SANDIA REPORT

SAND 2004-2888
Unlimited Release
Printed June 2004

Modelers and Policymakers: Improving the Relationships

Thomas H. Karas

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation,
a Lockheed Martin Company, for the United States Department of Energy's
National Nuclear Security Administration under Contract DE-AC04-94AL85000.

Sandia National Laboratories

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Telephone: (865)576-8401
Facsimile: (865)576-5728
E-Mail: reports@adonis.osti.gov
Online ordering: http://www.doe.gov/bridge

Available to the public from
U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Rd
Springfield, VA 22161

Telephone: (800)553-6847
Facsimile: (703)605-6900
E-Mail: orders@ntis.fedworld.gov
Online order: http://www.ntis.gov/help/ordermethods.asp?loc=7-4-0#online

SAND2004-2888
Unlimited Release
Printed June 2004

Modelers and Policymakers: Improving the Relationship

Thomas H. Karas
Advanced Concepts Group
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-0839

Abstract

On April 22 and 23, 2004, a diverse group of 14 policymakers, modelers, analysts, and scholars met with some 22 members of the Sandia National Laboratories staff to explores ways in which the relationships between modelers and policymakers in the energy and environment fields (with an emphasis on energy) could be made more productive for both. This report is not a transcription of that workshop, but draws very heavily on its proceedings. It first describes the concept of modeling, the varying ways in which models are used to support policymaking, and the institutional context for those uses. It then proposes that the goal of modelers and policymakers should be a relationship of mutual trust, built on a foundation of communication, supported by the twin pillars of policy relevance and technical credibility. The report suggests 20 guidelines to help modelers improve the relationship, followed by 10 guidelines to help policymakers toward the same goal.

Acknowledgments

The participants in Sandia workshop on Modeling and Policymaking, held at Sandia National Laboratories on April 22 and 23, 2003 are listed in Appendices I and II. This report is based upon their thoughtful contributions. Whatever you find herein that is interesting or useful should be credited to them. Whatever is irrelevant or erroneous should be attributed to the author.

Special thanks goes to the external visitors for taking the time and trouble to travel to Albuquerque to participate. They were the sine qua non of the workshop.

Contents

Modelers and Policymakers: Improving the Relationship

Executive Summary

On April 22 and 23, 2004, a diverse group of 14 policymakers, modelers, analysts, and scholars met with some 22 members of the Sandia National Laboratories staff to explores ways in which the relationships between modelers and policymakers in the energy and environment fields (with an emphasis on energy) could be made more productive for both. This report is not a transcription of that workshop, but draws very heavily on its proceedings.

A model is a representation of a physical (or social, or both) system (including objects—and possibly people—and processes) that in some way simulates the behavior of the system. Although models may be kept in the head or on paper, and mentally or hand (pencil, calculator) operated, the emphasis in this report is on models large and complex enough to require running on a computer. It is nevertheless important to keep in mind that computational models are based on human concepts about how the represented systems work, and get their data (usually) from human sources. For policymaking uses, what counts in the end is the human analysis, which may be based only in part on the outputs of the model. This report uses the term “model” as shorthand for the combined modeling and analysis activity.

Models may be used for many purposes, but this report focuses on their applications in support of public policymaking. These may include:

•Predictions for cost/benefit or cost/effectiveness analysis;
•Understanding complex relationships—and the uncertainties--in problem variables;
•Exploring a range of scenarios;
•Building a framework for discussion, group learning, or negotiation;
•Postponing difficult decisions;
•Finding a “scientific” answer to politically controversial issues;
•Building a rationale for a policy already chosen.

Models used in support of policymaking are, almost by definition, embedded in a political process. It is important for all involved to acknowledge the goals, constraints, and incentives the political context implied in each case.

In addition, it is important to recognize that modeling (along with the accompanying analyses) is likely to be just one of many inputs into the policymaking process—and perhaps only a minor one at that. Even so, modeling has the potential to enhance the process by improving understanding of the possible consequences of policy choices, deepening policymakers’ comprehension of the underlying problems and issues, clarifying decision-makers’ assumptions and values helping to build understandable narratives ("stories") in support of policy proposals, informing dialogue among stakeholders and policymakers, or providing a framework for negotiation and consensus building.

Policymakers are more likely to make use of analyses that come from modelers whom they have come to trust. By virtue of the client-specialist relationship, the burden of trust building falls primarily on the side of the modelers. They need, first of all, to communicate well with the policymakers. The policymaker trusts the modeler when the latter has shown that he or she can produce modeling and analyses that are both relevant to the former's needs and technically credible. Table 1 summarizes a set of guidelines that modelers might follow to improve their relationships with policymakers.

Table 1: 20 Guidelines for Modelers	
Guidelines for Enhancing Communication	**Guidelines for Establishing Credibility**
1. Accept the burden of effort.	12. Pay attention to reputation.
2. Understand the context.	13. Don't overreach
3. Explain Clearly.	14. Acknowledge data limitations.
4. Attempt continuing dialogue.	15. When predicting, show track record.
Guidelines for Being Relevant	16. Simpler is better.
5. Find the relevant audience.	17. Make models and analyses transparent
6. Address the purpose.	18. Include factors that audiences cares about
7. Address the salient questions.	19. Get reviews (peer and/or stakeholder)
8. Focus on the problem, not the model.	20. Compare and Collaborate
9. Don't assume the impossible.	
10. Tell a story that makes sense.	
11. Recognize time constraints.	

Although the burden of communication and trust building falls on the modelers, policymakers have an interest in getting the best products and services for their time and money. Therefore, Table 2 summarizes the report's proposed guidelines for policymakers to make the best use of modeling.

Table 2: 10 Guidelines for Policymakers	
<u>Guidelines for Improving Communication</u>	**<u>Guidelines for Getting More Credible Analyses</u>**
1. Explain the purpose.	7. Understand the limitations
2. Don’t withhold essential information.	8. Help make the data available.
3. Meet frequently	9. Get reviews.
<u>Guidelines for Getting More Relevant Analyses</u>	10. Get comparisons.
4. Involve the modelers earlier rather than later.	
5. State the issues and concerns clearly.	
6. Support capacity building.	

Introduction

What is a Model?

This report concerns the uses of models to support making decisions about public policy, particularly energy policy. But what is a "model"? Table 3 offers six definitions from various sources. No one of these alone seems satisfactory, but together they provide a collection of attributes that add up to a useful description. A model

- is a representation of a physical (or social, or both) system (including objects—and possibly people—and processes) that in some way simulates the behavior of the system;
- may consist of a mentally manipulated set of concepts, a physical system, a mathematical description, a computer program, or some combination of these;
- may analyze (or solve) a problem, increase understanding of the system it simulates, forecast future states of that system, or predict the outcomes of measures taken to change the system.

Although models may be kept in the head or on paper, and mentally or hand (pencil, calculator) operated, the emphasis in this report is on computational models—

Table 3: What is a Model? Some Definitions

A system of postulates, data, and inferences presented as a mathematical description of an entity or state of affairs.	*Merriam-Webster Online* (http://www.merriam-webster.com/)
A schematic description of a system, theory, or phenomenon that accounts for its known or inferred properties and may be used for further study of its characteristics: a model of generative grammar; a model of an atom; an economic model.	*YourDictionary.com* **(**http://www.YourDictionary.com**)**
A simplified version of something complex used, for example, to analyze and solve problems or make predictions.	*Encarta World English Dictionary* (http://www.Encarta.com)
A representation of reality used to simulate a process, understand a situation, predict an outcome, or analyze a problem. A model is structured as a set of rules and procedures, including spatial modeling tools that relate to locations on the Earth's surface.	Environmental Protection Agency, *Mid-Atlantic Integrated Assessment Glossary* (http://www.epa.gov/maia/html/glossary.html#m)
A way to represent a system for the purposes of reproducing, simplifying, analyzing, or understanding it. The standard representation in the Renewable Resource Data Center is the computer model, but models can be made of any substance such as clay, paper, abstract mathematics, or concepts.	National Renewable Energy Laboratory *Glossar,y of Solar Radiation Resource Terms* (http://rredc.nrel.gov/solar/glossary/gloss_m.html)
A representation of a set of components of a process, system, or subject area. A model is generally developed for understanding, analysis, improvement, and/or replacement of the process.	General Accounting Office, *BPR Glossary of Terms* (http://www.gao.gov/special.pubs/bprag/bprgloss.htm#sectM)

those large and complex enough to require running on a computer. It is nevertheless important to keep in mind that computational models are based on human concepts about how the represented systems work, and they get their data (usually) from human sources. Humans select the questions posed to the models and interpret the results.

How Are Models Used?[1]

Models may be used as tools to support public policy making (as well as for helping the making of decisions by non-governmental institutions), but they have other applications that do not relate directly to policymaking. Scientists may use models to increase their understanding of phenomena they are studying. Engineers may use models to design machines or structures that will perform in desired ways. Educators or trainers may use simulations to give their students the "feel" of a work environment (e.g., an airplane in flight, or a business situation). Military organizations may use simulations not only to train soldiers in the use of equipment, but to give experience in military decision-making.

As do the military, policymakers also sometimes use models to support training that gives practice or experience. Policy games (as opposed to war games) may help teach officials (and perhaps members of other organizations who interact with them) how the policy process works—who communicates to whom about what, and how decisions get made. Or, such games may increase the participants experience in dealing with difficult issues, where the focus is not on finding the "correct" policy answers, but on learning to cope with policy challenges competently and creatively.

