BERAC Report on the

Integrated Assessment Research Program Review

Prepared by a Subcommittee of the

Biological and Environmental Research Advisory Committee

May 2007

Introduction

Over the last 15 years, the Integrated Assessment Research Program (IARP) of the Office of Biological and Environmental Research (BER) has been the principal developer of the science-based tools and intellectual resources in the U.S. for assessing the long term human influences on climate change, the risks from those changes, and the implications of policies and technology options to mitigate those changes. This has occurred in the form of core funding for two integrated modeling programs, one at the Pacific Northwest National Laboratory (PNNL) and one at the Massachusetts Institute of Technology (MIT), funding for smaller, competitive grants for individual projects, and support for the Energy Modeling Forum (EMF) headquartered at Stanford University. These activities have positively influenced the course of policy analysis and discussion by providing integrated modeling systems that consider the linkages and feedbacks between natural and economic systems. This focus on science-based integrating tools has supplemented targeted work on climate change research by others in various scientific disciplines as well as on application of these tools to particular policy questions.

Integrated assessment (IA) offers a consistent way of investigating environmental and economic implications for different climate change mitigation and technology policy options and is supported by the IARP through development of models and other tools, and data. In addition, IA can offer insights into science policy questions. For example, how should we allocate scarce research funds to improve our estimates of climate sensitivity, as opposed to allocating them to improve estimates of the effect of aerosols, or to address other climate-related uncertainties? IA modeling offers the opportunity to estimate the economic value of information concerning these and other aspects of the climate system. While economic value should not be the only consideration in allocating resources, it is one indicator to be considered by science managers.

It is hard to understate the influence of IARP on current scientific and policy thinking. The IARP models, individual projects, and EMF activities have had a significant influence on the last three assessment reports of the Intergovernmental Panel on Climate Change (IPCC), especially in Working Group III. The IARP funded work has been widely cited in these assessments, and participation by IARP researchers as IPCC authors has improved the quality of the assessments and their scientific rigor. The most obvious contributions include the model comparison projects (EMF 14, 19, and 21)[1] that have featured prominently in reviews of mitigation costs, as well as the role of IARP models in developing scenarios – both for the IPCC assessments and for policy and other scientific investigations. The development of scenarios for the next round of IPCC study is already underway, and it will again be heavily influenced by IARP-funded work.

[1] See Weyant, J.P. and J. Hill (1999). Introduction and overview, *Energy Journal (Special Issue)*; Weyant, J.P. (2004) Introduction and overview. *Energy Economics*, 26(4); Weyant, John, Francisco C. de la Chesnaye, and Geoff J. Blanford (2007). Overview of EMF-21: Multigas Mitigation and Climate Policy, *Energy Journal (Special Issue)*.

Beyond the IPCC, IARP models were the basis of the recent Climate Change Science Program (CCSP) products 2.1a and 2.1b.[2] While the IARP itself does not support policy analysis, the models supported by IARP have been regularly utilized by other agencies, the White House Council of Economic Advisers, members of Congress, and various stakeholders to better understand the environmental and economic ramifications of various policy options. In negotiations of the Kyoto Protocol and other decisions surrounding the United Nations Framework Convention on Climate Change, IARP-supported models have often provided improved information for U.S. negotiators versus that available to their foreign counterparts.

The development of IARP-supported models has also spurred the development of IA models in other countries and regions, particularly Europe and Japan. A recent trend, however, is that national government financial support for these non-U.S. models has grown to the point that it is now, even taken on a country by country basis, considerably larger than the entire IARP budget. For comparison with U.S. government funding of $3 million through the IARP, core government funding for the Tyndall Centre on Climate Change in the UK is roughly $4 million annually with total Centre funding of roughly $7 million; total funding for the Dutch IMAGE model and Japanese modeling effort are each roughly $5 million annually (based on personal communications). Since IA models must be continually revised to incorporate the latest science, it is a troubling possibility that non-U.S. models may well dominate future discussions of climate change mitigation and adaptation, not to mention negotiations for the next round of international policy, should they surpass the policy and scientific capacity of the IARP models.

