse, and some may need likelihood guidance while others may not (they can decide on their own). The Subcommittee's judgment is a cautiously favorable one. At least for some scenario exercises, there should be transparency and explicitness in uncertainties. These practices are most useful when key variables are few and quantitative and potential users are numerous and diverse. They are least useful when scenarios are rich, complex narratives; when the purpose is sensitivity analysis or heuristic exploration; and when users are few, similar, and known (modelers should be working closely with the users).

Overall, the expert reviewers were favorable on the report but critical in specific points. They pointed out definitional issues and sequelae. There was disagreement over the value of rich, narrative scenarios. More was requested about the heuristic, exploratory role of scenarios, and that was added. More was requested on explicitly normative scenarios and back-casting. The reviewers felt that scenarios were taken too seriously, so the section on what scenarios are and are not was made more explicit. They also suggested specific institutional recommendations for scenario capacity, which were respectfully declined. They made specific criticisms of the SRES treatment, stating that privileged or confidential information was used; it was not; only public documents were used. The reviewers pushed hard on the treatment of uncertainty, pointing out that there are intermediate degrees of specificity. Some reviewers objected to reflexivity and the rejection of subjective probability.

Several comments emerged from the public and Committee reviews. One was that the report does not make recommendations (which comment then went on to critique the recommendations made in the report). Objection was made to the favorable judgments about SRES. Some said that enhanced scenario capacity was not worth the resources. And objections were raised about the recommendation about explicit likelihood judgments, saying that policymakers should be assigning probabilities and that probabilities cannot be objective. The Subcommittee is working on a tactful response to these objections.

The remaining tasks facing the Subcommittee are:

- To do lots more editing to sharpen, clarify, and simplify the language and to improve the organization, especially the Conclusions and Executive Summary.
- To refine nuanced language about the key uncertainty recommendation.
- To update the discussions and to connect them to current IPCC scenarios activity.

White noted that the comments by the reviewers had been very detailed. This Committee does not need to repeat those comments. A break was declared at 9:54 a.m. The floor was opened for general discussion of SAP 2.1.b by the Committee at 10:18 a.m.

Busalacchi said that he did not understand where the three U.S. models discussed in Part a fit in with the Hadley Centre models used in Part b. There is a British program that uses a variety of models. Most models are using the SRES scenarios.

Hawkins pointed out that, in the Executive Summary, on page 11, it says that "scenarios should be global in scope and century-scale in time." That may be misinterpreted to apply to all models and needs qualification. Also, in regard to the comments calling for a more probabilistic approach, nations are often not able to respond to a threat unilaterally; rather, they assess strategic alliances with scenario analysis, which is done for these high-risk decisions without high quantification. Parson replied that national security has been the biggest user of scenarios (e.g., in war games). The set of users tends to be small in number and homogeneous, so they do not need an explicit definition of the threat.

Pizer said that the report is an incredible effort. The extent to which scenarios are used for input into another analytical process involves visions of the future. An end user cares about what happens 10 years from now and how the available options will be altered. Parson answered that the Subcommittee does not have a decisive answer for that issue. When one does not know the answer and does not know what to do, one takes refuge in process. To look back on scenarios and assess how well they worked is a small part of the answer. Waiting until one knows everything will not work.

Gutowski said that there is a disconnect among scenarios and modelers and users. There could be more substantive integration among these groups. Parson replied that, if there is a disconnect, the scenario will be useless. However, if the users are diverse and numerous, one cannot get consensus. The partial answer of the Subcommittee is a multilevel approach that addresses a core of questions. The National Assessment recognized such a need.

Edmonds asked what that "permanent capacity" suggested by the SAP 2.1.b writing team might be. Might it be integrated assessment? That could develop decision-making tools. One could have a steady scenario development. He would see the tools as useful, but was not sure that constantly changing scenarios would be helpful. Parson replied that the text refers to "sustained capacity" and is purposely not specific. It was his belief that there is not currently a good method to produce scenarios. The Subcommittee is not recommending that scenarios be generated by a free-standing office. In regard to the core emissions scenarios, the current range is too narrow. Those scenarios cannot address all the possibilities. There are possibilities beyond causal relationships. SRES started with a scenario, and then quantitative reasoning took over.

Rosenzweig stated that communication among the different aspects of the issue of global climate change needs to be far greater. National preparedness sees a need for a variety of regional scenarios; but if different assumptions are used, that hurts national preparedness. And some programs are not using scenarios at all.

Winkler had some terminology issues and asked if they could be clarified in the report (e.g., between scenarios and projections). This will be an issue in SAP 3.1 and SAP 3.2, also. Are the model results a scenario or projections? Another issue is climate change versus emissions and global climate change scenarios. Parson acknowledged that the Subcommittee struggled hard with terminology. It has not yet scrubbed the draft enough to clear up this problem. He agreed that Winkler was exactly right.