More often, however, models are part of analytic efforts intended to improve policy decisions. "Public policy" consists (roughly) of governmental intentions, decisions, actions, laws, regulations and edicts. There are several ways in which models can be used to support public policymaking in general and energy policymaking in particular. The most obvious application is in the direct analysis and evaluation of possible policy choices. In this application, the model generates predictions about the outcomes of choices under consideration. For example, the model might predict that if legislation set a new corporate average fuel economy ("CAFE") standard at x miles per gallon of gas, then by the year 2nnn, national consumption of gasoline would be y gallons per year less than if the current standard were retained. Predictions might be made about the cost of changing the CAFE standard compared with the costs of alternative methods of achieving the same reduction in consumption (cost/effectiveness analysis.) Or, predictions might be made about both the cost of imposing the standard and the benefit of the expected reduction in consumption (cost/benefit analysis.)

Accurate predictions about the future—and about policy attempts to affect the future—would be nice to have, but can we really get them? Scholars have argued that for systems as complex as the environment, accurate predictions (especially long-term ones)

---

[1] For another review of how forecasting (with an emphasis on models) is used, see Paul. P. Craig, et. al., "What Can History Teach Us? A Retrospective Examination of Long-Term Energy Forecasts for the United States," *Annu. Rev. Energy Environ*. 2002. 27:83–118 . Available at http://arjournals.annualreviews.org/doi/pdf/10.1146/annurev.energy.27.122001.083425.

are highly unlikely.[2] When the complexities of technological change and human social, economic, political behavior are added in, achieving accurate predictions seems even more implausible. Most energy policy issues heavily involve environmental interactions, technological development, and human behavior.[3]

Even if accurate predictions are unattainable, it can still be argued that models can help policymaking in various other ways. One possible use is to increase understanding of relationships among important variables in the system of interest. Models may give policymakers an improved grasp of what goes up and what goes down, and why—even if accurate quantitative predictions are not possible. Unexpected modeling outcomes may suggest possible unintended consequences not previously considered. Sensitivity analyses may show what factors are most important: do small changes in some variables lead to big changes in desired outcomes, or do large changes in other factors have only marginal consequences? Note, though, that "understanding the relationships" still implies a degree, even if a very relaxed one, of prediction. Policymaking, after all, is about trying to affect the future: to maintain or improve on the status quo of public wellbeing. (Or even, if one is cynical about it, to maintain or advance the public official's political position.) The reason a policymaker would want to better understand the relationships relevant to some issue would be to improve his or her ability to estimate the consequences of policy decisions.

Some styles of policymaking, however, may use only a very loose form of prediction: exploration of a wide range of possible futures, without an attempt to identify the most or least probable among them. This is the idea behind the "scenario planning" method policymaking, in which organizations attempt to identify adaptive strategies that will be "robust" or "resilient" however the future turns out.[4] A team at the Rand Corporation has argued that quantitative modeling can support the scenario planning method.[5] Still, some degree of prediction is implied. Rough probability distributions of a range of possible outcomes may offer at least some reduction of the uncertainty under which decisions must be taken.

Even if models do not greatly increase policymakers' abilities to predict the future, they may at the very least improve their understanding of what is known and what is uncertain. Mental models, which all policymakers use either explicitly or implicitly, may be necessary, but they are subject to certain problems. Some (or many) of the mental modelers' assumptions about how the world works may be implicit and unexamined. The "running" of the model in policymakers' heads may or may not be internally consistent from one case to the next. The underlying reasoning leading to the policymakers'

---

[2] See, for example, Daniel Sarewitz, "Science and Environmental Policy: An Excess of Objectivity," Columbia University Center for Science, Policy, and Outcomes, at http://www.cspo.org/products/articles/excess.objectivity.html.

[3] In cases where the system modeled is (relatively) closed, predictions may be more reliable. Models have been used to reconstruct catastrophic events like airplane crashes, helping to determine causes and leading indirectly to changes in regulated hardware or procedures that seem likely to avoid such causes in the future.

[4] See the Global Business Network at http://www.gbn.org/AboutScenariosDisplayServlet.srv. On the other hand, there is only selective anecdotal evidence that the scenario planning method leads to any better outcomes (in terms of decision-makers' goals) than any other decision method. See Clare Harries, "Correspondence to what? Coherence to what? What is good scenario-based decision making?" *Technological Forecasting and Social Change* 70 (2003) 797-817.

[5] Robert J. Lempert, Steven W. Popper, Steven C. Bankes, *Shaping the Next One Hundred Years: New Methods for Quantitative, Long-Term Policy Analysis* (Santa Monica, CA: RAND Corporation, 2003), available at http://www.rand.org/cgi-bin/Abstracts/ordi/getabbydoc.pl?doc=MR-1626.

conclusions may be difficult to explain. Psychological biases and cognitive limitations may undermine the logical application of the model.[6] Building a formal model (whether in words, mathematical formulae, or computer programs), on the other hand, can ameliorate these problems. It forces identification of assumptions, specification of logical relations and procedures. The model should return the same results no matter who runs it (assuming, of course, the same inputs). At least if well documented, the model is explicable to others and examinable by others. It can provide a framework for discussion of what is known and what is not known about the system it represents.

Indeed, providing a framework for discussion can become the primary function of a model. When stakeholders and policymakers are involved in early stages of model design, development, and use, the model can become a tool by which they discuss their points of view, interests, and assumptions. Discussion of model relationships and data can give those involved a common language and focus of analysis. Sandia National Laboratories worked with The Middle Rio Grande Water Assembly (a non-governmental organization) to develop a hydrologic-ecologic-economic model of New Mexico water resources that could be used in long-term planning. The model builders concluded that

> Perhaps the most important role of the model in the planning process was in promoting, initiating, and informing dialogue. In many cases the dialogue arose simply from the process of exploring the impacts of alternative water conservation measures. Participants were naturally drawn to offer their "what if" scenarios for testing. This led to questions and discussions of the pros and cons of the different alternatives. In many cases the questions led to discussions lasting weeks and months, which often led to greater understanding and clarity. These discussions often helped participants consider the broader, system-wide implications of proposed actions.[7]

Certainly the modelers strove for at least roughly accurate prediction of the consequences of proposed policy alternatives (and appear to have achieved good "post-diction" of recent phenomena), but in any case the model permitted dialogue to be based on the best (commonly agreed) knowledge available of what the future might bring. In addition, the model could be used to educate the general public about the complexity of the water system, permitting graphical, "what-if" experimentation with the variables.

Participatory modeling can benefit those involved in building the model even when the completed model is not used as a communications framework. The very act of constructing a model requires learning, in a structured way, how the modeled system works. Thus the mental model that the participant leaves with may be more sophisticated and more reflective of the best knowledge on the subject—the analyst or policymaker becomes a more proficient expert himself.

---

[6] On biases, See Daniel Kahneman, "A Perspective on Judgment and Choice: Mapping Bounded Rationality," *American Psychologist ,(*September 2003), Vol. 58, No. 9, 697-720. On cognitive limitations, see James K. Doyle *et. al*., "Mental Models of Dynamic Systems," at http://www.wpi.edu/Academics/Depts/SSPS/Faculty/Papers/27.pdf.

[7] Howard D. Passell, et. al., *Cooperative Water Resources Modeling in the Middle Rio Grande Basin* (Albuquerque, NM: Sandia National Laboratories**),** SAND2003-3653, December 2003, at http://www.waterassembly.org/pdfs4/Modeling%20SAND%20Report%20FINAL.pdf.

The Political Dimension

A model may also contribute to the policymaking process by giving officials a clear and persuasive "story" about the course of action they propose that constituents and stakeholders accept. To give a simple example, the report of the Bush administration National Energy Policy Development Group opens with a graph derived from models forecasting U.S energy consumption through the year 2020, showing a large shortfall if U.S. energy production only continues to grow at recent rates.[8] The document then argues for (among other things) various measures to increase production.

Not only government officials, but private organizations (firms, associations, public interest groups) may use models to develop and tell a "story." Whether commissioned by a governmental or a non-governmental organization, models are at risk of being designed and used to support pre-existing conclusions. And even if they are not, their association with a particular sponsor may put them under among opposing groups. As Craig et. al. point out,

> The technical quality of an analysis does not assure impact. Energy forecasts are carried out for a variety of reasons. They are commonly released in complex, sometimes sharply polarized, political environments with contending interests, sometimes with the ruling political mindset already made up. Greenberger et. al. reviewed 14 major energy studies undertaken in 1972 to 1982.. They found 9 to be highly controversial and politicized in their execution, reception, or use…The Ford Energy Policy project, initiated in 1972 and released in 1974, called forth plaudits as well as resentment and antagonism owing to its conclusions emphasizing the need for energy conservation to be driven by regulatory measures…The Energy Research and Development Administration (ERDA) was stunned by the criticism of its first report (ERDA-48) released in 1975, which slighted conservation options and adopted a supply focus.[9]

A 1993 article by J. L. King and K.L. Kraemer goes even further, reporting that their study of the use of models in American federal policymaking found that

> …models were used because they were effective weapons in ideological, partisan, and bureaucratic warfare over fundamental issues of public policy. Those models that were most successful, as measured by the extent of their use, were those that had proven most effective in the political battles over what kinds of economic and domestic policy should be followed, whether Democrats or Republicans should get the credit, and which bureaucratic agencies would receive the power and funds to implement the policies. Successful combatants in the policy debates had to have strong models of their own, and moreover, they usually needed copies of the oppositions' models as well, in order to mount their offensive and defensive campaigns. Models in federal policy making were successful as a result of what we called "datawars" – the explicit use of model-based information in policy warfare.[10]

---

[8] http://www.whitehouse.gov/energy/Overview.pdf

[9] Op. cit. footnote 1, pp. 105-106.