In addition to the IPCC contributions noted above, it is also worth noting the critical role that the EMF and associated Snowmass workshops have played in advancing the state of IA modeling and in giving the models credibility. Organized model comparisons, where different models run the same scenarios, are a very effective method of evaluating models and determining what factors control their behaviors. Over the years, EMF has organized many of these exercises and has encouraged the open and objective evaluation of IA models. The EMF Snowmass workshops have played a complementary role. In particular, these workshops have been utilized to help keep the modelers apace with the advances in different sub-disciplines of climate science (e.g., climate modeling, ecosystems effects, carbon cycling, health effects). They also allow these experts from different sub-disciplines to learn about the IA models and to identify weaknesses. Models and their results are presented in the friendly, but skeptical environment of a broad research community; and the modelers return home informed about where they should be spending their research efforts. Finally, and most important, the workshops have spawned many new collaborations involving modelers and disciplinary experts.

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[2] See Clark, Leon, James Edmonds, Henry Jacoby, Hugh Pitcher, John Reilly, and Richard Richels (2007), *Scenarios of Greenhouse Gas Emissions and Atmospheric Concentrations: Synthesis and Assessment Product 2.1a, Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research*; Parsons, Edward A., Virginia R. Burkett, Karen Fisher-Vanden, David W. Keith, Linda O. Mearns, Hugh M. Pitcher, Cynthia E. Rosenzweig, and Mort D. Webster (2007), *Global Change Scenarios, Their Development and Use: Synthesis and Assessment Product 2.1b, Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research.*

Indeed, it is estimated that Snowmass inspired collaborations have produced more than 1000 papers for the scholarly literature.

While recognizing the high value and high impact of the IARP, the Subcommittee has identified a number of areas where even higher value and impact might be achieved. In particular:

- Improved integration of IA models with state of the art earth systems models that run on high performance computing platforms.
- Improved representation of impacts, primarily through a small (~5) set of indicators.
- Use of near-term objectives and metrics to improve both the transparency of setting near-term goals and the ability to better document progress in achieving them.
- Increased attention to validation, evaluation, and uncertainty surrounding model results.
- Near-term attention to tools for modeling practical policy implementation versus optimized, cost-effective policies (e.g., sub-global implementation, non-price policies, etc.).

Responses to the Specific Charge Questions (Appendix A)

1. *Assess the relevance of the goals and objectives of the IARP to the Climate Change Research Division's Long-Term Performance Goal of delivering improved data and models for policy makers to determine safe levels of greenhouse gases for the Earth's system. Is there a need for any changes in the scope, goals, and objectives of the program to increase its relevance to this long-term performance goal?*

The Subcommittee (Appendix B) believes the IARP scope, long-term goals, and long-term objectives are highly relevant to the Climate Change Research Division's Long-term Performance Goal of "delivering improved data and models for policy makers to determine safe levels of greenhouse gases for the Earth's system," and it feels that no changes are necessary.

2. *In what ways is the IARP advancing the state-of-the-science of integrated analysis methods and models for use in assessing the environmental costs and benefits of climate change? Are the methods and models developed in the IARP scientifically sound, and what additional research, if any, is most needed to enhance the scientific underpinning of integrated assessment methods and models?*

The Subcommittee finds that the IARP is advancing the state of the art science of integrated analysis via the usage of cutting edge reduced form earth system and economic / technology models. We believe greater interaction with the main stream climate modeling community could improve the IARP activity by keeping the IA models at the forefront of physical science modeling.

In addition, the Subcommittee also believes improved representation of ecosystem impacts should be a near-term priority. These impacts are diverse and complex, and this complexity has made it impossible to represent them adequately in IA models so far. However, we believe approaches could be developed that would enable the modelers to quantify and summarize impacts with a manageable number of indices or indicators. This might be achieved through a workshop or series of workshops that bring together experts on the ecosystem effects of climate change with IA modelers. The first step would be to identify the most important types of ecological impacts, where vulnerabilities and consequences are likely to be the greatest – similar to the upcoming IPCC Fourth Assessment Report's identification of "key vulnerabilities" in Working Group II. In addition to ecological impacts, the exercise should consider risk-based measures, such as population at risk of hunger, flooding, drought, other extreme events, the expansion of health risks, etc., as well as the likelihood of crossing critical thresholds (such as triggering a dramatic slowing of the thermo-haline circulation, the irreversible depletion of critical glaciers, the irreversible weakening of the West Antarctic ice sheet, the irreversible melting of the permafrost and release of methane, etc). The goal would be to produce a fairly small number (e.g., five) of classes of ecosystem impacts and climate related-risks. The more challenging second step would be to develop singular and comparable functions or measures for each of these five classes of impacts that are simple enough to be used in IA models yet also adequately represent the variety of potentially serious impacts in these different areas.

