NATURAL RESOURCES JOURNAL

Volume 46
Issue 3 *Summer*

Summer 2006

Seeing Clearly: Making Decisions under Conditions on Scientific Controversy and Incomplete and Uncertain Scientific Information

Ann Clarke

ANN CLARKE*

Seeing Clearly: Making Decisions under Conditions of Scientific Controversy and Incomplete and Uncertain Scientific Information

INTRODUCTION

In the first part of the twentieth century, the environment was viewed as a closed mechanistic system in equilibrium.[1] Congress established many of the federal agencies or their predecessors on the Progressive Utilitarian premise of scientific management by professionals in their respective fields of jurisdiction.[2] The potentially affected public had little opportunity to question agency decision making. By the mid-twentieth century, scientists had begun to conceive of the environment less as a mechanistic system that people could manipulate, and more as a complex, dynamic, multi-scale, and open system of which people were a part.[3] After World War II, and in the wake of nuclear devastation, the public became more wary of the potential impacts of science and technology, and Congress began opening agency decision-making processes to public review by enacting such statutes as the Administrative Procedures Act (APA).[4]

---

* The author is Chair, Environment, Energy, and Natural Resources Law Section, Federal Bar Association, Washington, D.C. However, this article is written in her personal capacity and, unless specifically noted, should not be interpreted as representing the views, opinions, or positions of the section, the association, or any agency the author has worked for either as an employee or a consultant.

1. Beth C. Bryant, *"Forensic Fisheries Science": Literature Review and Research Suggestions*, 66 MARINE FISHERIES REV. 1, 7 (2004); RICHARD J. LAZARUS, THE MAKING OF ENVIRONMENTAL LAW 8, 215 (2004). *See also* ALDO LEOPOLD, A SAND COUNTY ALMANAC AND SKETCHES HERE AND THERE 201, 214-20 (*The Land Ethic*) (1949). Among other accomplishments, Leopold founded the field of wildlife ecology and sought to infuse federal agency land management decision-making processes with scientific information about wildlife. *See* Who Was Aldo Leopold..., Aldo Leopold Wilderness Research Institute, http://leopold.wilderness.net/aboutus/aldo.htm (last visited Dec. 14, 2006).

2. *See generally* Samuel P. Hays, *Conservation and the Gospel of Efficiency: The Progressive Conservation Movement, 1890-1920*, HARV. HIST. MONOGRAPHS (Univ. Pittsburgh Press, 1999) (1959).

3. Bryant, *supra* note 1, at 7; LAZARUS, *supra* note 1; LEOPOLD, *supra* note 1.

4. Administrative Procedures Act of 1946, 5 U.S.C. §§ 551-59 (Administrative procedures), §§ 701-06 (Judicial review), § 1305 (Administrative law judges), § 3344 (Details, administrative law judges), § 5372 (Administrative law judges), § 7521 (Actions against administrative law judges). For additional information on the APA, see ADMINISTRATIVE CONFERENCE OF THE UNITED STATES, A GUIDE TO FEDERAL AGENCY

Later, amid growing public concern about environmental quality and on the eve of the first Earth Day, Congress enacted the National Environmental Policy Act (NEPA).[5] Lynton K. Caldwell, Staff Consultant to the Senate Committee on Interior and Insular Affairs on a National Policy for the Environment, 1968–1970, and one of the authors of NEPA, noted that "science has been a driving force behind the environmental movement."[6] In NEPA, Congress set forth a national environmental policy, goals, and procedures, including directing agencies to "[u]tilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decisionmaking which may have an impact on man's environment."[7] Congress in Title I of NEPA directed agencies to use an interdisciplinary approach[8] to conduct studies[9] and impact analyses[10] that employ the natural and social sciences,[11] including, for example, ecological science.[12] Further, Congress directed agencies to assure the scientific integrity of their information,[13] disclose their analyses, consult with expert agencies, and allow public comment[14] prior to making decisions[15] and with the intent of improving agency decisions and environmental quality.[16]

RULEMAKING (2d ed. 1991). In 1995, Congress authorized funding to terminate the Administrative Conference of the United States (ACUS), Pub. L. No. 104-52, title IV, 109 Stat. 480, 480 (Nov. 19, 1995). In the Federal Regulatory Improvement Act of 2004, Pub. L. No. 108-401, 118 Stat. 2255 (2004), Congress authorized funding for the Administrative Conference of the United States (ACUS) for two years and amended section 591 of Title 5, U.S.C. to state that the purpose of ACUS is to reduce litigation and improve the use of science in rulemaking. *See also* LAZARUS, *supra* note 1, at 58, 60, 81; SUSAN JASANOFF, SCIENCE AT THE BAR: LAW, SCIENCE AND TECHNOLOGY IN AMERICA 69 (1995).

5. National Environmental Policy Act of 1969, 42 U.S.C. §§ 4321–4347; Pub. L. No. 91-190, 83 Stat. 852 (1970), as amended by Pub. L. No. 94-52, 89 Stat. 258 (1975), Pub. L. No. 94-83, 89 Stat. 424 (1975), and Pub. L. No. 97-258, § 4(b), 96 Stat. 1067 (1982). *See generally* PAMELA BALDWIN, OVERVIEW OF NEPA REQUIREMENTS (2000), http://www.cnie.org/nle/crsreports/risk/rsk-49.cfm (last visited Dec. 14, 2006) (Congressional Research Service Report RS20621, Washington, D.C.).

6. Lynton K. Caldwell, *A Constitutional Law for the Environment: 20 Years with NEPA Indicates the Need*, 31 ENVIRONMENT 6, 6–11, 25–28 (1989).

7. National Environmental Policy Act § 102(2)(A) (codified at 42 U.S.C. § 4332).

8. *Id.* § 102(2)(A).

9. *Id.* § 102(2)(E).

10. *Id.* § 102(2)(C).

11. *Id.* § 102(2)(A).

12. *Id.* § 102(2)(H).

13. *Id.* § 102(2)(D).

14. *Id.* § 102(2)(C).

15. *Id.* § 101(b). *See also* Envtl Defense Fund v. Corps of Eng'rs, 325 F. Supp. 728, 759 (E.D. Ark. 1971), *aff'd*, 470 F.2d 289, 297 (8th Cir. 1972) (describing NEPA as, at minimum, an environmental full disclosure law); Claudia Goetz Phillips, An Evaluation of Ecosystem Management and Its Application to the National Environmental Policy Act: The Case of the

Caldwell has written that NEPA provided a vehicle for systematically using science to analyze the potential effects of our use of science and technology on society and nature.[17] Congress did not define science, but rather sought to infuse agency decision making with reliable information:

> Enlistment of science on behalf of policy was necessary because only through science, broadly defined, could the impact of man's activities upon the environment adequately be assessed and remedial measures be applied where needed. Achievement of the NEPA policy declaration required that reliable analyses of environmental effects and relationships be built into and guide the planning and decision processes of government, but without predetermining final action. Such analyses were to be derived from the sciences, but could not be obtained through the ways governments had traditionally used science. To achieve NEPA goals, an integrated interdisciplinary use of science was necessary to address complex and interrelated environmental problems. Recognition of the need to redeploy and reintegrate scientific knowledge to respond to the complex challenges of environmental policy gave practical expression to the theoretical unity of science....Science therefore provided the substantive element in redirecting national policy for the environment through procedural reform. The critical procedure—the environmental impact statement—became the vector, carrying integrated interdisciplinary sciences into the shaping of public policy.[18]

U.S. Forest Service 19 (Feb. 1997) (unpublished Ph.D. dissertation, Virginia Polytechnic Institute and State University, Blacksburg, Virginia) (on file with University of Vermont); Caldwell, *supra* note 6.

16. *Problems and Issues with the National Environmental Policy Act: Hearing Before the H. Comm. on Resources*, 105th Cong. 65–66, 88–92 (1998) (statement of Lynton K. Caldwell, Professor of Public and Environmental Affairs and Staff Consultant to the Senate Committee on Interior and Insular Affairs on a National Policy for the Environment, 1968–1970). LAZARUS, *supra* note 6, at 43-44, 51 (recounting the roots of environmental law in the late 1960s and early 1970s and noting that the apparent sudden appearance of environmental law, called a "republican moment" by some, was, in fact, the "culmination of an era of protest").

17. LYNTON K. CALDWELL, SCIENCE AND THE NATIONAL ENVIRONMENTAL POLICY ACT: REDIRECTING POLICY THROUGH PROCEDURAL REFORM 123–25 (1982).