[10] John L. King and Kenneth L. Kraemer, "*Models, Facts, and the Policy Process:The Political Ecology of Estimated Truth," ((*Center for Research on Information Technology and Organizations I.T. in Government ,University of California, Irvine), Paper 81, 1993, available at http://repositories.cdlib.org/crito/government/81/.

Despite this seemingly harsh finding, the authors conclude that models can still be useful because they can clarify issues in debate, enforce a discipline of analysis and discourse, and give policymakers at least some indication (whether used or not) whether a particular policy is likely to produce outcomes within an acceptable range. They point out, however, that

> Models are not much use in times of ideological upheaval, simply because the decisions are based on beliefs rather than facts. Ideological policy makers appeal to their own versions of facts, and dismiss the facts of others as falsehoods. In this way, the fundamental assumptions of policy modeling are upended.[11]

Sometimes, models may be used not to make arguments, but to avoid arguments. For example, policymakers may cast a difficult decision as one for "science" to resolve: if the model predicts that certain criteria (say, of safety or environmental impact) will be met, then the proposed actions should be taken (or not). Alternatively, uncertainties in current models may provide a reason to postpone action, either to pass difficult decisions on to later policymakers or to avoid an action altogether by continuing the postponement indefinitely.

Modeling in Context

Models and scientific and technical analysis will rarely play a decisive role in policy issues in such complex areas as energy and the environment. This is partly because a high degree of predictive certainty is almost never possible. Indeed, additional research and modeling may actually decrease political consensus, because additional conflicting perspectives and information may be developed.[12] Whether that happens or not, however, public policy decisions will be the product of many factors, including:

- consumer values and behavior;
- economic constraints;
- public opinion and electoral politics;
- stakeholder opinions and influence;
- political coalitions;
- existing laws and regulations;
- legislative politics;
- differing executive agency jurisdictions, perspectives, and interests;
- personal perspectives, biases, attitudes, and styles of decision makers;

[11] Ibid.

[12] See Sarewitz, op.cit. footnote 2

- regional differences; and
- international influences and obligations.

While policymakers may make use of models in one or more of the ways described above, society's processes for resolving conflicting values and interests are likely to remain more important. Indeed, Sarewitz argues that

> Even when science is alleged to have played a decisive role in resolving a policy dispute, as in the case of the international ban on production of chemicals that deplete stratospheric ozone, a closer look at the politics usually shows not that the science convinced policy makers to take the correct action, but that the science and the prevailing political interests fortuitously converged.[13]

Devising Guidelines for Modelers and Policymakers

Although the potential contributions of modeling (and associated analysis) may be limited, governments, foundations, universities, and companies continue to invest considerable money and effort in constructing and using models. How can the most benefit be derived from those investments? That was the primary question for the workshop. Following are some guidelines for modelers and policymakers to consider using to foster a more productive modeler/analyst-policymaker relationship.

Box 1: "Modelers" or "Analysts"?

The topic of the workshop reported here was the uses of modeling for policymaking, particularly in the area of energy policy. An important observation stressed repeatedly at the workshop was that models (whether mental or computational) are tools of analysis, and that the most important issues concern the relationship between analysts, rather than modelers, and policymakers. That certainly makes sense. However, when analysts do employ models (and here we mean more than just implicit or verbally described mental models), the analyst-policymaker relationship does take on additional features—such as the models processing much more complex and perhaps numerous scenarios than a mental operation could. Therefore, although many of the guidelines to follow would apply to analysts (or policymakers receiving analyses) whether they used models or not, several would apply only in the cases where models played a significant role. For convenience, this report will use the term "modeler" most often, even though it may be more accurately referring to "modeler-analysts" or "analysts who use models."

The larger set of recommendations is directed at the modelers (see Box 1). This is probably as it should be. First, modelers are usually providers of goods and services, while policymakers are usually customers or clients. It is generally up to the provider to attempt to meet the needs of the consumer, and not vice-versa. Moreover, the modeler's primary job is building and running the model, doing the analysis, and communicating the results to the appropriate audience. The policymaker, in contrast, is likely using the modeling and

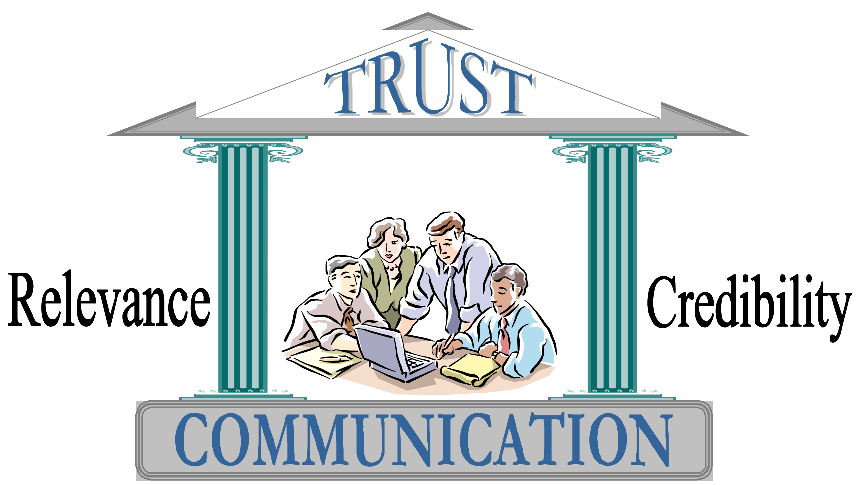
[13] Ibid.

analysis as only one input into a broader policy process (see the previous section on "Modeling in Context"). He or she has not only a much wider range of actors to deal with than just the modeler, but probably has a great many more issues to be concerned with than just those addressed by the particular modeler. It therefore behooves the modeler to take on the larger burden of the communication between the two.

Even so, it is in the interests of the policymaker to be an informed and active consumer. Doing so increases his or her chances of getting a useful product from the modeler. Therefore, this report also includes a set of guidelines for policymakers to consider as they interact with modelers.

Guidelines: Some General Concepts

The guidelines to follow were derived mainly from the insightful discussions of the workshop participants. The way in which the guidelines are presented here, however, is based on a conceptual framework illustrated in Figure 1.



• Figure 1: Trust Founded on Communication

Modeling and the analyses derived from it are more likely to have an effect on the policy process when they come from a source that the policymakers (or influential stakeholders) have come to trust. They believe that the model and analyst have dealt fairly with their values and concerns, have used good data, and have employed sound methods. A modeler's strong reputation may incline the policymaker toward trust, but a trusting relationship will likely have to be built with experience.

A pervasive theme of the workshop was the importance of good *communication* between modelers and policymakers. It is the basic requirement for building a trusting relationship, and symbolized as the foundation of trust in the figure. Communication, however, constitutes the process, rather than the substance of the relationship—the "how" rather than the "what." The two pillars in the figure—the "what"—are *relevance* and *credibility*. "Relevance" means that the policymaker gets analysis that addresses the questions that concern him or her, and gets it in a usable form. "Credibility" means that the model and associated analysis are scientifically and technically believable.

20 Guidelines for Modelers

Guidelines for Enhancing Communication

1. Accept the burden of effort.

As noted above, analyses (and the models they may be based on) are only one factor policymakers have to consider, and analysts are only one of many people with whom they interact. Policymakers have little time to think about the quality of their communication with analysts; analysts need to figure out how to communicate about their work most effectively to the policymakers. Do not be tempted to think that your work begins with building (or adapting) a model and ends with analyzing the output. If you want your work to have impact, you also need to consider communication an integral part of your work, not an afterthought.

2. Understand the context.

As noted earlier (in the section, "How Are Models Used?") models can be used in a variety of ways to support policymaking. Try to comprehend how the modeling and analysis will be used. Do homework. Ask questions. Get as clear a definition of the problem as possible (this may include helping policymakers reformulate their initial questions). Characterize what will be considered "success."

As described above (in the section on "Modeling and Context"), the policymaking process is a complex one, in which modeling and analysis play only one role, frequently a minor one. Identify the legal, political, institutional, and economic constraints under which policies must be made. Understand the role the model and analysis will play in the larger policy process—what else besides the analyses will influence the decision. Learn where the policymaker you are working sits in the process, and what he or she can or cannot affect.

3. Explain Clearly.

Policymakers need a story both that they can understand and that they can communicate to others in the policy process. This may mean a coherent narrative—"this happens, then that happens, then the result is…" Such "stories" are easier to grasp, remember, and retell than long, complex chains of reasoning interspersed with masses of data. Visualization tools—clear graphic representations of data, illustrations of processes, and metaphorical images may help.

One workshop participant suggested the "mother" test—see if you can communicate the message to an intelligent but non-expert listener. Like that listener, the policymaker probably does not want to deal with opaque jargon and obscure complexities. Remember that your job is to make the policymaker smart, not to show her how smart you are.