3. *Is the scope of the IARP sufficiently well defined with goals and near- and longterm objectives that are specific and achievable, given the current funding level for the program?*

While the Subcommittee found the scope, long-term goals, and long-term objectives to be highly relevant (see charge question 1), we found them lacking in near-term specificity. We believe the IARP would benefit from the regular development and review of more specific near-term objectives and performance metrics as part of its program management efforts (see charge question 4).

4. *Does the program have specific near-term and longer-term performance metrics or targets for measuring progress toward both the IARP goals and objectives and the long-term goal of the BER CCSP? If not, provide a set of recommendations concerning the scope, goals, and objectives of the program and its near- and longterm performance targets toward the long-term of the CCSP.*

The Subcommittee found specific near-term objectives and performance metrics lacking. We believe the IARP would benefit from the regular development and review of specific near-term objectives and performance metrics as part of its portfolio. While we provide our own specific priorities (see charge questions 2 and 6-9), we recommend two channels for regularly revisiting and revising the near-term agenda. First, the core modeling teams should be consulted annually to identify priority areas where they plan to make modeling improvements within their own core funding and areas where outside investigations

would be useful. Second, regular meetings of the modeling community in Snowmass (and elsewhere) should be used to assemble external recommendations for priority areas of work.

We recommend that these two channels be used to establish and revisit near-term objectives and performance metrics for the IARP, recognizing that additional and opportunistic activities contributing to the longer-term objectives should remain part of the portfolio. While these two channels may have been used informally in the past, we believe the program will benefit from greater transparency of the process, greater clarity of the near-term objectives and metrics, and the ability to better document progress.

5. *Is there a need for more research to develop methods and models for assessing environmental costs and benefits of climate change at local to regional scales which could then be integrated up to a national level if needed? If so, provide a set of recommendations as to the kinds of research needed and how the IARP might be configured to address the needed research.*

There is certainly a need for more research to develop methods and models for assessing climate risks and opportunities at local and regional scales (including the ability of adaptation to abate those risks and/or exploit those opportunities). However, we believe it is not in the purview of IARP modeling efforts to conduct this research, as the IARP budget is relatively small and the IARP needs to remain focused on integration and modeling at the national and global level.

Nonetheless, IA modelers are customers of this regional assessment work. Their models must be able to accommodate new knowledge generated by this research in a timely fashion, especially as the capacity for local and regional scale modeling improves. It follows that the IARP should monitor progress in this area to assure its routine and appropriate assimilation by the IA community and its appropriate incorporation into IARP sponsored tools and methods.

6. *Is the IARP effectively utilizing data, information, and models developed in other Climate Change Research Programs funded by BER, such as the climate modeling, carbon cycle, and ecosystem functioning and response research programs, to advance integrated assessment modeling? If not, what changes in the IARP does BERAC recommend to more effectively utilize such data, information, and models?*

We believe that the IARP could be better integrated with the mainline geophysically grounded earth system modeling community. The Subcommittee recommends that IARP consider activities and interactions that increase awareness of ongoing DOE and other agency research in general, and DOE Office of Science in particular. For example, the Climate modeling activity in the Scientific Discovery through Advanced Computing (SCIDAC) was discussed as a promising area of interaction, with significant climate modeling expertise that could contribute to the impact and credibility of the IARP. This particular interaction could be facilitated by targeted sessions at the Snowmass meetings.