18. *Id.* at 2-3. Caldwell later notes:

In Title II of NEPA, Congress established the White House Council on Environmental Quality (CEQ).[19] President Nixon issued Executive Order 11, 514, Protection and Enhancement of Environmental Quality,[20] requiring CEQ to issue guidelines to federal agencies, which it did in 1971[21] and later revised in 1973.[22] President Carter, in amending Executive Order 11,514, added section 3(h) directing CEQ to establish implementing regulations to require agencies to prepare impact statements that are "concise, clear, and to the point, and supported by evidence that agencies have made the necessary environmental analyses."[23] In the implementing regulations,[24] CEQ directed federal agencies to develop implementing procedures after consultation with CEQ and publication in the Federal Register for comment.[25] CEQ, using sections 102(2)(C) and 102(2)(E) of NEPA, directed agencies to address unresolved conflicts through an alternatives analysis[26] and required them to allow additional time for public review if an action is without

---

> The environmental impact statement is not a scientific document, nor does the statute specify the use of science in its preparation. But use of science is implicit in the impact statement because the five points upon which the act requires the agencies to report findings could not be adequately addressed without recourse to science. This practical necessity became an explicit requirement under *Regulations for Implementing the Procedural Provisions of NEPA* issued in 1978 by the Council on Environmental Quality.
>
> The integrated use of science as required in Section 102(2)(a) of NEPA was explicitly joined to the preparation of impact statements by the regulations (e.g., Section 1502.6) and was reinforced by other provisions regarding the uses of science, especially Section 1502.24 on methodology and scientific accuracy. Section 1500.3 declares that "the regulations apply to the whole of Section 102(2) [of the statute].

Id. at 13 (brackets in original).

19. National Environmental Policy Act, § 202 (codified at 42 U.S.C. § 4342).

20. Exec. Order No. 11,514, 3 C.F.R. 902 (1966–1970), *as amended by* Exec. Order No. 11,991, 3 C.F.R. 123, *reprinted as amended in* 42 U.S.C. § 4331 n.

21. Interim Guidelines, 35 Fed. Reg. 7,390 (May 12, 1970); Guidelines, 36 Fed. Reg. 7,724 (Apr. 23, 1971).

22. Proposed Guidelines, 38 Fed. Reg. 10,856 (May 2, 1973); Guidelines, 38 Fed. Reg. 20,550 (Aug. 1, 1973).

23. Exec. Order No. 11,991, *supra* note 20. Executive Order No. 11,991 also amended section 2(g) of Exec. Order No. 11,514 to require Federal agencies to comply with CEQ regulations except where such compliance would be inconsistent with statutory requirements.

24. 40 C.F.R. pts. 1500–1508.

25. 40 C.F.R. § 1507.3(a). *See also* Protection and Enhancement of Environmental Quality, Exec. Order No. 11,514, § 2(b).

26. 40 C.F.R. §§ 1501.2(c), 1502.14(a), 1507.2(d), 1508.9(b); *see also* Dinah Bear, *Some Modest Suggestions for Improving Implementation of the National Environmental Policy Act*, 43 NAT. RESOURCES J. 931, 937–41 (2004).

precedent.[27] In the 1978 rulemaking,[28] CEQ created procedures for referring interagency controversies to CEQ and allowing the applicant and other interested persons to comment[29] and provided for consideration of the degree to which the possible effects on the human environment are likely to be highly controversial, highly uncertain, or involve unique or unknown risks.[30] In 1986, CEQ amended its regulations[31] to provide a mechanism for addressing scientific uncertainty and incomplete information.[32]

During this period, Congress also enacted or strengthened a variety of environmental laws, each with its own specific goals and requirements.[33] In several of these, beginning with the Marine Mammal Protection Act of 1972, Congress introduced the term "best scientific information available"[34] and authorized agencies to conduct research to improve scientific knowledge. As in NEPA, Congress did not define science or scientific methods, but authorized the technical agencies with jurisdiction to develop regulations for implementing their respective statutes under similar conditions of scientific uncertainty, incomplete information, and controversy.

Scientific uncertainty,[35] incomplete information, and controversy among experts are inescapable facets of the scientific process.[36]

---

27. 40 C.F.R. § 1501.4(e)(2)(ii) (referring to findings of no significant impact). 40 C.F.R. § 1506.10 provides for public notice and a comment period of at least 45 days following issuance of a draft environmental impact statement and public notice of availability of at least 30 days following issuance of a final environmental impact statements.

28. NEPA, 43 Fed. Reg. 55,990 (Nov. 29, 1978); NEPA—Regulations, 44 Fed. Reg. 873 (Jan. 3, 1979).

29. 40 C.F.R. pt. 1504.

30. In 1978, CEQ issued regulations (effective 1979) (43 Fed. Reg. 55,990, Nov. 29, 1978). The draft regulations were published for comment (43 Fed. Reg. 25,230, June 9, 1978), responses to comments were discussed in the preamble to the final rule (43 Fed. Reg. 55,978, Nov. 29, 1978), and a technical correction was made the following year (44 Fed. Reg. 873, Jan. 3, 1979). The regulations included § 1508.27(b)(4) ("The degree to which the effects on the quality of the human environment are likely to be highly controversial)" and § 1508.27(b)(5) ("The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks").

31. 51 Fed. Reg. 15,625 (Apr. 25, 1986) (responses to comments on the proposed rule discussed in preamble beginning at 51 Fed. Reg. 15,618).

32. 40 C.F.R. § 1502.22.

33. Lazarus, *supra* note 1, at 52, 69–70.

34. NAT'L RES. COUNCIL, IMPROVING THE USE OF THE "BEST SCIENTIFIC INFORMATION AVAILABLE" STANDARD IN FISHERIES MANAGEMENT 1 (2004) [hereinafter NRC, BSIA] (Report of the Ocean Studies Board Committee on Defining Best Scientific Information Available for Fisheries Management); *see also* Bryant, *supra* note 1, at 4 n.10 (citing references to "best scientific information available" in statutes).

35. F. DAVID PEAT, FROM CERTAINTY TO UNCERTAINTY: THE STORY OF SCIENCE AND IDEAS IN THE TWENTIETH CENTURY 1–26 (2002).

Uncertainty will be present due to such factors as complexity, natural variability, random variation, measurement error, and lack of knowledge.[37] Information will be incomplete to some degree because the subject of the study is itself dynamic and, as time passes, new opportunities for data collection and testing may occur or new instruments may be developed to measure what could not be measured earlier.[38] Scientists will inevitably disagree to some extent since the scientific process, by definition, encourages testing and critical thinking.

Congress and the agencies in these early statutes and regulations emphasized relevance, inclusiveness, objectivity, transparency and openness, timeliness, and consultation such as through peer review by subject matter experts[39] or an interdisciplinary consultative process.[40] This essay will examine the continuing applicability of these principles in light of judicial deference to agencies in reviewing environmental information and recent suggestions to the courts to apply evidentiary tests and data quality standards. This essay will discuss the growing need to augment insights from "reductionist" science with those of systems theory—both within the prevailing empiricist scientific perspective. It will also discuss the need not only for science, but for better decision systems, and will examine emerging fields such as sustainability science and its component, vulnerability science. It will explore innovative uses of the laws of thermodynamics to facilitate sustainability in business and of collaboration between scientists and the potentially affected community to clarify goals and inform research design.

AGENCY PROCESS: THE HARD LOOK

Congress in enacting NEPA provided a rare forum for public discussion with the government about the benefits and risks of utilizing scientific information or deploying a technology. The public may have

36. Sheila Jasanoff, *What Judges Should Know About the Sociology of Science*, 32 JURIMETRICS 345, 345–49 (1992); *see generally* Bryant, *supra* note 1.

37. COMM. ON THE APPLICATIONS OF ECOLOGICAL THEORY TO ENVTL. PROBLEMS, COMM'N ON LIFE SCIS., NAT'L RES. COUNCIL, ECOLOGICAL KNOWLEDGE AND ENVIRONMENTAL PROBLEM-SOLVING: CONCEPTS AND CASE STUDIES 88–92 (1986) [hereinafter NRC, *Ecological Knowledge*].

38. NRC, BSIA, *supra* note 34, at 45.

39. *Id.* at 5–6.

40. Garry D. Brewer & Kerstin Lövgren, *The Theory and Practice of Interdisciplinary Work*, 32 POL'Y SCIS. 315, 315–17 (1999); Garry D. Brewer, *The Challenges of Interdisciplinarity*, 32 POL'Y SCIS. 327, 327–37 (1999) (discussing the importance of multiple perspectives in assuring definition of the research problem and comprehensive interpretation of the results).

become concerned about a particular technology but did not necessarily have an early mechanism to voice their concerns to agencies with jurisdiction or expertise aside from writing to an agency or elected official. Thus, by the time an agency and the external proponent, if present, propose an activity using a new technology, the public's concern may result in seemingly intractable controversy.