4. Attempt continuing dialogue.

Mutual feedback is better than an interview at the beginning and a briefing at the end. Dialogue at the beginning can clarify objectives and expectations (see Guideline 2 above). Beyond inviting the policymaker to clearly state the questions he would like answered, the modeler may be able to help reformulate the questions in ways that lead to more useful answers. Dialogue in the course of a project can give the modeler feedback about whether expectations are being met and can increase the policymaker's understanding of what is going into the model and the analysis.

In the case of a policymaker contracting for a piece of analysis, the modeler may find it difficult to get much of the policymaker's time. Try. At least ask for a knowledgeable representative with whom to meet regularly.

In some cases, the major purpose of a model is to provide a framework for discussion, mutual learning, and negotiation among a group of policymakers or stakeholders. Then, dialogue about the model may have to consume as much, or even more, of the modeler's time than the technical details of constructing and running the model.

Guidelines for Being Relevant

5. Find the relevant audience.

As one workshop participant put it, if the policymaker is going to use the modeler's work, she has to know about it first. A modeler who understands the policy context for his or her work (see Guideline 2) has a better chance of identifying the policymakers for whom it will be relevant. Publishing, speaking, and attending meetings in the field of interest should increase the chances of the policymakers hearing about the work. A policymaker may contract for a modeling job directly, or the policymaker-modeler relationship may not directly be a financial one. In either case, the modeler, to put it bluntly, needs to do market research to identify those most in need of his services and then do marketing to let the potential "customer" know how he can help.

6. Address the purpose.

Be clear about what purposes are being served. As noted above, models and analysis can serve a variety of purposes in the policymaking process. Possible purposes include:

- predictions for cost/benefit or cost/effectiveness analysis;

- understanding complex relationships—and the uncertainties—in problem variables;
- exploring a range of scenarios;
- building a framework for discussion, group learning, or negotiation;
- postponing difficult decisions;
- finding a "scientific" answer to politically controversial issues; or
- building a rationale for a policy already chosen.

It might be argued that it does not matter which of the purposes the modeler signs up for, as long as he or she shapes the work to the purpose. That is a major determinant of making it relevant to the policymaker.

Some argue, however, that modelers need to confront ethical problems shared with all those who offer scientific support to policymaking. First is the tension between science and politics; second is the resisting pressures or temptations to tailor the model and analysis to produce the desired conclusions.

Science-PoliticsTensions[14]

Most environmental and energy issues are multivariate, complex, nonlinear, and involve both physical systems and human behavior. Science seeks to increase understanding of these phenomena but is—some argue—unlikely to produce meaningful predictions that would permit controlling them. Policymakers, on the other hand, frequently want predictions that will help them build consensus on actions attempting to affect the future. The record suggests scientific prediction for policymaking, at least in the environmental area, has not been particularly successful. For example, a great deal has been spent on the research feeding the reports of the Intergovernmental Panel on Climate Change, but many uncertainties remain, as does much political controversy on what actions, if any, to take the current policy of the U.S. is to conduct further research in hopes of more conclusive predictions.

If predictions (such as those sought by policymakers attempting to conduct cost-benefit or cost-effectiveness analyses) are not really feasible, should modelers accept projects whose goal is prediction? In the 1980s, the National Acid Rain Precipitation Assessment Program was conducted with the purpose of producing findings on which to base a national program to limit the sources and ameliorate the effects of acid rain. Instead, although much scientific research was conducted, no timely policy prescriptions emerged from the program; policies were adopted without its direct input.[15]

---

[14] The argument in this sub-section is drawn from Sarewitz, op. cit. footnote 2 and from Daniel Sarewitz, Roger A. Pielke, Jr., and Radford Byerly, Jr., eds., *Prediction: Science, Decision Making, and the Future of Nature* (Washington, D.C.: Island Press, 2000). See also Roger A. Pielke, Jr., "The Role of Models in Prediction for Decision," 6 September 2001, at http://sciencepolicy.colorado.edu/admin/publication_files/2001.12.pdf.

[15] Charles Herrick, "Predictive Modeling of Acid Rain: Obstacles to Generating Useful Information," in Sarewitz, et. al., op. cit. footnote 14.

Biasing the Outcome

For perhaps all but the most mercenary modeler, tailoring a model and associated analysis to produce only the desired results would probably be ethically out of bounds. But the problem of bias may not always be starkly clear.

For example, a policymaker believes that an “honest” model will produce results that support her preferred policy position. If the modeler knows this to be the situation (or even if she does not), does producing the expected results necessarily mean that the modeler has performed in a biased or unethical way?

Any model of a real system will inevitably require simplifications, assumptions about uncertain factors and data, and focus on some questions at the expense of others. These may all introduce biases towards a particular outcome or range of outcomes. On the other hand, attempting to change them to counteract the biases may simply introduce biases in another direction.

Finally, complex environmental and energy issues will likely be subject to many uncertainties, with diversity of scientific opinion and debates about what is “true.” Whenever the results of the modeling coincide with the predilections of the sponsor, there will be the risk of suspicions of made-to-order science.

7. Address the salient questions.

Within the general purpose of a modeling study, policymakers will have specific substantive questions to be answered about the issue at hand. The elements of identifying what will be salient may be found in the guidelines above on understanding the context, engaging in continuing dialogue, finding the relevant audience, and addressing the purpose. But identifying what is salient needs to be followed by framing the modeling, analysis, and reporting to actually produce results that policymakers will be perceive as useful.

8. Focus on the problem, not the model.

Don’t let the tool become the end in itself. Provide information to help the policymaker work the problem, not to show how wonderful the model is. The danger to the modeler is to become wrapped up in the cleverness or beauty of the methodology and to lose sight of purpose and relevance. Don’t let the model you happen to have already become a hammer looking for a nail. Also recognize that sometimes a computerized model is not necessary or appropriate for the level of decision involved. Remember that it is the analysis that counts, not the model.

9. Don’t assume the impossible.

Model scenarios that stray too far from the bounds of the economically and politically feasible may result in ignored analyses. This is another reason for Guideline 2, “Understand the Context.” Conclusions that are too far from accepted wisdom may be rejected as irrelevant or not credible.

The modeler does have a dilemma here. One the one hand (unless they are merely trying to bolster their preconceived notions), policymakers do not want to waste time and money on analyses that just tell them what they already know. On the other hand, excessively unconventional findings or policy options that seem totally infeasible are likely to be dismissed—and the rest of the analysis may be dismissed along with them. An example cited at the workshop was an energy policy study that suggested the option of substantial tax increases on gasoline—a political non-starter that led to dismissal of the entire study.

10. Tell a story that makes sense.

The presentation of the model output (and other analytic efforts) should be in the form of a coherent story (that can be retold), not disjointed pieces of information. This is important not only for the sake of clear communication between modeler and policymaker (Guideline 3 above). It is also important for the policymaker's ability to communicate clearly and persuasively with other players in the policy process.

11. Recognize time constraints.

Since policy decisions are based on many inputs, with modeling being only one, a situation often arises where the best technical analysis possible within the time constraints is welcomed. Be clear from the beginning about what can and cannot be accomplished in the time allotted. Analysis that comes after decisions are made may be irrelevant or unwelcome. The modeler must carefully weigh the risks and rewards in such situations. Hasty analyses could later be characterized as faulty, damaging reputations. The modeler should consider whether the policymaker understands the limitations of the analysis and will use the analysis prudently.

Guidelines for Establishing Credibility

12. Pay attention to reputation.

Policymakers listen to those whom they trust. This trust may be based in part on past experience with the analysts, on word of mouth about them, or on their professional reputation. Obviously, it would be better if the policymaker had had previous positive experiences with the modeler, but this is not always possible—there always has to be a first time.

One way to be seen as trustworthy is to conduct processes that seem fair and aredesigned to counter bias. Openness about limitations (Guidelines 13 and 14), transparency (Guideline 17), and review processes (Guideline 19) may help.

In studies where multiple, diverse stakeholders are involved in developing the model from the beginning, those stakeholders may come to trust in the fairness of the process. If those outside the process see that diverse stakeholders were monitoring each others' input, they, too, may see the work as more credible.

On the other hand, even very scientifically sound studies are subject to being seen as biased and not credible if they have been sponsored by organizations with known interests at stake.[16] A lack of scientific consensus over the issues involved will increase the likelihood of challenges to credibility.[17] The prevailing political environment will greatly affect how this phenomenon plays out.

13. Don't overreach

Sometimes modelers try to use existing models beyond or outside the purposes for which they were designed. Even modeling carefully tailored to the purpose at hand risk omitting significant outliers that are just not quantifiable—such as high-impact, single instance events like wars or terrorist acts. Long-range forecasts are already difficult, but especially vulnerable to unpredictable outliers.

Models are by their nature distortions and simplifications of reality (otherwise they would *be* reality). Explain what is represented, what is left out, and why. Acknowledge your model's limits. Note the major simplifications. Spell out assumptions that may have a substantial impact on results. Overselling a model or concealing its limitations undermines credibility.

14. Acknowledge data limitations.

The most relevant and up-to-date data are not always available. Drawing conclusions from inadequate data risks loss of credibility. Use sensitivity and uncertainty analysis to better understand data limitations. Consider making recommendations for activities to improve the quality of important data for future uses.

15. When predicting, show track record.

When predictions (or, in weaker form, an explanation of likely trends and relationships among variables) are offered, the ability of the model (computational or mental) to explain the past lends credibility. It does so even more when it was actually used in the past to predict a future that came true. This is rare. Moreover, past results do not always indicate future performance. First, predictions may turn out to be accurate, but for the wrong reasons. If the model incorrectly simulates the underlying process, the same luck probably will not hold in the future. Second, even if the process was modeled correctly in the past, conditions in complex systems can change enough so that the same model cannot accurately predict outcomes for later periods.