Flannery had hoped that this report would demystify scenarios. However, it often descends into heavy terminology. The Subcommittee might want to divide the use of scenarios into those considered by decision analysts and those considered by insiders. Decision makers have a reference case in their heads. Scenario writers should make a reference case of where things are going and make that explicit. There is a real merit in discussing the use of reference cases. However, using the scenario to organize the assessment becomes incestuous. Also, some large assessments are done on the basis of bad assumptions. Finally, the recommendation on capacity needs to be explained much more clearly. There are other tools (e.g., integrated assessment tools) that can be used. Scenarios are context-specific. Parson replied that those were helpful comments. The Subcommittee will try to do a better job. Capacity is addressed by dividing it between decision making and model building. The reference case is the standard model, but risk increases as one goes further into the future, and the meaning of a reference case diminishes. There is a lot more to assessments than scenarios. There is real merit to standardization. Integrated assessment is not an alternative to models; one has exogenous variables with them, also. There is not enough expertise to design an organization; however, what is known is what has not been done. The risks of wasted resources have to be thought through carefully.

Pizer noted that nothing is exempt from politics. This report needs to communicate. Standardized emission scenarios are needed. That is a communication issue. One needs to think about the germane economic issues. Higher-resolution data may be needed in the results. This is not a trivial problem.

Zhang said that one might want to refer to conditional probability in regard to scenarios. Richels replied that the Subcommittee considers uncertainty to have been resolved before the models are run. One could assume that a decision is made when, in actuality, one does not know what path is being followed when one is some way down the road. The probability of the correctness of the pathway could be reconsidered as one goes along. Parson noted that the Subcommittee has two mantras: diverse uses and transparency. An adaptive approach in which judgments are updated periodically would likely be helpful.

Keith said that there are times when people need a set of references. One can look at how people thought 25 years ago and see how little they knew. People are probably not that much better at viewing the future now.

Miller asked how one prioritizes among uncertain scenarios. Parson answered that one needs some standardized scenarios. Ultimate users ask, “What do we need to think about?” There has to be convergence between these two views.

Yohe stated that one view is that everything is so inadequate that one cannot do anything. One of the clients that is not addressed is the research community itself. It is there that an infrastructure would pay off. The emphasis on the decision maker focuses on someone who needs something else. One learns from the improvements of scenarios. Parson asked if Yohe was saying that interim decision making does not need scenarios, just adaptive ability. Yohe answered that the inability to craft scenarios cannot be allowed to cripple decision making. Parson added that this report cannot be allowed to give an excuse for delay; this Committee does not mean to do that.

Reilley said that the report raises good issues: If one creates capacity to create scenarios, does one produce separation between institutions? Do generic scenarios

separate one from the users? Parson replied that the tension is there but is not explicitly recognized. Maybe there is an emphasis on method and process. That is not what the Subcommittee has in mind. There are real tensions here that the text needs to describe better.

Keith shared Reilly's concern. A centralized office that serves everyone and therefore no one is not wanted. What is wanted is a group to focus on history, process, and pitfalls. Burkett noted that there is a tension between efficiency and specific needs of users. The National Park Service is using the National Assessment for long-range plans for several national parks. The Department of Transportation needs to know how climate change will affect a highway in California.

Flannery suggested that what is being asked for is a capacity for agencies to ask for scenarios to help in long-range planning, not an ability to construct scenarios. Parson pointed out that there are not scenarios without scenario makers. There is merit in consistency in underlying assumptions, and there needs to be transparency in the use of assumptions.

White asked if the Subcommittee was planning to revise this report. Parson answered, absolutely. These comments and suggestions have been extremely helpful. Modifications will be made accordingly.

White called for public comment. Chuck Hakkarinen observed that a good summary of key insights and recommendations is needed in SAP 3.1. The scientific community will be called upon to write scenarios and could use guidance.

White asked for the sense of the Committee about whether this was an acceptable report. A majority of the committee agreed that it is.

Houghton stated that one of the dangers that program managers face is running out of resources because good people are used time and again. In these reports, the quality of people and of the reviews has been very good. He was concerned about using up the available community resources but was pleased with the products. He was grateful for all the work that has gone into this effort.

Bamzai said that it is hoped that SAP 3.1 has a framework for writing the report. Bader expects it in January. She asked what the time frame would be for the next meeting. White said, about the first week of December, and it might be done via teleconference. Bamzai suggested that there might be another meeting needed about the end of January.

White thanked all of those present for their participation and adjourned the meeting at 11:39 a.m.

Respectfully submitted,
Frederick M. O'Hara, Jr.
Recording Secretary
Sept. 14, 2006

Corrected,
J. A. Houghton and Anjuli Bamzai
Sept. 15, 2006