Both science and law, however, are concerned with fact finding and the credibility of sources. Jasanoff notes that the courts play an important role in society by carrying out at least three tasks: The first task involves "getting the facts right," that is, deconstructing expert authority and "making transparent the values, biases, and social assumptions that are embedded in many expert claims about physical and natural phenomena." The second task is civic education by informing the litigants and the larger community about "the epistemological, social, and moral dilemmas accompanying technological change." The third function is to assure effectiveness, that is, justice within a certain timeframe.[41] In its concern for achieving a just resolution within a reasonable time, law is different from science and technology, which, while concerned with problem solving, are concerned with discovering knowledge and developing technical solutions. Law, thus, not only deconstructs science and technology, but then also constructs scientific authority and credibility.[42]

Jasanoff in *Science at the Bar* notes that, due to the historic penchant of Americans to resolve political controversies and achieve social order through law, "[i]t is hardly surprising that in an age of anxiety about the products of science and technology the U.S. public has increasingly turned to law to reassert control over the processes of scientific and technological change or to seek recompense for the failed promises of technology."[43]

Congress did not explicitly provide for judicial review of agency actions under NEPA. The U.S. Circuit Court of Appeals for the D.C. Circuit, however, determined in *Calvert Cliffs' Coordinating Committee v. United States Atomic Energy Commission*[44] that the court had a role under

41. JASANOFF, *supra* note 4, at 20–21.

42. *Id.* at 22.

43. *Id.* at 4.

44. 449 F. 2d 1109, 1115 (D.C. Cir. 1971). *See also* Caldwell, *supra* note 6, at 10 (quoting Judge Skelly Wright: "The reviewing courts probably cannot reverse a substantive decision on its merits, under Section 101, unless it be shown that the actual balance of costs and benefits that was struck was arbitrary or clearly gave insufficient weight to environmental values. But if the decision was reached procedurally without individualized consideration and balancing of environmental factors—conducted fully and in good faith—it is the responsibility of the courts to reverse.").

the APA (section 701) in reviewing whether agencies abused their discretion in implementing NEPA as part of the agency's decision-making process.[45] The general rule in judicial review of NEPA cases under section 706(2)(A) of the APA is whether agencies took a "hard look" at environmental information during agency decision making, that is, the agency was not arbitrary and capricious.[46] Courts give substantial deference to agency procedures, especially those involving review of scientific and technical issues.[47] Some argue that courts give deference to the point that agency review need not be more than a "soft look."[48] In limited situations, agencies when authorized by congressional agencies with jurisdiction by law have used Federal Register notice and comment to establish requirements for using specific methods or criteria.[49] In such instances, the courts will give *Chevron* deference[50] when "it appears that Congress delegated authority to the agency generally to make rules carrying the force of law, and that agency interpretation claiming deference was promulgated in the exercise of that authority."[51] If "an agency is not entitled to *Chevron* deference it may still be entitled to a standard of review lower than de novo...because of [the agency's] power to persuade the court based on the agency's expertise in a particular area."[52] Under *Skidmore*,[53] the deference given to an agency decision should "depend upon the thoroughness evident in [the agency's] consideration, the validity of its reasoning, its consistency with earlier

45. *Id.*

46. Marsh v. Or. Natural Res. Council, 490 U.S. 360, 375-78 (1989); Kleppe v. Sierra Club, 427 U.S. 390, 410 n.21 (1976).

47. Vt. Yankee Nuclear Power Corp. v. Natural Res. Defense Council, Inc., 435 U.S. 519, 558 (1978); Strycker's Bay Neighborhood Council, Inc. v. Karlen, 444 U.S. 223, 227-28 (1980).

48. Jim Chen, *Legal Mythmaking in a Time of Mass Extinctions: Reconciling Stories of Origins with Human Destiny*, 29 HARV. ENVTL. L. REV. 279, 294 (2005).

49. For example, the FAA, following direction in the Federal Aviation Act of 1956, as amended, established a requirement in Appendix A, FAA Order 1050.1E, Environmental Impacts: Policies and Procedures A-60 (June 8, 2004), http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgOrders.nsf/0/9552db552fd4495b862570660068adb1/$FILE/Order1050-1E.pdf, to use specific noise impact models. With respect to demonstrating compliance with other laws as part of the NEPA process, agencies with jurisdiction by law have in some instances prescribed methodology. Under the National Historic Preservation Act, the National Park Service established Archeology and Historic Preservation: Secretary of the Interior's Standards and Guidelines, 48 Fed. Reg. 44,716 (Sept. 29, 1983).

50. Chevron U.S.A., Inc. v. Natural Res. Def. Council, 467 U.S. 837, 843-44 (1984).

51. Cynthia A. Reid, United States v. Mead Corp.: *The Supreme Court's Failed Attempt to Clarify the Law of Agency Deference*, 8 ENVTL. LAW. 407, 414 (2001-2002) (citing United States v. Mead Corp., 533 U.S. 218, 226-27 (2001)).

52. *Id.*

53. Skidmore v. Swift, 323 U.S. 134 (1944).

and later pronouncements, and all those factors which give it power to persuade, if lacking power to control."[54]

SCIENTIFIC PROCESS: THE OBSERVATION

The scientific information agencies consider is itself the product of a process, the scientific process, which, if followed, is given deference among scientists as reliable knowledge. This process must be set in a historical context in which science is defined as "knowledge"[55] and the process of "knowing" is an epistemological[56] endeavor. Until the early 1800s, experts in a field of knowledge about the natural world were known as natural philosophers. The term "scientist" was not coined until 1833.[57] The scientific process, of necessity, involves a cycle of inductive and deductive reasoning, where inductive reasoning involves developing conclusions or theories from limited observations and is thus more exploratory. Deductive reasoning involves using observations to test or explain the conclusions or theories.[58] The scientific method provides a mechanism for establishing the reliability of observations. "[S]cience is a method of investigating nature—a way of knowing about nature—that discovers reliable knowledge about it."[59]

The prevailing philosophy of science in the United States in the twentieth century and the early part of the twenty-first century is generally known as empiricism. Empiricism, derived from the Greek term for "experience,"[60] is based on the premise that "scientific theories are objective, empirically testable, and predictive—they predict empirical results that can be checked and possibly contradicted."[61] That is, if a theory is defined as a body of ideas and a model is defined as a construct, then a scientist with a research problem or question can use a

54. *Id.* at 140.

55. *See, e.g.*, Online Etymology Dictionary, http://www.etymonline.com/index.php?term=science (last visited Dec. 14, 2006) (describing the etymology of "science" from the Latin "scientia" or "scire," meaning knowledge).

56. *See, e.g.*, Online Etymology Dictionary, http://www.etymonline.com/index.php?term=epistemology (last visited Dec. 14, 2006) (describing the etymology of "epistemology" from the Greek terms for the study or philosophy of knowledge).

57. *See* Wikipedia, http://wn.wikipedia.org/wiki/Scientist (last visited Dec. 14, 2006).

58. *See* Wikipedia, http://en.wikipedia.org/wiki/Philosophy (last visited Dec. 14, 2006).

59. Steven D. Schafersman, *An Introduction to Science: Scientific Thinking and the Scientific Method* (Jan. 1994), http://www.freeinquiry.com/intro-to-sci.html.

60. *See* Wikipedia, http://en.wikipedia.org/wiki/Empiricism (last visited Dec. 12, 2006). *See also* Online Etymology Dictionary (describing the derivation of empiricism from en- "in" + peira "trial, experiment"), http://www.etymonline.com/index.php?term=empirical (last visited Dec. 14, 2006).

61. *See* Wikipedia, http://en.wikipedia.org/wiki/Science (last visited Dec. 14, 2006).

theory or model to formulate a hypothesis or tentative explanation of observations.[62] From a hypothesis, a scientist develops predictions that, under specified conditions or assumptions, will result in a particular outcome or observation.[63] A scientist then uses observations, experiments, mathematics, statistical analyses, or simulations to test if the predicted outcome occurs and then determine the validity of the observations.[64] The term "experiment" is derived from the same root as "experience," where an experiment is a controlled experience. Reproducibility of the observation or outcome suggests greater reliability of the results.[65] The process is repeated as conclusions are challenged by new questions, hypotheses (predictions), simulations or tests, and observations. With each successive investigation, the theory or body of ideas is either strengthened, revised, or discarded. Positivism as a form of empiricism gives priority to direct observations, argues that there is little difference between social and natural science, and asserts that society can use science to make decisions.[66]

Empiricism, though dominant in science, is one of several perspectives. For example, rationalism, sometimes contrasted with empiricism, is based on the premise that one can have knowledge without necessarily having direct experience. Logic and mathematics are forms of rationalism. Some rationalists, however, limit rationalism to only what can be observed empirically.[67] Alternatives to both empiricism and rationalism include, for example, irrationalism and mysticism.[68]

Empiricism and positivism are also not without criticism. For example, some argue that observations cannot be completely objective or independent; that is, the scientist's observations are made within the scientist's theory or paradigm.[69] Bias is inherent, but scientists often use

62. *See* Wikipedia, http://en.wikipedia.org/wiki/Scientific_method (last visited Dec. 14, 2006).

63. *See* Wikipedia, http://en.wikipedia.org/wiki/Prediction (last visited Dec. 14, 2006).

64. Validity is defined in terms of whether the experiment or observation measures what it is intended to measure. An assertion or hypothesis is valid if it is supported by observations or facts. *See, e.g.*, Merriam-Webster On-line Dictionary, http://www.m-w.com/dictionary/valid+ (last visited Dec. 14, 2006). Reliable means dependable or giving the same result in repeated trials. *See id.*, http://www.m-w.com/dictionary/reliable (last visited Dec. 14, 2006). Reliability relates to consistency. *See id.*; *see also* Wikipedia, http://en.wikipedia.org/wiki/Reliability (last visited Dec. 14, 2006).