Responding to comments that IA modeling work has been constrained by the computing power available on conventional desktop computers, we suggest that IARP activities consider taking greater advantage of current DOE activities in high performance computing. The SciDAC (Scientific Discovery through Advanced Computing) computational infrastructure, along with DOE's Office of Advanced Scientific Computing Research (ASCR) programs in high performance computing, could contribute to IARP. DOE should consider various ways its high performance computing facilities might support and accelerate IARP activities. This direction would augment such activities as risk management, extreme events prediction, critical thresholds and uncertainty analyses.

7. *Is the IARP paying sufficient attention to evaluating both the performance and utility of IA methods and models for decision support, and determining where reductions in uncertainties and improvements are most needed to enhance their reliability and utility? If not, provide a set of recommendations concerning the kinds of research the IARP should consider supporting to evaluate the performance of models and methods being developed by the program.*

The Subcommittee believes validation and evaluation of IARP model performance is important and can be improved, possibly through back-casting exercises and sensitivity analyses, continued model comparison work, and possibly other approaches (which we would encourage IARP to explore).

Integrated assessment modeling attempts to represent a large variety of atmospheric, oceanic, terrestrial and economic analyses across different sectors and regions to enable an analysis of possible futures over long time horizons. Limited economic data and the structural evolution of technological and economic conditions make it difficult to validate such models in the same way that climate models are evaluated, such as back-casting – that is, using IA model to predict historic periods for comparison to observed historic data. While such an assessment would provide one consistency check, it is not clear that it would significantly inform us about the accuracy of IA predictions about the future, given structural changes and out-of-sample conditions.

A likely more valuable method for evaluation – and one has been successfully pursued within the program – is the model comparison exercises that take place through the Stanford EMF. These activities force teams to air different model assumptions and attempt to identify those assumptions that tend to make the largest difference in future projections. Other activities ask researchers to exercise their models with a common set of background drivers – another diagnostic tool for identifying why model results differ in some cases and why they might be the same in others. This regular requirement to explain their model's behavior, especially relative to others, provides a powerful evaluation tool. We recommend continued focus in this area.

In addition to the possibility of back-casting exercises and continued support for inter-model comparisons, we recommend that specific uncertainty analysis should be

undertaken. This could be similar to the model uncertainty analyses employed by the Hadley Center Climate model: the systematic variation of model parameters with the focus of determining the most uncertain aspect of the models. Such a study could help set short term goals for model improvement, especially through the vehicle of the regular Snowmass workshops. Use of the Snowmass meetings for uncertainty discussions would have the benefit of both increasing intellectual support from, and highlighting needs to, the wider climate modeling community.

8. *Since the IARP is part of the interagency U.S. CCSP, is it appropriately focused on developing decision support tools and information relevant to the needs of the CCSP?*

One of the unquestionable successes of the IARP has been its development of relevant decision support tools. It has continually evolved with an eye to emerging policy and scientific questions. The significant financial support the IARP models receive from sources other than the IARP – sources exclusively interested in applications of the models – demonstrates the success IARP models have achieved in developing relevant decision supports tools.

Specific examples of the use of IARP models include:

- 2003 CCSP Strategic Plan
- The CCAP Human Dimensions Subcommittee work
- IPCC scenario development and assessments of the state of mitigation options research
- Work for the White House Council of Economic Advisers during the last two administrations
- Support for the CCTP
- Analyses by other agencies

Even as the IARP tools have been enormously successful in the past, policy and scientific decision support depends on continuing capacity to improve the models. The core support for these decision support tools is therefore crucial if the tools will continue to be relevant for policy applications in the future.

Further, the IARP must develop the science-based tools to answer policy-makers' questions, and so it must anticipate those questions in the near term. To that end, the Subcommittee recommends a focus on tools for modeling practical policy implementation versus optimal policies. For example, policymakers may need information about the cost of delay in implementing mitigation policies – costs expressed not only in terms of economic estimates of impacts that could have been avoided, but also in terms of the changes in the likelihoods of crossing critical thresholds of significant impacts (e.g., are certain environmental targets impractical after 10 or 15 years of business-as-usual emissions). This modeling toolkit should include the capacity to analyze policies that move too slowly, too quickly, or involve incomplete and staggered participation by the world's major emitters of greenhouse gases. A related modeling

toolkit might consider the cost of policy adjustment under various regimes as the scientific knowledge base evolves.