As noted above (p. 10), there is a school of thought that says that predictions of complex environmental phenomena, as well as those that contain a large human behaviorial component, are not really feasible. Modelers agreeing with this position will probably not want to offer predictions in the first place. The problem is that policymakers

[16] See quotation from Craig et. al. above on page 13.

[17] Cf. William Clark et. al., "Information as Influence: How institutions mediate the impact of scientific assessments on global environmental affairs," (Cambridge, MA: John F. Kennedy School of Government, Harvard University, November 2002) Faculty Research Working Papers Series No. RWP02-044, available at http://ksgnotes1.harvard.edu/research/wpaper.nsf/rwp/.

frequently want numbers. One answer is to explain the limitations of models (see Guideline 13), then "… project rough trade-offs between competing objectives, using sensitivity and uncertainty analyses to check for robustness of conclusions."[18]

16. Simpler is better.

A large, complex, very detailed model structure with many interactions may be technically impressive, but no better at making predictions or offering insight into relationships than a simpler approach. Models with detailed data but with an overly complext structure may not be very helpful. False precision should not be confused with predictive accuracy. Masses of data may only confuse.

17. Make models and analyses transparent (having traceable conclusions).

A simpler model structure is also easier to make transparent (the opposite of a black box, whose inner workings are completely concealed from the user). Policymakers who understand how the model works may be more likely to trust the story it is used to tell. Transparency also facilitates comparisons of models with one another, which allows modelers to learn from one another by tracking differences in output to differences in assumptions, algorithms, and data. Full documentation is an important component of transparency, but also try to make the model explicable to non-experts in relatively simple terms. (At the same time, do not oversimplify or talk down to the policymaker.)

18. Include factors that audiences care about.

This is not just a matter of relevance—addressing what matters. It is also a matter of reassuring policymakers (or stakeholders) that their interests and values have been taken into account, and therefore that they can believe that the model is not biased against them. When the model building process itself is participatory (with stakeholders and policymakers involved), this kind of inclusiveness is explicit. Where only a single modeler (or modeling team) and a single policymaker are involved, they may have to draw on their understanding of the larger policy context to produce a model whose output will be seen as credible by other actors. External reviews (see Guideline 19) may help.

A risk of building models with stakeholder and policymaker participation is that the need to build consensus might lead to oversimplifications or over-weighting of some factors, possibly reducing the technical validity of the model.

19. Get reviews (peer and/or stakeholder)

"Validation" of models, in the sense of testing their predictive abilities against long-term, real-world events, is rarely possible. Other means of assuring that they are providing the best possible (even if still limited) information are necessary. For models running in software, various software engineering verification tools (systematic developer

[18] From a summary of a presentation by John Weyant, "Treatment of Uncertainty in Integrated Assessments," before a meeting at the Aspen Global Change Institute, 1996, available at http://www.agci.org/publications/eoc96/AGCIEOC96SSSII/AGCIEOC96WeyantSSSII.html.

tests, alpha tests, beta tests) can be applied. In addition, however, the modelers may seek the peer reviews, in which outside experts render opinions on the assumptions, biases, methods, and data used in the models and analysis. Affected stakeholders might also conduct reviews, which may uncover either value biases or methodological shortcomings.

20. Compare and Collaborate.

Since 1976 the Stanford Energy Modeling Forum has provided a venue for modelers and policymakers to come together to compare and contrast models addressing the same problems. The process can illuminate the structure and parameters of the models, make modeler's assumptions and biases more explicit, reveal model strengths and weaknesses, and enhance everyone's insights in to the policy issues being addressed.[19]

Policymakers do not want to be the arbiters of competing technical approaches: they are foremost interested in the policy issues, not the methodologies. However, when model comparisons can bring in policymakers as participants, the process can become a communications forum between modelers and policymakers. Both sides can appreciate the role of simplicity and transparency and the benefits of continuing dialogue. They can refine the appropriate frameworks for addressing particular issues. Finally, they can understand the underlying bases for agreements and disagreements among various parties on important issues. The least important part of the process is the detailed technical comparison of the estimates provided by the models.

10 Guidelines for Policymakers

Granted that the burden of effort in building a productive modeler-policymaker relationship is on the modelers' side, there are things policymakers can do to ease the way, and it is in their interests to do so.

Guidelines for Improving Communication

1. Explain the purpose.

If the modeler is going to tailor the modeling and analysis process to your objectives, he or she needs to know what they are. Analyses intended to produce specific predictions of policy outcomes (and you should probably be skeptical of these) will be different from those intended to explore scenario spaces or show trade-off relationships. Explain your goals for the modeling project and specify what a successful outcome will look like. This can be difficult if you do not know exactly what you want. Be prepared to engage in dialogue with the modeler to clarify things.

[19] See H.G. Huntington et. al., "Modeling for Insights, not Numbers: The experiences of the Energy Modeling Forum, "*OMEGA: THE International Journal of Management Science*, Vol. 10 No. 5 (1982), pp. 449-462.

2. Don't withhold essential information.

Give modelers what they need to know about the larger policy context in which you will be using their results. In particular, if certain assumptions are simply unacceptable, or if certain options are just beyond the pale, it is better they know sooner rather than later.

3. Meet frequently (or designate a representative who can).

Perhaps easier said than done, but if the modeler just gets an initial discussion of your objectives and then must go off and figure out how to meet them without further guidance, disappointment may follow. Moreover, continuing interactions with the modeler may help you clarify your on thinking on the subject and help refine the questions to get more useful results.

Guidelines for Getting More Relevant Analyses

4. Involve the modelers earlier rather than later.

Modelers sometimes feel that policymakers want instant answers to complex questions—and policymakers sometimes feel they are getting answers too late to be relevant to the policy process. Of course it is up to the modelers to meet their deadlines, but giving them enough time to study the problem, work it through, and develop analyses should result in a better product. Asking for instant answers to big, complicated problems will result in a worse product. Be prepared to make trade-offs between relevance and credibility if facing budget or schedule constraints.

5. State the issues and concerns clearly.

To get relevant results, explain what you see the relevant issues to be. Of course modelers and analysts are not decision-makers, but they will deliver more relevant results if they feel they can contribute something to the policy process.

6. Support capacity building.

At the workshop, this principle was jokingly phrased as "Modelers want a retainer." Finding the money to support the continuing operations of a modeling group is, no doubt, usually difficult.[20] Nevertheless, studies that draw on an up-to-date repository of substantive knowledge and modeling expertise are more likely to produce relevant analyses. In addition, this ongoing activity can be a source of "early warning" for you on trends and possibilities that you should be aware of. In contrast, only asking for—and only being willing to pay for—fast responses to urgent problems draws down intellectual capital and prevents its replenishment. A modeler at the workshop told of having been denied requested funding to study a particular issue. Two years later, the modeler was asked to provide a fast turn-around analysis on that very topic.

[20] Maintaining an in-house capability, such as the Energy Information Administration, is one solution, but the exception rather than the rule.

Guidelines for Getting More Credible Analyses

7. Understand the limitations

Demand transparency in modeling and analyses, and become familiar with the assumptions and limitations. Try explaining the assumptions and limitations to the satisfaction of the modeler(s). Ask for sensitivity analyses to show how assumptions affect outputs. Don't expect more prediction than is reasonable.

8. Help make the data available.

Sometimes the data that a modeler needs to do a credible job are difficult to come by. Or, the data is not available in formats the modeler can use. When you can bring government resources to bear on making the data available, do so. This may mean investing more in data collection, or more in "cleaning" it for modeling applications. Be willing to invest in data collection for use in future decision-making.

9. Get reviews.

Reviews of the models used by external technical experts can reveal assumptions, biases, or limitations you should know about. Reviews by external policy specialists can expose weaknesses in arguments or evidence—or can put you on firmer ground in making use of the study's results.

10. Get comparisons.

Policymakers may not often have the opportunity to put diverse modelers and analysts to work on the same problems. But at least they may be able to participate in, and perhaps join in sponsorship of, third-party efforts to carry out such comparisons. As with getting external technical reviews, such comparisons could lead to better understanding of the capabilities and limitations of the models used by the modelers they employ. Comparisons may also lead to better insight into the sensitivities of outcomes to modeled variables and into the inherent uncertainties in the problems under study.

Conclusion

Modeling can be a valuable way to bring scientific and technical knowledge to bear on problems of public policy. But for maximum value, the modelers and policymakers need to be aware not only of the technical issues they are commonly addressing, but also of the dynamics of their professional relationship. This can be especially difficult for the modelers, who may be more comfortable attending to the substance of the problems they are addressing and the tools of analysis they are applying. Nevertheless, if they want their work to have impact and contribute to the public good, they need to take on the burden of communicating and building trust with the policymakers. The policymakers, for their part, can make this process harder or easier.