65. *See* Wikipedia, *supra* note 62.

66. *See* Wikipedia, http://en.wikipedia.org/wiki/Positivism (last visited Dec. 14, 2006).

67. *See* Wikipedia, http://wn.wikipedia.org/wiki/Rationalism, Nov. 8, 2005.

68. *See* Wikipedia, http://en.wikipedia.org/wiki/Epistomology (last visited Dec. 14, 2006).

69. *See* Wikipedia, *supra* note 61.

internal and external independent peer review, though not perfect, as a check.[70] Others argue that knowledge of reality is constructed based on values and subjective understanding rather than on passive acquisition of objective facts or logic.[71] Taking "social constructionist" criticism to an extreme, some would argue that scientific knowledge is completely relative.

Empiricism, like other epistemologies, is subject to metaphysical questions such as those posed in the following course description:

> Eternalism is the doctrine that all times are equally real, be they past, present or future. Opposed to this are various accounts that ontologically privilege some times over others (*e.g.*[,] presentism). Four-dimensionalism is the view that objects have temporal parts and are extended in time (much as they are in space). Opposed to this is three-dimensionalism, the view that objects lack temporal parts and are wholly present at any times at which they exist. Disputes over Eternalism and Four-dimensionalism lie at the heart of contemporary metaphysics of time. This course is a focused study of these disputes. Topics to be addressed might include: the experience of time; fatalism; the relationship between tense and time; the possibility of time travel and backward causation.[72]

The discussion above provides a taste of the nuanced debates about science within epistemology and metaphysics. These debates will likely continue as part of the human condition "underlin[ing] the fact that science is in the first and last instance a human pursuit."[73] Science has, thus, also become the subject of historical analysis, and where the history of science was considered "new and fairly exotic" in the 1950s,[74] it is now an established field. Similarly, the organization, culture, values, and politics of science are the subject matter of relatively new fields. In

---

70. NRC, BSIA, *supra* note 34, at 45.

71. *See* Wikipedia, http://en.wikipedia.org/wiki/Constructivism (last visited Dec. 14, 2006); *id.*, http://en.wikipedia.org/wiki/Constructivist_epistemology (last visited Dec. 15, 2006).

72. J. Mozersky, *Phil. 452, Current Issues in Metaphysics*, Univ. Queens, Kingston, Canada (2005) (course description) (on file with author).

73. John Tresch, *Mapping the Roads to Current Science*, 309 SCIENCE 2167 (2005) (reviewing PETER J. BOWLER & IWAN RHYS MORUS, MAKING MODERN SCIENCE: A HISTORICAL SURVEY (2005)).

74. J.B. Shank, *An Old Approach to a Revolutionary Regime*, 309 SCIENCE 2168 (2005) (reviewing CHARLES COULSTON GILLISPIE, SCIENCE AND POLITY IN FRANCE: THE REVOLUTIONARY AND NAPOLEONIC YEARS (2004)).

the sociology of science;[75] researchers are interested in such questions as whether funding is directed to issues of interest to society or relevant groupings within society. In the political history of ecology, researchers address questions of governance in the individual's relationship to nature and society.[76]

REDUCTIONISM AND SYSTEMS THEORY: SEEING THE TREES AND THE FOREST

Against this philosophical, historical, sociological, and political backdrop, debate within the prevailing empiricist perspective[77] between reductionists and systems theorists is brought into sharp relief in the study of the environment and human-environment interactions. Reductionists generally adhere to the view that phenomena can be reduced to their smallest unit for explanation,[78] which is consistent with the derivation of the term "science" to mean knowledge; that is, "to separate one thing from another, to distinguish."[79] Examples include effects of a constituent of an emission plume on a particular biochemical process in the cell structure of earthworms. General systems theorists argue that reductionism is not enough and should be supplemented by study of the whole, where the structure of something is as important as its parts.[80] Examples of systems include organisms such as earthworms or a plant community such as a tropical forest.

---

75. Bryant, *supra* note 1, at 10-11.

76. *See generally* ANNA BRAMWELL, ECOLOGY IN THE 20TH CENTURY: A HISTORY (1989).

77. *See, e.g.*, Frederick Kirschenmann, Director, Leopold Center for Sustainable Agriculture, What Constitutes Sound Science?, Lecture at the annual Sigma Xi lecture, Iowa State University (Dec. 5, 2002), *available at* http://www.leopold.iastate.edu/pubs/speech/files/120502_science1.pdf; Peter M. Sand-man, Sound Science (Sept 5, 2001), http://www.psandman.com/col/soundsci.htm. Dr. Sandman is a journalist who has specialized in communication of environmental risk. He describes the debate between the precautionary principle and its alternative, sound science. *See also* Daubert v. Merrell Dow Pharm., Inc., 509 U.S. 579 (1993) (sometimes referred to as the "junk" science decision); Sharon Begley, *Fingerprint Matches Come Under More Fire as Potentially Fallible*, WALL ST. J., Oct. 7, 2005, at B1.

78. *See* Wikipedia, http://en.wikipedia.org/wiki/Reductionism (last visited Dec. 14, 2006).

79. *See, e.g.*, Online Etymology Dictionary, http://www.etymonline.com/index.php?term=science (last visited Dec. 14, 2006) (discussing the origin of the term "science" from the Latin "scientia" or "scire," meaning knowledge, and noting that these terms are related to "scindere," meaning "to cut, divide," from the Proto-Indo-European base *skei- (compare to Greek "skhizein," meaning "to split, rend, cleave," Gothic "skaidan," Old English "sceadan," meaning "to divide, separate")).

80. *See* Wikipedia, http://en.wikipedia.org/wiki/Systems_theory (last visited Dec. 14, 2006).

Scientists using the scientific method have expanded modern capability in environmental science.[81] Recognizing the difficulty in obtaining a large-scale control for a systems analysis, the National Research Council Committee on the Geologic Record of Biosphere Dynamics, for example, has recommended using the geologic record as a benchmark:

> The profound effect of human activities on natural environments and ecosystems is clearly evident, but the consequences are less well understood. In effect, an unintentional global experiment is already in progress. However, the initial conditions of this far-reaching experiment are largely unknown, because the onset of human interactions with natural systems—both intentional and unintentional—predate scientific monitoring efforts, which largely extend back at most to the late 1800s. There is also no "control" in this experiment; completely natural habitats are no longer available either locally or globally to use as a benchmark for comparison with habitats that have been modified.[82]

As the data, such as those from the geologic record and recent observations, have increased and computer capabilities have improved, scientists have increasingly used modeling and other simulations to improve understanding of what is known and not known about human-environment interactions under different assumptions. Scientists test the reliability of methods, that is their ability to reproduce results, by repeated simulations and by convergence of results from multiple models and observations. Through these techniques, scientists are increasingly able to describe complex systems and the risks to those systems and subsystems. Validity, or the risk of correctly predicting outcomes, is discussed below.

Gatekeeping

In the NEPA process, an agency receives and reviews information from many sources. The agency develops responses using its technical expertise and an interdisciplinary process. The agency generally must request or allow comment from other agencies and the

81. *See, e.g.*, EDWARD O. WILSON, CONSILIENCE: THE UNITY OF KNOWLEDGE 73 (1998).

82. COMM. ON THE GEOLOGIC RECORD OF BIOSPHERE DYNAMICS, NAT'L RES. COUNCIL, THE GEOLOGICAL RECORD OF ECOLOGICAL DYNAMICS: UNDERSTANDING THE BIOTIC EFFECTS OF FUTURE ENVIRONMENTAL CHANGE 5 (2005).

public on the information received and the agency's responses to it. In several recent court challenges to agency decisions under NEPA and other environmental laws, plaintiffs have begun to suggest that judges use the test in *Daubert v. Merrell Dow Pharmaceuticals, Inc.*[83] as a guideline in determining whether agencies were arbitrary in following or not following a particular approach and associated results in a particular agency action.[84]

The Texas court, in adopting *Daubert* in *E.I. du Pont de Nemours & Co. v. Robinson*,[85] distinguished between credibility of the witness and reliability of the methodology:[86] "An expert witness may be very believable, but his or her conclusions may be based upon unreliable methodology."[87] Further, "a person with a degree should not be allowed to testify that the world is flat, that the moon is made of green cheese, or that earth is the center of the solar system."[88] Under *Daubert*, "[t]he subject of an expert's testimony must be "scientific knowledge." The adjective "scientific" implies a grounding in the methods and procedures of science. Similarly, the word "knowledge" connotes more than subjective belief or unsupported speculation....But, in order to qualify as "scientific knowledge," an inference or assertion must be derived by the scientific method. Proposed testimony must be supported by appropriate validation—i.e., "good grounds," based on what is known. In short, the requirement that an expert's testimony pertain to "scientific knowledge" establishes a standard of evidentiary reliability."[89] The court in Daubert acknowledged the following four factors that bear on the court's inquiry[90] but noted that the inquiry is flexible.[91]