9. *Is the balance between funding the two large integrated assessment models and the smaller investigations appropriate?*

The Subcommittee found the balance between funding the two large IA models (and EMF) and the smaller investigations appropriate. In particular, we found that funding for the large IA models was highly leveraged, with every dollar of IARP funding yielding 2-6 dollars of outside funding (depending on how the modeling boundaries are drawn). We also found considerable evidence that the smaller investigations were yielding highly relevant results, both for the IA models and for the longer-term goals and objectives of the IARP.

We believe that the closer alignment of objectives for *some* of the smaller investigations with the needs of the two large IA models would be valuable. This could be accomplished through the regular review of near-term objectives (charge question 4) as well as encouraging the IA modeling teams to engage with teams conducting the smaller investigations (e.g., providing specifications that would ease the process of incorporating their results into the IA models). Such efforts should then be reflected in the program's regular request-for-proposals.

To the extent that additional funds become available, we believe that these additional funds should focus on expanding the smaller investigations, and particularly in ways that directly contribute to the IA modeling efforts.

Finally, we believe the IARP should leave the door open to support of another large-scale IA model, but only if a platform emerges that offers a clear and promising complement to the two existing platforms and only to the extent that funding is sufficient to avoid subtracting from support of existing activities (the two existing IA models, EMF, and the suite of smaller investigations). We believe that the possible genesis of such a platform already exists within the suite of smaller investigations.

Conclusion

The Subcommittee has found the IARP to be an extremely high value, high impact program. Nonetheless, we have identified possible areas of improvement. Among our detailed responses to particular charge questions, we have identified five themes:

- Improved integration of state of the art earth systems modeling, with particular attention to the possible use of high performance computing resources.
- Improved representation of impacts, primarily through a small set of indicators.
- Use of near-term objectives and metrics to improve both the transparency of setting near-term goals, and the ability to better document progress in meeting achieving them.
- Increased attention to validation, evaluation, and uncertainty surrounding model results.

- Near-term attention to tools for modeling practical policy implementation optimized, cost-effective policies.

In addition to these improvements, we wish to draw attention to two high-level questions that might be asked: the overall level of funding and the location of the program in the DOE Office of Science.

At a minimum, we believe the program should be restored to its original real, inflation-adjusted level of funding at inception ($3,000,000 in 1992 or roughly $4,000,000 in 2006) and continue to keep pace with inflation. We believe a case exists for increased, real levels of funding, but such a case should be based on a more detailed quantitative analysis of past grant competitions, business cases prepared by the core IA teams, and comparisons with other countries' support for IA modeling. We believe the latter concern is especially relevant for U.S. strategic interests.

We also believe that the Office of Science is the proper location for the IARP. First, better integration of physical and biological science with IA models represents the majority of our detailed recommendations (e.g., improved earth systems modeling and representation of impacts). Second, IA modeling provides an integrating framework for climate science research. While such research has tremendous value on its own merits, its value is further enhanced when it can be integrated into a model useful for decision support. Finally, the core of the IARP activity is methods development – i.e., science – and not application of those methods to specific policy questions. That the tools are then used for such analysis testifies to the activities' unquestionable usefulness, but not its need to be located in a policy or application-related office. Put another way, not only has its location in the Office of Science not been an impediment, arguably, it has promoted the IARP's success as a modeling platform grounded in science.

Appendix A – Charge Letter

Under Secretary for Science
Washington, DC 20585

August 14, 2006

Dr. Michelle S. Broido
Associate Vice Chancellor for Basic Biomedical Research,
and Director, Office of Research, Health Sciences
University of Pittsburgh
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Dear Dr. Broido:

By this letter, I am charging the Biological and Environmental Research Advisory Committee (BERAC) to convene a panel to review the Biological and Environmental Research (BER) Integrated Assessment Research Program (IARP), which is one of the Department of Energy (DOE) Climate Change Research Programs. Although the level of funding for the program has been relatively modest « $3 million per year), the IARP is unique in the portfolio of Federal programs that are part of the interagency U.S. Climate Change Science Program (CCSP). It is the only program that develops fully integrative models for use in assessing both the contributing causes and consequences of humaninduced climate change. This includes economic activities that drive emissions of greenhouse gases (GHG), the emissions that result from both anthropogenic and natural sources and their fate and effect on the Earth's clImate, and the impacts of resulting climate change on managed and unmanaged sectors. It also provides tools for assessing the implications of potential policy options for mitigating greenhouse gas emissions information at a national and international scale.