Appendix I: Visiting Workshop Participants

Carl Bauer has served as Associate Laboratory Director at the National Energy Technology Laboratory (NETL) since July 1997. He heads the Office of Coal and Environmental Systems with responsibility for all of NETL's activities related to coal and environmental research, including power systems advanced research, gasification and combustion technologies, CO2 sequestration and greenhouse gas management, and environmental and water resources. Previously, he served as associate laboratory director, Office of Product Management for Environmental Management, with responsibility for development and demonstration of hazardous and radioactive waste cleanup technologies. He has more than 30 years of experience in technical and business management in both the public and private sectors. His positions at the Department of Energy headquarters have included director of the Division of Work for Others Agencies; director of the Idaho and Chicago Environmental Restoration Operations Division; acting director for the Environmental Management Office of Acquisition Management; and director of the Office of Technology Systems.

Dean Brunton is Manager of Financial Assessment with Public Service Company of New Mexico (PNM) in Albuquerque. PNM is the largest electric and natural gas utility in the State of New Mexico. PNM also has non-utility businesses including wholesale power sales in the western US. He is responsible for economic and financial analysis of capital projects and corporate strategic initiatives. Previously he was manager of the Financial Planning and Gas Supply Planning departments with responsibility for modeling utility production and financial systems. He has also served as Risk Manager for natural gas trading operations. He has an M.A. in economics from the University of New Mexico.

Stephen R. Connors is Director of Analysis Group for Regional Electricity Alternatives (AGREA) at M.I.T.'s Laboratory For Energy And The Environment (LFEE). In July 2001, he also became the coordinator of multidisciplinary research for the newly formed LFEE. In this role he has built on his expertise in integrated assessment research to develop and promote LFEE multidisciplinary research and outreach initiatives. AGREA's primary research focus is in strategic energy planning in electricity and the environment, with an emphasis on regional electric sectors. Fundamental to AGREA's approach is the use of electric sector planning tools within a multi-attribute tradeoff analysis framework. This approach automatically looks for cost-effective ways to attain multiple goals of cost-competitiveness and environmental quality, and also encourages public participation in the planning process via stakeholder interaction and input.

John J. Conti is the Director of the International, Economic and Greenhouse Gases Division of the Energy Information Administration. In this position, he is responsible for the publication of the International Energy Outlook, the Emissions of Greenhouse Gases in the United States, the Voluntary Reporting of Greenhouse Gases, major sections of the Annual Energy Outlook, and various EIA service reports. He is responsible for the macroeconomic forecasts used in the Annual Energy Outlook and the development of the System for the Analysis of Global Energy (SAGE), a model of worldwide energy supply and demand used to produce forecasts for International Energy Outlook. For the past 23 years, he has held various positions in the Energy Information Administration and Office of Policy and International Affairs. His work has focused on economic, financial and systems analysis of energy systems with special emphasis on the electric power sector. He has developed and used many energy models that the Department relies on to make energy projections. He has a Master of Science degree in management and policy sciences and an undergraduate degree in economics from the State University of New York at Stony Brook.

James K. Doyle is Associate Professor of Psychology, Social Science and Policy Studies Department, Worcester Polytechnic Institute, where he conducts research at the interface of psychology and computer modeling of social, economic, and environmental systems. He is interested in the effect of computer simulation models on learning, mental models, and decision making, the relative effectiveness of alternate knowledge elicitation techniques, the effects of group processes on model building, and public understanding and acceptance of simulation modeling. He has a B.A. in Environmental Science from the University of California at Berkeley and a Ph. D. in Social Psychology from the University of Colorado at Boulder.

Alex Farrell is Assistant Professor in the Energy and Resources Group, University of California Berkeley, where he conducts research on energy and environmental technology, economics, and policy. More specifically, he is interested in the use of technical (i.e. scientific and engineering) information in policy-making, market-based environmental regulation (i.e. emission trading), the environmental impacts of energy, the application of sustainability in decision-making, security in energy systems, and alternative transportation fuels. He has a B.S. in Systems Engineering from the U.S. Naval Academy and a Ph.D. in Energy Management and Policy from the University of Pennsylvania. His prior experience has been with Carnegie Mellon University, Harvard University, the American Association for the Advancement of Science, Air Products and Chemicals, and the U.S. Navy.

Jill Halverson has for the past six years worked in the Albuquerque office of U.S. Senator Jeff Bingaman. She serves as his lead on economic development issues with special emphasis on Science and Technology. She is the Senator's liaison to Sandia National Laboratories, the Air Force Research Lab and Kirtland Air Force Base. She also serves as the Senator's representative to ten American Indian tribes, working with tribal leadership on issues including energy and infrastructure. Previously, she served for two years as a Peace Corps Volunteer in India, founded the Downtown Women's Center (providing a day center and housing for homeless mentally ill women in Los Angeles), was Chief of Staff to a Los Angeles City Councilwoman, and served as Vice President and Manager of Community and Local Government Affairs for First Interstate Bank. She received a BA in English Literature from St. Cloud State, a Certificate in Entrepreneurial Studies from the Anderson School of Management at U.C.L.A., and an Honorary Doctorate from Loyola-Marymount University.

Hillard Huntington is Executive Director of the Stanford Energy Modeling Forum, where he conducts studies to improve the usefulness of models for understanding energy and environmental problems. His current research interests are modeling electricity competition, natural gas markets, energy price shocks, and energy market impacts of environmental policies. He was President of the United States Association for Energy Economics and Vice-President for Publications for the International Association for Energy Economics. He was also a member of the American Statistical Association's Committee on Energy Data and served on a joint USA-Russian National Academy of Sciences Panel on energy conservation research and development.

Dan Metlay is a member of the Senior Professional Staff of the U.S. Nuclear Waste Technical Review Board, an independent Federal agency charged with evaluating the technical and scientific validity of the Department of Energy's high-level radioactive waste management program. Before joining the Board, he taught organization theory and public policy at Indiana University, Bloomington, and at the Massachusetts Institute of Technology. He was a research scientist at Brookhaven National Laboratory. He served on the staff of two Secretaries of Energy: James Watkins and Hazel O'Leary. His publications include "From Tin Roof to Torn Wet Blanket: Predicting and Observing Groundwater Movement at a Proposed Nuclear Waste Site" in *Prediction: Science, Decision Making, and the Future of Nature,* D. Sarewitz, R. A. Pielke, Jr., and R. Byerly, Jr., eds; and "Institutional Trust and Confidence: A Journey into a Conceptual Quagmire. in *Social Trust and the Management of Risk*, G. Cvetkovich and R. E. Lofstedt, eds. He received his B.S. degree in molecular biology and history from the California Institute of Technology and his Ph.D. in political science and public policy from the University of California, Berkeley.

Shirley Neff is the Goldwyn International Strategies Senior Advisor for domestic energy practice and international oil, gas, and power. A nationally recognized expert in energy markets and energy policy, she served as staff economist for the Senate Energy and Natural Resources Committee from 1995-2003. She has served as an economist for the Kansas Corporation Commission, Shell Oil Company, and an electric utility holding company in New England. She is on the Advisory Board of the Institute for Energy, Law & Enterprise at the University of Houston, and she is a Vice President of the U.S. Association for Energy Economics.

Craig O'Hare is New Mexico Governor Bill Richardson's Special Assistant for Renewable Energy in the Energy, Minerals, and Natural Resources Department. He is responsible for guiding the implementation of the Governor's clean energy agenda, including: energy efficiency, renewable energy, alternative fuels, and the emerging promise of a hydrogen economy. His particular focus is on the Governor's goals of making state government a national leader in energy efficiency, meeting at least 10% of New Mexico's electricity needs with renewable sources by 2010, and promoting the construction of environmentally sound buildings through Green Building initiatives. Previously, he worked for the City of Santa Fe's Water Division for six years as the Water Programs Administrator. He was responsible for the Water Division's media relations and public outreach, water conservation and efficiency programs, and drought emergency management. He also coordinated planning efforts with the Santa Fe National Forest on restoration of the fire-prone Santa Fe Watershed. Earlier work included serving as an Executive Assistant to a Tucson (AZ) City Councilmember and addressing water management for the Arizona Department of Water Resources. He has bachelor's degrees in Business Economics and Geography from the University of California at Santa Barbara.

Alison Silverstein is Senior Energy Policy Advisor to the Chairman, Federal Energy Regulatory Commission. She has experience in the central issues involved in energy industry operations and restructuring. She was advisor to Chairman Wood when he headed the Public Utility Commission of Texas and was active in the National Association of Regulatory Utility Commissioners. During this period, the Texas Commission presided over the transformation of the state's electric industry into a sound competitive wholesale market as well as moving Texas' telecommunications industry to retail competition. She advised the Chairman on most facets of wholesale and retail market design. From 1984 to 1994, she held a number of positions with Pacific Gas & Electric Co. in San Francisco, including supervisor of information and communications services and senior communication planner. She also served as an operations research analyst with the U.S. Department of the Interior in the 1970s. She holds a master of business administration degree from Stanford University, an MSE in systems analysis and economics from The Johns Hopkins University and a bachelor of arts degree in economics from The Johns Hopkins University.