1. Theory, technique, or method can be or has been tested.[92]

2. Whether the theory or technique has been subject to peer review and publication (relevant, though not dispositive),[93]

3. What the court understands about the known or potential rate of error for particular scientific technique (or

83. 509 U.S. 579 (1993).
84. Bear, *supra* note 26, 944 & nn.49-52.
85. 923 S.W. 2d, 549, 560 (Tex. 1995).
86. Kenneth A. Wright, *Daubert Challenges in Condemnation*, 32 URB. LAW. 507-22, 511 (2000).
87. *Id.* at 560.
88. *Id.*
89. *Daubert*, 509 U.S. at 589-90.
90. *Id.* at 593.
91. *Id.* at 594.
92. *Id.* at 593.
93. *Id.* at 593-94.

the known or potential rate of error and degree of control to which the technique is subjected),[94] and

4. Whether the theory or technique has received general acceptance or at least more than minimal support.[95]

Courts have rejected application of *Daubert* in NEPA cases except in the District of Oregon where the court used the *Daubert* test to allow plaintiffs to introduce into evidence affidavits casting doubt on the adequacy of the Federal Highway Administration's (FHWA) biological assessment.[96] The court's purpose in allowing the affidavits as evidence was to determine whether under the APA arbitrary and capricious standard the FHWA had acted reasonably. The court found that the FHWA had acted reasonably in basing its decision on a reasoned evaluation of all the relevant factors. The court considered the discretion traditionally granted to an agency's reliance on its own expert advice and dismissed the claims brought by the plaintiff.[97]

In *Sierra Club, Wisconsin Forest Conservation Task Force & Wisconsin Audubon Council, Inc. v. Floyd J. Marita*,[98] the court stated that deference does not mean obeisance.[99] Deference shall not "shield [an agency] action from a thorough probing, in-depth review."[100] The court added, "Where an agency has relied on factors which Congress has not intended it to consider, entirely failed to consider an important aspect of the problem, offered an explanation for its decision that runs counter to the evidence before the agency, or is so implausible that it could not be ascribed to a difference in view or the product of agency expertise," the agency has violated the standards of the APA."[101] The plaintiffs argued that the field of conservation biology was sufficiently well developed that the Forest Service should have adopted its principles in a Forest Plan to maintain diversity of species. The Seventh Circuit, however, found that, since neither Congress in NEPA nor the Forest Service in its regulations had specified a methodology, and the agency had considered conservation biology but had not unreasonably chosen to rely on a

94. *Id.* at 594.

95. *Id. See also* Bear, *supra* note 26, at 944, n.49 (citing *Daubert* in summarizing four factors).

96. Hells Canyon Preservation Council v. Jacoby, 9 F. Supp. 2d 1216, 1223-24 (D. Or. 1998).

97. *Id.* at 1241. *See* Council on Environmental Quality, *Selected NEPA Cases in 1998*, NEPANET http://ceq.eh.doe.gov/nepa/nepanet.htm (last visited Dec. 15, 2006).

98. 46 F.3d 606, 619 (7th Cir. 1995), reh'g denied (Apr. 5, 1995).

99. *Id.*

100. *Id.* (citing Citizens to Preserve Overton Park, 401 U.S. 402, 415 (1971)).

101. *Id.* (citing Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co., 463 U.S. 29, 43 (1983)).

variety of approaches in the particular setting given that conservation biology was uncertain in its application, the agency did not act irrationally and should be granted deference.[102]

The court declined to accept plaintiff's argument in favor of using *Daubert* to determine whether to grant the Forest Service's scientific assertions deference under NEPA.[103] The court stated that,

> [w]hile such a proposal might assure better documentation of an agency's scientific decisions, we think that forcing an agency to make such a showing as a general rule is intrusive, undeferential, and not required. An EIS [Environmental Impact Statement] is designed to ensure open and honest debate of the environmental consequences of an agency action, not to prove admissibility of testimony in a court of law.[104]

At about the same time, Congress enacted the Data Quality Act of 2001.[105] Some have seen the Act as a mechanism for assuring the objectivity of scientific information used in agency decision making.[106] Under the Data Quality Act, Congress directed agencies to assure the "quality, objectivity, utility, and integrity" of all information they disseminate to the public, and the public may ask an agency to correct publicly released information. CEQ, for example, has drafted guidelines for assuring that information submitted to it by another agency conforms to the Data Quality Act.[107]

Critics of the Data Quality Act have argued that the process for asking an agency to correct information is not adversarial;[108] that is, the process does not provide for a "specific and focused conflict" [109] such as a science court might offer. Congress, however, did not provide an explicit

---

102. *Marita*, 46 F.3d at 621.

103. *Id.* at 622.

104. *Id.*

105. Treasury and General Government Appropriations Act for Fiscal Year 2001, Pub. L. No. 106-554, § 515, 114 Stat. 2763A-125, 2763A-153 to 2763A-154 (2000) (codified at 44 U.S.C.A. § 3516 n.).

106. M. Andrew McLain, Note, *An Update on the Implementation of the Data Quality Act: The Cost of Sound Science*, VT. J. ENVTL. L., Apr. 28, 2005, http://www.vjel.org/editorials/2005S/MclainFinal.htm.

107. Council on Environmental Quality, Notice of Availability: Final guidelines for ensuring and maximizing the quality, objectivity, utility and integrity of information, 67 Fed. Reg. 65,354 (Oct. 24, 2002).

108. McLain, *supra* note 106, at 12 n.50.

109. Sheila Jasanoff & Dorothy Nelkin, *Science, Technology, and the Limits of Judicial Competence*, 68 AM. B. ASS'N J. 1094, 1099 (1982). *See also* Bryant, *supra* note 1, at 6–8, 11; Wikipedia, http://en.wikipedia.org/wiki/Adversarial_process (last visited Dec. 15, 2006).

judicial review provision in the Data Quality Act. The courts that have addressed the issue have held that the "plain language of the act precludes a private right of act[sic] for private parties to challenge an agency's decision to ignore a request for correction in federal court."[110] The question of whether the courts can review agency decisions under the Data Quality Act has nonetheless generated concern among some that "judges are often ill equipped to make determinations on the reliability of hyper-technical scientific data...and that agencies may anticipate such action by courts and become timid about disseminating information and slower with rule-making."[111]

The relationship of changes in human activities to changing Earth conditions and vice versa raises some of the most challenging questions in science.[112] Jasanoff and Nelkin, writing in 1982, noted that

> [e]quipping the courts with scientific and technical support may facilitate the adjudication of these [the broad questions that flow from scientific and technical activities] issues, but it also may divert attention from the public responsibility for major policy decisions and encourage the conversion of moral and political questions into technical debates among experts.[113]
>
> [T]echnical uncertainty underlying many disputes is genuine; in many cases the evidentiary basis for definitive resolution simply does not exist."[114] The adversarial process, depending upon the applicable rules, has the potential to provide greater due process. Bryant, however, observes "the difficulties inherent in translating between legal and scientific evidentiary standards, burdens of proof, and treatments of uncertainty."[115]

The Data Quality Act instead provides an administrative appeal process, albeit limited to the information and not necessarily any subsequent decision flowing from use of that information. Even so, under the First Amendment, persons have had and continue to have the constitutional right to petition the government without necessarily

---

110. McLain, *supra* note 106, at 11.

111. Susan Bisong, *Federal Agencies Subject to Data Quality* Act, MODRALL SPERLING, 2003, *available at* http://library.findlaw.com/2003/Jan/14/132464.html.

112. Thomas Dietz et al., *The Struggle to Govern the Commons*, 302 SCIENCE 1907 (2003).

113. Jasanoff & Nelkin, *supra* note 109. *See also* Bryant, *supra* note 1, at 35 (discussing what some have called an "excess of objectivity").

114. Jasanoff & Nelkin, *supra* note 109.

115. Bryant, *supra* note 1, at 4.

triggering a formal adversarial process.[116] Rulemaking and various administrative processes, such as those provided in CEQ regulations implementing NEPA, have also provided opportunities for notice and comment, including requests to correct agency information.