About half of the overall IARP funding is currently allocated to support the continuing development and improvement of three integrated assessment models, the Massachusetts Institute of Technology Integrated Global Systems Model and the Pacific Northwest National Laboratory Mini Climate Assessment Model (MiniCAM) and Second Generation Model (SGM). These three models are being used to address "what-if' questions about potential economic costs, benefits, and tradeoffs of alternative technology or policy options for reducing greenhouse gas emissions at a national or global scale.

The other half of the IARP funding is oriented towards individual research projects, with an emphasis on information to improve assessments of mitigation costs and benefits. Individual research projects on the development and improvement of models for assessing environI1?-ental costs and benefits of climate change itself, including the extent to which such environmental costs could be altered by different possible technology and policy options for reducing such change, has been a lower priority for the other half of the IARP.

I am specifically charging the BERAC to address the following in its review of the program:

- Assess the relevance of the goals and objectives of the IARP to the Climate Change Research Division's Long-Term Performance Goal of delivering improved data and models for policy makers to determine safe levels of greenhouse gases for the Earth's system. Is there a need for any changes in the scope, goals, and objectives of the program to increase its relevance to this long-term performance goal?
- In what ways is the IARP advancing the state-of-the-science of integrated analysis methods and models for use in assessing the environmental costs and benefits of climate change? Are the methods and models developed in the IARP scientifically sound, and what additional research, if any, is most needed to enhance the scientific underpinning of integrated assessment methods and models?
- Is the scope of the IARP sufficiently well defined with goals and near- and long-term objectives that are specific and achievable, given the current funding level for the program?
- Does the program have specific near-term and longer-term performance metrics or targets for measuring progress toward both the IARP goals and objectives and the long-term goal of the BER CCSP? If not, provide a set of recommendations concerning the scope, goals, and objectives of the program and its near- and long-term performance targets toward the long-term of the CCSP.
- Is there a need for more research to develop methods and models for assessing environmental costs and benefits of climate change at local to regional scales which could then be integrated up to a national level if needed? If so, provide a set of recommendations as to the kinds of research needed and how the IARP might be configured to address the needed research.
- Is the IARP effectively utilizing data, information, and models developed in other Climate Change Research Programs funded by BER, such as the climate modeling, carbon cycle, and ecosystem functioning and response research programs, to advance integrated assessment modeling? If not, what changes in the IARP does BERAC recommend to more effectively utilize such data, information, and models?
- Is the IARP paying sufficient attention to evaluating both the performance and utility of IA methods and models for decision support, and determining where reductions in uncertainties and improvements are most needed to enhance their reliability and utility? If not, provide a set of recommendations concerning the kinds of research the IARP should consider supporting to evaluate the performance of models and methods being developed by the program.
- Since the IARP is part of the interagency U.S. CCSP, is it appropriately focused on developing decision support tools and information relevant to the needs of the CCSP?
- Is the balance between funding the two large integrated assessment models and the smaller investigations appropriate?

I suggest you meet with Jerry Elwood and John Houghton to develop a format for the review. They can provide names of experts in integrated assessment research whom you may want to consider asking to serve on the BERAC subcommittee that conducts the review. I would like to have a report of the review from BERAC at its spring 2007 meeting.

Sincerely,

Raymond L. Orbach

Cc: Elwood, Jerry
Thomassen, David

Appendix B – Subcommittee Members

Billy Pizer, Resources for the Future
Rick Bradley, International Energy Agency, Paris, France
David Erickson, Oak Ridge National Laboratory
Joyce Penner, University of Michigan
Lou Pitelka, University of Maryland
Gary Yohe, Wesleyan University