Bob Wessely is serving his third year as Chair of the Water Assembly, organizing the regional water planning effort for the Middle Rio Grande Region—Sandoval, Bernalillo and Valencia Counties. This role included coordinating and blending the interdisciplinary issues in the regional water planning situation – including the political, public, hydrological, legal, modeling and funding aspects. Prior to working in water issues, he co-founded SciSo, Incorporated in 1971 to provide expert consulting services on large scale scientific, engineering, and software systems, advising or developing systems concepts, requirements, design, implementations, testing and validation. He was responsible for business development and for the technical execution of systems engineering projects in support of commercial businesses and major government prime contractors. HIs Ph.D. is in Theoretical Solid State Physics from Rutgers University

Frances P. Wood is a Director with OnLocation, and has over twenty years of consulting experience with government and private clients. She has performed and managed numerous national energy and environmental policy analyses using integrated energy models such as IDEAS, NEMS, and POEMS. For many years she has managed assessments of DOE's energy efficiency and renewable programs using NEMS. Other policy analyses have included energy related legislative proposals and actions to reduce carbon dioxide emissions. She has participated in analyses of electricity markets that include impacts of restructuring, electricity price forecasting, transmission usage and congestion, and environmental regulations. Before joining OnLocation in 1997, she was Director of Consulting for AES Corporation. She managed studies that focused on the investment criteria and market potential for non-utility generation, energy efficiency options, and integrated resource planning. She has an A.B. from Dartmouth College and a M.S. in Engineering Economic Systems from Stanford University.

Appendix II: Sandia Workshop Participants

Arnold B. Baker is the Chief Economist. He serves as the primary strategic planning resource for the Energy & Infrastructure Assurance Business Unit, manages the Unit's economic and public policy analysis and modeling, and serves as economic and strategic planning advisor to Sandia Corporation. He is also the President Elect of the International Association for Energy Economics (2004) and former President of the United States Association (2002). He holds a BA in History and MA and Ph.D. degrees in economics from Virginia Polytechnic Institute and State University. Prior to joining SNL in 1996, he served for 17 years at Atlantic Richfield Company (ARCO), holding a number of challenging positions including Director of Political Economic Analysis, Director of Public Issues, Director of Energy Market Analysis, and Manager of Strategic Planning (ARCO Oil and Gas Company). His assignments included market analysis and scenario based planning, as well as chairing internal planning studies on the future of the oil, natural gas, coal and electricity industries. Prior to joining ARCO he served at the U.S. Department of the Treasury as Special Assistant to the Undersecretary for Monetary Affairs, and as a staff economist at the U.S. Federal Trade Commission.

David Borns is the manager of the Geotechnology and Engineering deparment. The focus of this department is the security, supply and storage of the nation's fossil energy systems. He joined Sandia in 1981 after being a graduate student and member of the research faculty at the University of Washington. At Sandia, he has worked on the monitoring and performance assessment of geologic repositories for nuclear waste and environmental remediation. Dr. Borns has additional technical expertise in remote sensing and fiber-optic sensors for monitoring applications.

Mark Boslough is a Member of the Technical Staff in the Evolutionary Computing and Agent-Based Modeling Department. His background is in physics and geophysics, with an emphasis on computational modeling. His current projects include climate model development and genetic programming for robot behavior design.

Nancy S. Brodsky is currently working within the infrastructure interdependency analysis team. She conducts studies and analyses in response to immediate needs of Dept. of Homeland Security. Research interests include applications of complexity science to infrastructure interdependencies and interrelationships between infrastructure disruptions and social response. Her previous work was primarily in laboratory rock mechanics and thermal rock properties in support of national nuclear waste isolation projects (WIPP and Yucca Mountain). B.S. in Geological Sciences, SUNY Binghamton; MS in Geology and PhD in Geophysics from Univ. of Colorado at Boulder.

Theresa Brown has, in 10 years at Sandia, specialized in the analysis and modeling of infrastructure interdependencies; systems analysis for vulnerability assessments; probabilistic performance assessment; risk assessment; hydrogeology; and numerical modeling of atmospheric, unsaturated and saturated groundwater flow and transport. Her work has focused on conceptual model development and decision-making under uncertainty, using vulnerability and risk analyses and probabilistic performance assessments. Her recent activities have included leading the Dynamic Infrastructure Interdependency Simulation and Analysis (DIISA) team's development if a National Infrastructure Interdependency Model, the Seattle and Portland Port Operations and Port Economics Simulators, the California Oil Simulator; and performing scenario analyses using those simulators for the Department of Homeland Security, Department of Energy and Department of Defense. Her Ph.D. in Geology is from the University of Wisconsin.

Peter B. Davies is the Director of the Geoscience and Environment Center with responsibility for Sandia’s geoscience capabilities work on hardened and deeply buried targets, U.S. Strategic Petroleum Reserve, fossil energy exploration/production, environmental restoration, and fundamental geoscience research. He also has responsibility for transportation capabilities in package design, testing, analysis, and risk assessment. He also serves as the coordinating Director for Sandia's Water Initiative, managing a cross-laboratory program focused on water safety, security and sustainability. Current projects in this initiative include research, development, and technical collaborations in water infrastructure security, real-time water monitoring, water treatment and desalination technology, and cooperative decision modeling. Work in this program is being extended to international settings (e.g. Jordan, Egypt, Israel) where growing tension over increasingly scarce water has high potential to undermine stability and precipitate conflict.

Charles Hanley has been working in Sandia's renewable energy programs since 1994. Previously, he led an internally-directed R&D project to develop a modeling and simulation package that projected policy decisions into the future of land use, traffic patterns, and mobile emissions in the Albuquerque region. In the renewable energy area, he managed international programs until 2002, overseeing the implementation of more than 400 remote solar and wind projects for rural uses in Mexico, Central, and South America. Since 2002, he has played a broader role in the systems-integration activities of Sandia's solar programs, principally working with the Department of Energy to develop a new multi-year technical plan and to implement the DOE's Systems-Driven Approach across the solar program.

Don Hardesty is the Deputy Director for Combustion and Industrial Technology at Sandia's Combustion Research Facility (CRF) in Livermore California. He provides programmatic leadership and line management for the CRF's applied energy research programs including Engines Combustion, Hydrogen and Combustion Technologies, and Remote Sensing and Energetic Materials. These programs address a rich customer mix including DOE, DoD, DHS, DP, NNSA, EPA and US Industry. He leads Sandia's broad initiative on Hydrogen Energy, with activities ranging from fundamental chemical and materials science of hydrogen storage, hydrogen production and energy conversion, to more applied work on engineered systems, safety, codes and standards, and systems analysis related to development of the US hydrogen infrastructure. He holds s a PhD from the Aerospace and Mechanical Sciences Dept. at Princeton University. He notes that he is, in fact, trained as a rocket scientist, should we ever need one.

Mike Hightower is a Distinguished Member of the Technical Staff in the Energy Security Center. He is a civil and environmental engineer with over 25 years experience in and research and development projects. This includes structural and geomechanics research in support of space and weapons systems, research and evaluation of innovative environmental technologies for industrial and nuclear waste treatment and cleanup, and security and protection of critical infrastructures. He supports research and development projects addressing water and energy resource sustainability and water and energy infrastructure security and protection issues and concerns. These efforts include developing novel water treatment and water monitoring technologies, developing models and techniques to improve water resource use and management, desalination and produced water treatment, impact of water availability on energy security and reliability, and water, electric power, and natural gas infrastructure security and protection. He holds Bachelor and Master degrees in civil engineering from New Mexico State University.

Scott Jones is a Principal Member of the Technical Staff in the Energy Systems Analysis Department and has assisted with organizing this workshop. After joining Sandia in 1994, he performed research and development on high-temperature solar thermal technologies. His systems analysis work has supported DOE solar program planning and technology evaluations and a National Academy of Sciences review of the technology. He is interested in improving analytical support of energy issues for policy makers and in the complex tradeoffs between energy cost, reliability, safety, security, and sustainability. He holds a Masters Degree in Mechanical Engineering from the University of Minnesota.

John E. Kelly is Deputy Director for Advanced Nuclear Energy Programs. He leads Sandia's efforts to develop advanced concepts for space nuclear power, Generation IV reactors, nuclear-assisted hydrogen generation, proliferation-resistant fuel cycles, and fusion materials. During his 24 years at Sandia, he has been engaged in a broad spectrum of nuclear reactor safety research and national security programs for DOE and NRC. In the reactor safety field, his main interests have been in thermal hydraulics, severe accidents, and probabilistic risk assessment. In the national security arena, he contributed to national efforts to assess the safety and technical viability of tritium production technologies. He also managed the development of advanced modeling and simulation tools and high-performance computing systems.

Peter H. Kobos is a Staff Economist, Office of the Chief Economist. He has a B.S. in Biology from Hobart College, a M.S. in Economics from Rensselaer Polytechnic Institute (RPI) and a Ph.D. in Ecological Economics from RPI. Previously, he served as a consultant to Sandia, and briefly with the International Institute for Applied Systems Analysis developing energy economic and policy models. His current research interests are system dynamics, energy consumption in developing countries, learning in technological innovation, and emerging technology cost parameterization.

Glenn Kuswa is a physicist who earned his Ph.D. in magnetic confinement fusion at the University of Wisconsin. He has managed or conducted research in plasma and particle beam diagnostics, particle accelerators, and inertial confinement fusion. He has led groups at Sandia on Future Options, Technology Transfer, Business Development, Laboratory Assessments, and Nuclear Weapons Surveillance. He served the Department of Energy during three two-year assignments: Program Manager in Inertial Confinement Fusion, Advisor to the Assistant Secretary of Energy for Defense Programs,; and study manager with the Secretary of Energy Advisory Board. He is author or co-author of numerous publications and presentations. His current interests center on energy production issues and related resources.