The NEPA review process, moreover, provides a mechanism for assuring information quality under conditions of scientific uncertainty, incomplete information, and controversy among experts and the public.[117] The NEPA process is, as mentioned, also subject to judicial review under the APA, which provides an additional forum and specific rules of procedure for supplementing or correcting the record. But from a historical perspective, Congress addressed NEPA to agencies with technical expertise in their respective areas of jurisdiction in part to return disputes to the agencies. Congress also granted administrative agencies considerable technical deference. Caldwell notes that, until NEPA was enacted, agencies had argued that their statutory authorities did not provide for consideration of environmental impacts. In section 103 of NEPA, Congress directed agencies to bring their authorities into conformance with NEPA. In section 105, Congress established NEPA as a supplement to the existing authorities of agencies.[118] As an additional measure to assure effective use of science in reviewing agency proposals, Congress also directed agencies to use an interdisciplinary approach,[119] assure scientific and professional integrity, disclose methodology and references,[120] and communicate or consult with agencies with expertise or jurisdiction by law.[121] To further allay agency concerns that environmental review would delay decisions, NEPA and the CEQ regulations, as mentioned, provided for addressing uncertainty, incomplete or unavailable information,[122] and controversy[123] while still assuring rigor[124] and accuracy.[125]

The National Research Council has suggested that what is needed is for agencies to present more carefully drafted explanatory

116. GEORGE W. PRING & PENELOPE CANAN, SLAPPS: GETTING SUED FOR SPEAKING OUT 3 (1996).

117. McLain, *supra* note 106, at 6-7.

118. CALDWELL, *supra* note 17, at 9-10. *See also* 40 C.F.R. § 1500.6.

119. 40 C.F.R. §§ 1501.7, 1502.6.

120. 40 C.F.R. § 1502.24.

121. 40 C.F.R. §§ 1501.6, 1501.7, 1502.25.

122. 40 C.F.R. § 1502.22 (51 Fed. Reg. 15625, Apr. 25, 1986).

123. NEPA, § 102(2)(E) (authority for preparing Environmental Assessment); 40 C.F.R. §§ 1502.12, 1508.27(a)(4).

124. 40 C.F.R. § 1502.14(a).

125. 40 C.F.R. §§ 1500.1(b) ("The information must be of high quality. Accurate scientific analysis, expert agency comments, and public scrutiny are essential to implementing NEPA."), 1502.24.

findings.[126] CEQ regulations, in addressing incomplete and unavailable information, require that agencies discuss existing credible scientific evidence relevant to evaluating reasonably foreseeable significant adverse impacts where "for purposes of this section [section 1502.22] 'reasonably foreseeable' includes impacts which have catastrophic consequences, even if their probability of occurrence is low, provided that the analysis of the impacts is supported by credible scientific evidence, is not based on pure conjecture, and is within the rule of reason."[127] Bryant suggests that agencies develop and present the foundation for their findings in terms that will facilitate understanding by the public, other agencies, and the courts of the agencies' reasoning. Executive Order 11,990, Protection of Wetlands,[128] and Exec. Order 11,988, Floodplain Management,[129] both signed on May 24, 1977, by President Carter, provide detailed examples of how to prepare the foundation for and the statement of specific findings.

VISION

What people will do with scientific information remains the greatest uncertainty. In making day-to-day decisions, people are uncertain whether the scientific understanding they have will be debunked each time new information becomes available.[130] Bryant notes:

> [S]ocial psychology research shows that most people are willing to risk huge future potential losses in order to avoid the certain, immediate loss incurred by temporarily restricting their current level of resource use. People tend to be overly optimistic about the future, believing that they will be able to avoid or ameliorate future risks....[I]n conditions of high scientific uncertainty, people faced with tough choices "engage in tremendous wishful thinking," overestimating the abundance of the resource and

126. NRC, BSIA, *supra* note 34, at 43, 58–59; *see also* Bryant, *supra* note 1, at 13 (noting that most of the losses by the National Marine Fisheries Service have been because the Agency "fails to provide a rational connection between the evidence in the administrative record and the action").

127. 40 C.F.R. § 1502.22(b) (51 Fed. Reg. 15,625, Apr. 25, 1986).

128. 42 Fed. Reg. 26,961 (May 25, 1977), *reprinted in* 42 U.S.C. 4331 n. (Exec. Order No. 11,990 was amended by Exec. Order No. 12,608, 52 Fed. Reg. 34,617 (Sept. 9, 1987), to delete reference to the Water Resources Council.).

129. 42 Fed. Reg. 26,951 (May 25, 1977), *reprinted in* 42 U.S.C. 4331 n. (Exec. Order No. 11,988, § 2(d), was amended by Exec. Order No. 12,148, 44 Fed. Reg. 43,239 (July 20, 1979), to update the name of the Federal Emergency Management Agency.).

130. PEAT, *supra* note 35, at 154–86.

> underestimating the threats....[I]n formulating rules for spreading the regulatory burden around, people egocentrically believe that the fairest rule is the one that benefits them the most. Thompson suggests ways to counter these problems, such as reducing uncertainty, reducing temporal discounting, focusing on present costs, finding acceptable solutions, and engaging in discussions about fairly allocating the burdens.[131]

Risk can also be described in terms of making a Type 1 or Type 2 error. A Type 1 error (false positive) or false alarm occurs when test results indicate that a predicted outcome should be rejected when it should have been accepted.[132] A Type 2 error (false negative) occurs when a test concludes that the predicted outcome should be accepted, when it should have been rejected.[133] A Type 3 error occurs when an outcome is correctly predicted but the cause is not correctly identified.[134] Whether to adopt a precautionary approach,[135] and risk a Type 1 error, has been the subject of international debate. In international law, the precautionary principle has come to mean shifting the burden of proof to the proponent to demonstrate that the proposed action will not cause undue harm. A cautious approach can mean acting prudently now to avoid certain harm later. Alternatively, some would argue that the proponent may proceed if the opponent cannot demonstrate that the proposed action will cause harm. The risk is of making a Type 2 error.

Analysts in conducting NEPA reviews have tended to emphasize specific problem definition (purpose and need for the action), information gathering, alternatives analysis, and selection. This approach has tended to work well with discrete actions. In the context of more complex actions, adaptive governance and adaptive management approaches, such as collaborative problem solving,[136] have gained saliency. Adaptive governance offers a middle ground for people with varying perceptions of risk and differing desires for certainty. Adaptive governance allows the possibility of making mid-course corrections[137]

---

131. Bryant, *supra* note 1, at 12 (citing B.H. Thompson, Jr., *Tragically Difficult: The Obstacles to Governing the Commons*, 30 ENVTL. L. 241, 241–78 (2000)).

132. NRC, BSIA, *supra* note 34, at 22–23, 48.

133. *Id.*

134. *See e.g.*, Wikipedia, http://en.wikipedia.org/wiki/Type_I_and_typeII_errors (last visited Dec. 31, 2007).

135. *See, e.g.*, Sharon Schwartz & Kenneth M. Carpenter, *The Right Answer for the Wrong Question: Consequences of Type III Error for Public Health* Research, 89 AM. J. PUB. HEALTH 1175 (1999); Bryant, *supra* note 1, at 7.

136. Bryant, *supra* note 1, at 7.

137. *Id.*

while gathering information to assist in resolving difficult and overarching social and political value choices.[138] The challenge of adaptive governance is in developing requisite monitoring protocols that affected parties agree are appropriate.[139] Adaptive governance is more likely to succeed if a collaborative atmosphere of trust has been established.[140] Further, if a programmatic[141] or tiered approach[142] is used in the NEPA process, agencies can resolve issues of when and under what circumstances they will reopen reviews and decisions can be resolved. Otherwise, agencies may be reluctant to reopen decisions.[143] Under Executive Order 13,148, Greening the Government Through Leadership in Environmental Management,[144] agency environmental management systems have the potential to dampen the abruptness of changing course by adding adaptive elements, such as audit functions (monitoring and evaluation) and corrective action functions (mitigation), before and after agency NEPA reviews of proposed actions.[145]

To put problem definition, alternatives analysis, and monitoring functions into context, systems theorists in studying human-environment interactions have suggested creating a new discipline of "sustainability science" and have outlined its core research questions.[146] Kates et al. argue that "[t]he sustainability science that is necessary to address these questions differs to a considerable degree in structure, methods, and content from science as we know it."[147] Critics have suggested that there is no need for a new discipline that would in effect

138. *See, e.g.*, Erik Stokstad, *Learning to Adapt*, 309 SCIENCE, 688, 688-90 (2005); Wikipedia, http://en.wikipedia.org/wiki/Adaptive_management (last visited Dec. 15, 2006).

139. ANN M. HOOKER, REPORT OF THE 1993 MONITORING AND EVALUATION TASK FORCE (1993) (prepared for the U.S.D.A. Forest Serv. Nat'l Forest Sys. & Res. Deputy Areas, Washington, D.C.). *See also* Stokstad, *supra* note 138, at 688-90.

140. Bryant, *supra* note 1, at 8; *see also* NRC, BSIA, *supra* note 34, at 25.

141. 40 C.F.R. §§ 1500.4(i), 1502.4, 1502.20, 1508.18, 1508.28.

142. 40 C.F.R. §§ 1500.4(i), 1502.4(c), 1502.20, 1508.28.

143. Bryant, *supra* note 1, at 7-8 (noting that "legal and political institutions seek long-term certainty").

144. Exec. Order No. 13,148, 65 Fed. Reg. 24,595 (Apr. 26, 2000).

145. *Id.* at 24,595-98 (§§ 202, 301, 401, 402).

146. NAT'L RES. COUNCIL. OUR COMMON JOURNEY: A TRANSITION TOWARD SUSTAINABILITY (1999). *See also* Robert W. Kates et al. *Sustainability Science*, 292 SCIENCE 641, 641-42 (2001); and a related article by same title and the same authors presented at the Belfer Center for Science & International Affairs at the Harvard University, John F. Kennedy School of Government, Dec. 2000, *available at* http://ksgnotes1.harvard.edu/BCSIA/sust.nsf/pubs/pub7/$File/2000-33.pdf.

147. Kates et al., *supra* note 146.

be "the science of everything."[148] Regardless, "science for sustainability"[149] would acknowledge the complex, non-linear nature of systems with long time lags between actions and their consequences.[150]

NEPA analysts depend, in part, on using scientific information to describe the potentially affected environment and reasonably foreseeable effects of human actions on the environment. Analysts may consider feedback responses to determine whether the impact will be significant. The question of vulnerability, or resilience of the nature-society system, which is one of the core questions of sustainability science (science for sustainability),[151] is especially relevant. According to Turner et al.,

> Vulnerability is the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress/ stressor....A central lesson of this [research and practice] recognizes that a focus limited to perturbations and stressors is insufficient for under-standing the impacts on and responses to the affected system or its components. This lesson is underscored by two archetypal reduced-form models that have informed vulnerability analysis: the risk-hazard (RH) and pressure-and-release (PAR) models.[152]

RH models do

> not treat: (i) the ways in which the systems in question amplify or attenuate the impacts of the hazard; (ii) the distinctions among exposed subsystems and components that lead to significant variations in the consequences of the hazards, and (iii) the role of political economy, especially social structures and institutions, in shaping differential exposure and consequences.[153]

---

148. David Dickson, *"Sustainability Science" Is No Solution*, SCI. & DEV. NETWORK, Aug. 12, 2002, http://www.scidev.net/dossiers/index.cfm?fuseaction=dossierReadItem&type=4&itemid=22&language=1&dossier=4.

149. Peter H. Raven, *Science, Sustainability, and the Human Prospect*, 297 SCIENCE 954 (2002) (Presidential address to the American Association for the Advancement of Science annual meeting, *Science in a Connected World*, Feb. 2002).

150. *Call for a Shift to "Sustainability Science,"* NEWS IN SCIENCE, AUSTRALIAN BROAD. CORP., June 27, 2001, http://www.abc.net.au/science/news/stories/s319176.htm, accessed Mar. 30, 2005) (interview with Ian Lowe, Professor, Griffith University, Nathan, Australia).

151. Kates et al., *supra* note 146.

152. Turner et al., *Science and Technology for Sustainable Development Special Feature: A Framework for Vulnerability Analysis in Sustainability Science*, 100 PNAS 8074, 8074 (2003).

153. *Id.* (citations omitted).

The PAR model explicitly draws attention to the root causes of the risk. The PAR model is limited in that it does not address the hazard's causal sequence or "nested scales of interactions."[154] Turner et al. argue further that vulnerability analysis addresses issues of resource capacity, coping capacity, and adaptive capacity. Resource capacity or entitlement refers to legal and customary rights to exercise control over resources necessary to life and varies among individuals and groups and by location. Coping capacity refers to the ability to respond to or avert the harm. Multiple coping mechanisms provide a stronger safety net. Coping capacity, like resource capacity, varies across social units. Adaptive capacity or resilience refers to the ability to bounce back to a reference state after disturbance. The alternative is to shift to a different state. Adaptive capacity similarly varies from social unit to social unit.[155]

Because social factors, such as the availability of resources, safety nets, and flexibility, affect the degree of vulnerability or risk, the process of knowing need not and cannot be exclusive to scientists located outside the potentially affected community.[156] People and their changing environment are in a co-evolutionary race.[157] A major question is whether people have the adaptive capacity to learn enough fast enough to make decisions well enough to sustain society and the environment.[158]

Scientists must be open to defining the research problem in light of the concerns of potentially affected communities,[159] and potentially affected communities must become knowledgeable of and engaged in the scientific process to understand sources of scientific uncertainty and controversy, and make decisions accordingly. Erlich and Kennedy, for example, take this challenge a step further and proposed a Millennium Assessment of Human Behavior to intentionally bring people together in small groups throughout the world to "focus on the way in which people make decisions about resource allocation and risk."[160]

But before controversies reach the courts, and ideally before conflict arises, agencies may want to turn to the field of policy science. Policy science can provide a problem-oriented, contextual, and multi-

154. *Id.*

155. *Id.* at 8075.

156. Bryant, *supra* note 1, at 7 (citing A. Dan Tarlock, *Who Owns Science?* 10 PA. ST. ENVTL. L. REV. 135 (2002)).

157. Dietz et al., *supra* note 112, at 1907.

158. Elizabeth Kolbert, *The Climate of Man – III: What Can Be Done?* NEW YORKER, May 9, 2005, at 52, 63.

159. Turner *et al.*, *supra* note 152, at 8076 (citing NAT'L RES. COUNCIL, UNDER-STANDING RISK: INFORMING DECISIONS IN A DEMOCRATIC SOCIETY (P. Stern & H.V. Fineberg eds., 1996).

160. Paul R. Erlich & Donald Kennedy, *Millennium Assessment of Human Behavior*, 309 SCIENCE 562, 563 (2005).

method decision framework for applying science in a circumspect, pragmatic, and creative process to meet human needs. The concept for policy science was introduced by Harold Lasswell,[161] who has argued that leadership and "followership" are about giving and receiving orientation, respectively. In this sense, the scientist and the community with local knowledge can participate sometimes as leaders and sometimes as followers in the scientific endeavor at hand.[162] Such an approach addresses values of both for enlightenment, respect, power, rectitude, affection, skill, wealth, and well-being that people strive for through institutions affecting resources.[163]

Problem orientation is "perhaps the most tractable of the main policy sciences schema," and "identifying variation in policy contexts [of participants] is a major aim of problem orientation."[164] Problem definition, as an activity in policy or decision processes and in science is of particular importance in not only defining the scope of the NEPA process,[165] but in determining research design.[166] Specific tasks in problem definition include goal clarification, factors or actions that have affected or are affecting goal attainment (trend description), the magnitude and direction of the trends, the likelihood of attaining the goal(s), and possible strategies and their alternatives.

The tasks involved in problem orientation can be daunting for a particular community, but not necessarily fatal. To fill some of the gaps in understanding human-environment interactions and decision making processes, the National Research Council (NRC) of the National Academy of Sciences (NAS) has proposed a research agenda for improving the use of the social and behavioral sciences in environmental decision making,[167] including fostering decision-relevant science.[168]

---

161. *See, e.g.*, HAROLD D. LASSWELL, THE DECISION PROCESS: SEVEN CATEGORIES OF FUNCTIONAL ANALYSIS 2 (1956).

162. Harold D. Lasswell, *Conflict and Leadership: The Process of Decision and the Nature of Authority*, *in* CIBA FOUNDATION SYMPOSIUM ON CONFLICT IN SOCIETY, at ch. 13 (A.V.S. de Reuck & Julie Knight eds., 1966).

163. Harold D. Lasswell, The Nature of Leadership: A Policy Sciences Approach 4 (n.d.) (unpublished manuscript, on file with the Yale Manuscripts and Archives, Yale Univ. Library, New Haven, Conn.).

164. Matthew R. Auer, The Policy Sciences in Critical Perspective (Oct. 22-24, 2004) (unpublished manuscript, on file with author) (presented at the Annual Policy Sciences Institute, Yale Law School, New Haven, Conn.).

165. 40 C.F.R. §§ 1500.4(g), 1501.7.

166. Hooker, *supra* note 139.

167. NAT'L RES. COUNCIL, DECISION MAKING FOR THE ENVIRONMENT: SOCIAL AND BEHAVIORAL SCIENCE RESEARCH PRIORITIES (Garry D. Brewer & Paul C. Stern eds., 2005) (report by the Panel on Social and Behavioral Science Research Priorities for Environmental Decision Making, Committee on the Human Dimensions of Global Change) [hereinafter NRC, DECISION MAKING]; Ehrlich & Kennedy, *supra* note 160, at 562-S63.

The report recommends developing four substantive research elements in a research strategy that emphasizes decision relevance:

> (1) Developing decision-relevant indicators for environmental quality, including pressures on the environment, environmental states, and human responses and consequences;
>
> (2) Making concerted efforts to evaluate environmental policies;
>
> (3) Developing better methods for identifying the trends that will determine environmental quality in the future; and
>
> (4) Improving methods for determining the distributional impacts of environmental policies and programs.[169]

The report further argues that the measurement and analysis may need to depart from routine practices in three ways:

> (1) By measuring and analyzing the environmental implications of human actions that are taken for non-environmental reasons and which can exert major pressures on environmental systems or shape human responses to environmental conditions;
>
> (2) By involving the social and behavioral sciences in developing measures of human influences, consequences, and responses; and
>
> (3) By involving the likely producers and users of the evidence in deciding which measures and analyses to conduct with the intent of "promot[ing] the accuracy, rigor, decision relevance, transparency, and credibility of environmental information and analysis."[170]

Within the policy sciences framework,[171] collaborative approaches in carrying out the scientific process can and are being used effectively.[172] Growing evidence is suggesting that such approaches enable creative problem solving, maintain and even strengthen scientific

168. NRC, DECISION MAKING, *supra* note 167, at 85.

169. *Id.*

170. *Id.* at 87.