Andrew Scholand is Deputy Team Lead of N-ABLE, the NISAC (National Infrastructure Simulation and Analysis Center) Agent Based Laboratory for Economics. He, along with Team Lead Mark Ehlen, has used N-ABLE to study endogenous, market-driven adaptations to proposed policy changes, such as residential real-time pricing of electric power in California. He is particularly interested in how policy, through both first order effects and unanticipated consequences, can evolve system resilience to infrastructure disruptions. Andy has a Ph.D. in Mechanical Engineering from Georgia Tech, an M.S. in Electrical Engineering from King's College London, and a B.S. in Mechanical Engineering from Worcester Polytechic Institute.

Les Shephard is Vice President of Energy, Information, and Infrastructure. He leads Sandia's energy research programs, which include fundamental research as well as support for applied programs, such as the Yucca Mountain Project. Previously, he spent 18 years in the nuclear waste program areas at Sandia, becoming the Director of Nuclear Waste Management Programs (1995,) where he led the scientific and engineering efforts resulting in the certification of the Waste Isolation Pilot Plant (1998). He then moved to the Geoscience and Environment Center prior to becoming Executive Staff Director (2000). Most recently, he served as Director of the Stockpile Resources Center. He received a Ph.D. in Geological/Geophysical Oceanography from Texas A&M University, an M.S. in Geological/Geophysical Oceanography from Texas A&M University, and a B.S. in Geology from the State University of New York.

Marjorie (Margie) L. Tatro is Director of the Energy, Infrastructure and Knowledge Systems Center, where she leads a group of approximately 260 people working to make the nation's energy and air transportation systems safer, more secure, and more reliable. She is responsible for a portfolio of programs that include a $12M fossil energy program, a $40M renewable and energy storage program, and $5M of infrastructure programs (energy and transportation). She holds BS and MS degrees in mechanical engineering, and has been at Sandia since 1985, working in renewable energy research, facilities design, software design, and energy reliability groups. She is a member of the Central New Mexico Section of the Society of Women Engineers, as well as the American Society of Mechanical Engineers, and has served on the Board of Directors of the New Mexico Engineering Foundation.

Steve Thomas is manager of the Computational Sciences and Mathematics Research Department in Livermore, California, and manager for energy systems analysis with Sandia's hydrogen energy program. His interests include developing the systems science base for long-term planning and policy analysis for national energy security. Special interests include: simulation-enabled robust analysis and planning; hydrogen technology R&D investment and future energy infrastructure adaptability; and electric power grid bottlenecks and reliability. Steve's career in engineering systems R&D includes several years each at AT&T Bell Labs and Mobil (Oil) Research. He holds a Ph.D. in computer science, and degrees in engineering science and electrical engineering.

Vincent Tidwell is a Principal Member of the Technical Staff in the Geohydrology Department. He is engaged in several technology development projects focused on water resource development and management. Working with local, state and federal water management teams, he is developing a decision support model aimed at engaging the public in the water planning process. He is also exploring the use of Time Domain Reflectometery as a novel means of measuring stream stage, channel depth, and salinity in real-time on perennial and ephemeral streams. He is also developing modeling tools to evaluate the security risk posed to water distribution systems and optimization technologies to prioritize mitigation strategies. Finally, he is involved with volunteer agencies striving to bring safe drinking water to the poor in developing countries.

Craig E. Tyner is currently manager of the Geothermal Research Department at Sandia National Laboratories, overseeing Sandia's geothermal drilling and related programs. From 2002 to 2004, he managed the Solar Programs Department, including Sandia's Photovoltaics, Concentrating Solar Power (CSP), and Solar Buildings Programs, and serving as a member of the Department of Energy's solar management team. He previously worked in the Concentrating Solar Power Program from 1985 to 2002, conducting research in various areas of power tower, solar detoxification, and solar chemistry technology (including solar thermochemical hydrogen research) before moving in 1989 to management positions overseeing those activities. From 1995 to 2002, he served as the director of the SunLab (Sandia/NREL virtual laboratory overseeing implementation of the CSP program for DOE) management team, coordinating SunLab's technology development, planning, and program implementation activities. He has a Bachelor's degree in chemical engineering from the California Institute of Technology and Master's and Ph.D. degrees in the same field from the University of Illinois.

Paul Veers has worked in wind energy technology at Sandia National Laboratories since joining the Labs in 1980, first on the analysis and durability of wind turbine structures, and then on opportunities for cost of energy reduction. He has conducted research on various aspects of wind systems including atmospheric turbulence simulation, fatigue analysis, structural reliability, aeroelastic tailoring, and the evaluation of design safety factors. He has managed the Wind Energy Technology Department at Sandia since March 2003, and with the National Renewable Energy Laboratory is part of the U.S. Wind Program Laboratory Management Team. He is the Chief Editor for Wind Energy, an international journal for progress and applications in wind power published by John Wiley and Sons, Chichester, England, and is a past Associate Editor for the Journal of Solar Energy Engineering, Transactions of the ASME.

John B. Whitley is a Nuclear Engineer, receiving his B.S. Degree at Kansas State University and his M.S. and Ph.D. at the University of Wisconsin. His career at Sandia has included research and development of high heat flux materials and components for magnetic fusion devices such as Tokamaks; helping develop a science education outreach program for Sandia; and managing an information systems group that supported, among other things, a knowledge management program. Shortly after the terrorist's attacks of 9/11, he moved to the Advanced Concepts Group (ACG), which was concentrating on counter-terrorism studies. His focus areas have been on Radiological Dispersal Devices (dirty bombs), information systems for crisis and consequence management, on processes to help the intelligence community "connect the dots," and on enhancing human cognition. His other areas of interest include asymmetric warfare (terrorism); nuclear energy issues; the impact and direction of Information Technologies; and resource issues such as energy, food and water.

Gerold Yonas is Principal Scientist and Vice President. He joined Sandia National Laboratories in 1972, and initiated and directed the particle beam fusion program and the particle beam weapon program. In 1983, he chaired of the Directed Energy Weapon Panel of the "Fletcher" study that formed the basis for the Strategic Defense Initiative (SDI) Program. He later served as the first Chief Scientist and Acting Deputy

Director for the Strategic Defense Initiative Organization (SDIO). In 1986, he became President of Titan Technologies. He rejoined Sandia in 1989 as Director of Laboratory Development, then became Vice President of Systems Applications, where he focused on strategic leadership in new initiatives in global surveillance, battlefield sensors, and nonnuclear high precision weapons. In 1995, he became VP of Systems, Science, and Technology; in 1999, he became Principal Scientist and initiated Sandia's Advanced Concepts Group (ACG), the co-sponsor of this workshop. The ACG investigates potential contributions that Sandia National Laboratories might make to solving long-range problems that impact national and global security.

Distribution:

Carl Bauer
National Energy Technology Laboratory
3610 Collins Ferry Road
Morgantown, WV 25507-0880

Dean Brunton
Public Service Co. of New Mexico
Alvarado Square MS-2812
Albuquerque, NM

Stephen Connors
Massachussetts Institute of Technology
Laboratory for Energy and the Environment
One Amherst St, Rm E40-465
Cambridge, MA 02139-4307

John J. Conti
EI-81, Room 2F081
1000 Independence Ave SW
Washington, DC 20585

James K. Doyle
Worcester Polytechnic Institute
Social Science and Policy Studies Dept
100 Institute Road
Worchester, MA 01609

Alexander Farrell
University of California – Berkeley
310 Barrows Hall #3050
Berkeley, CA 94720-3050

Jill Halverson
625 Silver SW, Ste 130
Albuquerque, NM 87102

Hilliard Huntington
Stanford University, Energy Modeling Forum
450 Terman Center
Stanford, CA 94305-4026

Daniel Metlay
US Nuclear Waste Technical Review Board
2300 Clarendon Blvd, Suite 1300
Arlington, VA 22201

Shirley Neff
Goldwyn International Strategies
1325 19th Street NW #303
Washington, DC 20005

Craig O'Hare
NM Energy Department
1220 S. St. Francis Drive
Santa Fe, NM 87505

Allison Silverstein
Federal Energy Regulatory Commission
888 First Street NE, CH-1
Washington, DC 20426

Robert Wessely
Middle Rio Grande Water Assembly
303 Camino de San Francisco
Placitas, NM 87043

Frances Wood, Senior Consultant
OnLocation, Inc.
501 Church Street, Suite 300
Vienna, VA 22180

MS0318	Mark Boslough, 9216
MS0451	Andrew Scholand, 6221
MS0451	Theresa Brown, 6222
MS0701	Peter Davies, 6100
MS0703	Glenn Kuswa, 2900
MS0706	David Borns, 6113
MS0708	Max Valdez, 6202
MS0708	Paul Veers, 6214
MS0708	Scott Jones, 6202
MS0710	Mike Hightower, 6202
MS0724	Les Shephard, 6000
MS0727	John Kelly, 6870
MS0735	Vince Tidwell, 6115
MS0741	Margie Tatro, 6200
MS0749	Arnold Baker, 6010
MS0749	Peter Kobos, 6010
MS0753	Charles Hanley, 6216
MS0753	Connie Brooks, 6216
MS0778	Nancy Brodsky, 6222
MS0839	Gerry Yonas, 16000
MS0839	Jessica Turnley, 16000
MS0839	John Whitley, 16000
MS0839	Judy Moore, 16000
MS0839	Simon Goldfine, 16000
MS0839	Tom Karas, 16000
MS9041	Ron Stoltz, 12122
MS9054	Don Hardesty, 8360
MS9217	Steve Thomas, 8962
MS9018	Central Technical Files, 8945-1
MS0899	Technical Library, 9616(2)