171. Brewer & Lövgren, *supra* note 40, at 315; *but see* William Ascher, *Resolving the Hidden Differences Among Perspectives on Sustainable Development*, 32 POL'Y SCIS. 351, 351-77 (1999).

172. *See generally* RONALD D. BRUNNER ET AL., ADAPTIVE GOVERNANCE: INTEGRATING SCIENCE, POLICY, AND DECISION MAKING (2005).

rigor, resolve seemingly intractable controversies, and foster enduring policies.[173] These approaches go beyond collaboration among scientists and across disciplines to involve potentially affected and interested communities in the scientific process. While scientists have tended to refrain from becoming involved in the fray, so to speak, collaborative approaches are consistent with efforts in other sectors, such as medicine, law, and government, to be more client-oriented. At minimum, such approaches address basic human needs for rectitude.[174] Decision support systems that continue to provide scientific information, for example, from satellites, in a usable form over time sustain knowledge even as controversies wax and wane and groups dissolve and regroup.[175]

As an immediate and practical approach, business and industry, in certain instances, have effectively adopted the laws of thermodynamics to develop guiding principles in their decision making.[176] In brief, the law of entropy indicates that the structure of matter eventually breaks down; however, biological systems have evolved to capture energy, typically sunlight, to create and maintain structure on which we depend. Preserving these self-sustaining systems is thus paramount.

The laws of conservation of energy and matter indicate that energy and matter do not disappear. Recapturing and retaining energy and matter in the "technological" cycle, therefore, becomes important. This includes recapturing energy, such as coal and petroleum, their byproducts, and other minerals, such as mercury, that had been sequestered in the Earth's crust over the past 4.5 billion years. Such process changes would protect biological systems that have evolved to require a specific temperature range, or only trace amounts of a chemical, or that have not evolved to metabolize artificial substances.

These relatively straightforward principles have led to profound reengineering of business processes and products with often positive results not only for environmental quality, but also for human well-being

173. Herman A. Karl & Elena Daly, Challenges and Obstacles to the Promise of Collaborative Approaches as a More Effective Way for Restoring Ecosystems, Deciding Environmental and Land Use Policy (Oct. 21-23, 2005) (panel presentation at the Policy Sciences Annual Institute, Yale University); *see also* Welcome, What Is Music?, MIT-USGS Science Collaborative, http://web.mit.edu/dusp/epp/music/ (last visited Dec. 15, 2006).

174. HAROLD D. LASSWELL, A PREVIEW OF POLICY SCIENCES 43 (1971).

175. Interview with Ronald J. Birk, Director, Applied Sciences Program, National Aeronautics and Space Agency, in Washington, D.C. (Nov. 1, 2005).

176. BRIAN NATTRASS & MARY ALTOMARE, THE NATURAL STEP FOR BUSINESS: WEALTH, ECOLOGY & THE EVOLUTIONARY CORPORATION 32-35 (1999).

and corporate success.[177] More recently, law firms have begun to develop niche markets in facilitating transactions compatible with sustainability principles, and some have themselves adopted such principles in their offices.[178] Financial institutions, asset managers, and government agencies are disclosing environmental risk on their balance sheets.[179]

CONCLUSION

Science is a necessary but insufficient component of agency decision making.[180] Uncertainty, incompleteness, and controversy are inescapable aspects of science. Policy fills the gaps left by incomplete science[181] just as it does in law.[182] Likewise, public participation is necessary, but is not sufficient to counter abuses of expert authority.[183] Science is not democratic.[184] However, science cannot be "owned" in the sense that its production and use can be controlled.[185] Indeed, cooperative research need not be any less rigorous and may even be more rigorous. Data sources can be distinguished as those that are collected independent of the user or affected community and those that are collected by the user or affected community, with the latter serving to supplement and corroborate the former.[186] Each source of data is subject to questioning and critique by the other. In areas where trust exists between the scientific community and the user community, the flow of information in both directions increases and becomes "data rich."[187]

Agency decisions and legal disputes often cannot wait until the science is settled. Scientific controversy is often difficult for lay practitioners to understand. In such situations, the NRC notes that even

177. *See, e.g., id.* at 31–42. For an earlier work, see, for example, PAUL HAWKEN, THE ECOLOGY OF COMMERCE: A DECLARATION OF SUSTAINABILITY (1993).

178. Stacy Lynn Bettison & Jeremy Greenhouse, *Profile: The Sustainable Business Lawyer*, PURSUITS (Env't, Energy, & Natural Res. L. Sec., Fed. B. Ass'n, Washington, D.C.), Spring 2005, at 1, 7–8.

179. Mindy Lubber, Luncheon Address at the American University, Washington College of Law, American Bar Association Section on Environment, Energy and Resources, New York State Bar Assoc., and Center for International Environmental Law Conference: The Legal Dimensions of Climate Change: A Conference by and for the Legal Profession, Washington, D.C. (Nov. 15, 2005).

180. Bryant, *supra* note 1, at 2.

181. *Id.* at 3.

182. Jacob A. Stein, *The Sweet Science*, WASH. LAW. , Mar. 2006, at 48.

183. Bryant, *supra* note 1, at 6–7.

184. *Id.* at 6 n.13 (citing William Ruckelshaus, Science and Public Policy: The Twain Must Meet, Wolfle Lecture at the University of Washington (May 16, 2002)).

185. Bryant, *supra* note 1, at 7 (citing Tarlock, *supra* note 156).

186. NRC, BSIA, *supra* note 34, at 25, 27.

187. *Id.* at 25.

the "best science" "cannot win."[188] Managers and judges take the risk of prematurely selecting one choice over another[189] or of allowing science to be "swamped repeatedly for reasons of economics, convenience, or preference."[190] To mitigate against such outcomes, the NRC recommends that not only should scientists improve communication to experts in other disciplines, lay practitioners, and the public,[191] agencies also should provide more findings to inform the record and the judicial review process[192] and provide public accountability.[193] The NRC notes:

> The rules for judicial review of science-based administrative choices are well known, but only in a general and frustratingly indeterminate fashion. Operative here is the so-called hard-look doctrine of judicial review that insists courts require agencies to explain, justify, and defend their decisions with a comfortable wrap of good sense, plausibility, and fair process. In several "best scientific information available" cases, the courts disapproved of the agency's treatment of science, condemning uses of poor analogy, stale data, end-run procedures, implausible assumptions, unexplained and erratic changes of course, failures to answer forceful objections, and fanciful guesswork....[194]

Further, "[c]ourts also afford agencies ample room to make predictions, order their own affairs, and experiment with process."[195] "Courts [also] afford a continuing scrutiny of and commentary on agency performance on matters of scientific information that are not available from other entities."[196] The NRC also noted that although "[c]ourts have reversed and remanded agency decisions contrary to 'best scientific information available' concepts that are intuitive, ad hoc, and derived from values articulated in individual judicial decisions[,]...the 'common law' of judicial review of 'best scientific information available' is insufficiently mature, elaborate, and credible for day-to-day use...."[197]

---

188. *Id.* at 59.
189. Bryant, *supra* note 1, at 10.
190. NRC, BSIA, *supra* note 1, at 59.
191. *Id.* at 32.
192. *Id.* at 53, 58–59.
193. Bryant, *supra* note 1, at 8 (citing A. Dan Tarlock, *Slouching Toward Eden: The Eco-pragmatic Challenges of Ecosystem Revival*, 87 MINN. L. REV. 1173 (2003)).
194. NRC, BSIA, *supra* note 34, at 35.
195. *Id.* at 36.
196. *Id.*
197. *Id.* at 39.

Scientists play a critical role in assisting agencies in complying with other environmental laws during the NEPA process. The principles of relevance, inclusiveness, objectivity, transparency and openness, timeliness, and an interdisciplinary, consultative process are essential to addressing the "ownership" challenge and improving the record. Science, due to inherent uncertainty, cannot be asked to answer what are essentially policy questions such as the decision to shift risk between the user and the resource. What decision makers must recognize is the difference between Type 1 and Type 2 errors, and they must explain their rationale. Through early and continued collaboration, self-learning and self-correcting mechanisms[198] can reduce risk for all. This is one experiment we cannot afford to fail. Agencies that can marshal the resources for fostering early dialogue are likely to be seen as wise:

> At its heart, the NEPA process is grounded on certain basic beliefs about the relationship between citizens and their government. Those core beliefs include an assumption that citizens should actively participate in the government, that information matters, that the environmental impact assessment process should be implemented with both common sense and imagination, and that there is much about the world that we do not yet understand.[199]

198. *Id.* at 48.
199. Bear, *supra* note 26, at 932.