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Harnessing the Power of Science in Environmental Law: Why We Should, Why We Don't, and How We Can

Mary Jane Angelo*

I. Introduction

Environmental law was born out of the new scientific understandings of ecology in the mid-twentieth century. Although science has historically played an important role in environmental law, its role has been more limited than may seem appropriate for an area of law that is so dependent on science to inform sound decision making. Environmental law has not taken full advantage of the plethora of scientific ideas developed in universities and other research institutions throughout the world.[1] Unfortunately, these new scientific ideas that could inform and improve environmental decision making rarely seem to find a home in the legal arena.

An example of a well-developed scientific idea that has the potential to benefit environmental decision making is "emergy synthesis." Emergy synthesis provides a method to value natural resources and ecosystem services in a way that captures their inherent value, rather than relying on consumer preferences and other neoclassical-economic approaches to assign them a dollar value. Emergy synthesis could improve environmental decision making under several existing environmental statutes. A few examples where emergy synthesis could play an important role include informing alternatives analysis under the National Environmental Policy Act[2] (NEPA), informing cost–benefit analysis, providing a methodology to value services under ecosystem-services-payment programs, and providing useful information under wetlands-regulatory programs to determine if mitigation proposals adequately offset impacted wetlands. Unfortunately, despite the potential benefits of incorporating emergy synthesis into environmental law—and despite the widespread use of emergy synthesis by the scientific community for more than thirty years—legal scholars, practitioners, and regulators have failed to even consider it as an option. While admittedly more work would need to be done to determine what role emergy synthesis

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1. *See* Michael E. Soulé et al., *Strongly Interacting Species: Conservation Policy, Management, and Ethics*, BIOSCIENCE, Feb. 2005, at 1, 1 (describing how environmental laws and regulations quickly become obsolete because they fail to keep up with new scientific developments).

2. 42 U.S.C. §§ 4321–4370e (2000).

should play in environmental decision making, it is curious that a well-developed scientific idea with such potential benefits has almost completely slipped under the radar screen of the legal and policy communities.

Emergy synthesis is just one example that illustrates the reluctance or inability of the law to incorporate certain scientific ideas that could greatly advance efforts aimed at sound environmental decision making. While some scientific ideas have easily found a home and proliferated in environmental law, others wait on the sidelines for someone to take notice. One example of a scientific idea that has become ubiquitous in environmental law is that of "risk assessment," a mainstay in modern environmental law. An example of a scientific idea that has received much attention by scientists, regulators, resource managers, and legal scholars, but that has not yet found a home in the law, is that of "adaptive management."

Why do some scientific developments easily gain a foothold in the law while others, which appear to have the potential to be equally useful, remain unknown or unutilized? A number of factors appear to limit the ability of environmental law to adapt to and incorporate new scientific developments that could greatly improve environmental decision making. Some of these factors reflect the inherent conflicts between science and law, while others are more specific to the scientific idea at issue. This Article seeks to identify some of the factors that influence whether scientific ideas are integrated into the law and to explore ways in which the law could be more accepting of potentially beneficial scientific ideas. This Article begins by reviewing the ways in which science informs and enhances environmental law, as well as the barriers that often inhibit new scientific developments from being used in environmental law. While recognizing that barriers and opportunities exist in a number of legal forums, including the judicial setting and the legislative setting, this Article focuses on barriers and opportunities in the administrative-rulemaking and policy-development settings.

To illustrate how legal scholars, lawmakers, environmental agencies, and practicing lawyers have attempted to incorporate new scientific developments into environmental law, particularly in the administrative context, this Article traces the journeys of three distinct scientific developments—risk assessment, adaptive management, and emergy synthesis—from scientific academia to environmental administrative law. These three scientific developments were chosen because, although all three are relatively recent developments, they have had unique journeys and varying degrees of success in being incorporated into the law. Risk assessment has been embraced by regulatory agencies and has become an integral part of environmental law. Adaptive management, on the other hand, while endorsed by scientists and legal academics, has not yet successfully found a home in the law. Finally, emergy synthesis—although it has existed for more than thirty years, has been widely accepted in the scientific community, and has the potential to transform environmental decision making—has been largely ignored by the legal community. Using the framework put forth in the book *The Tipping Point*[3] to evaluate why some ideas catch on and others do not, this Article then explores the reasons why the law has treated these different scientific developments in such dramatically different ways. The Article concludes by making observations about what types of scientific developments are most likely to be incorporated into the law and suggesting ways for improving the likelihood that new beneficial developments will be adopted to inform the law.

II. The Importance of Science in Environmental Law (Why We Should)

Environmental law is a system consisting of numerous statutes, regulations, policies, and court decisions that attempts to reduce or eliminate certain harms to humans and the environment. To reduce or eliminate harm, it is necessary to understand the harm by gaining an understanding of, among other things, the following: whether the risk of harm exists; what the nature of the harm is; under what circumstances or at what levels of exposure the harm is likely to occur; how the risk of harm changes as circumstances change or as levels of exposure change; what technologies, processes, or alternatives can be employed to reduce the risk of harm; how effective those technologies or processes are at reducing that risk; and how cost-effective the different alternatives are. Science can provide information that can help to answer virtually all of these questions.

Of course, the role of science should not be overstated. Science can play an important role in informing decision making, but it cannot answer policy questions, such as how much risk we are willing to tolerate or how much money we are willing to pay to reduce a risk. Pure science may tell us what is likely to happen as a result of a certain action, but it cannot in itself tell us whether that outcome is "good" as a matter of policy. On the other hand, a policy decision about a desired outcome is worth little without scientific information demonstrating whether a particular action is likely to achieve the desired outcome. Because of the stark difference between their two disciplines, lawyers and scientists go about solving problems in ways that do not always make sense to one another. However, there is no question that both are needed to have sound environmental decision making.

The natural world is complex and ever-changing. As the science of ecology has blossomed over the past several decades, our understanding of the uncertainties and complexities inherent in the natural world has grown. Sophisticated scientific understanding is needed to understand how human activity impacts the natural world. Questions regarding the extent of an impact, the long-term implications of an impact, and the ability of the natural world to recover from a particular impact simply cannot be answered without the assistance of science. Neither science standing alone nor law standing

3. MALCOLM GLADWELL, THE TIPPING POINT: HOW LITTLE THINGS CAN MAKE A BIG DIFFERENCE (2000).

alone can fully address the environmental issues we face. Ultimately, environmental decision making must be based on an integration of science and policy.

III. The Disconnect Between Law and Science (Why We Don't)

The uneasy relationship between science and law flows from the inherently different purposes and processes of the two disciplines, which are not easily harmonized.[4] The purpose of science is to seek the truth, whereas the purpose of the law is to seek justice or at least reasonable and fair resolution to disputes.[5] The scientific process relies on the ability to test hypotheses through the scientific method.[6] No matter the inspiration for a scientific hypothesis, every scientific hypothesis ultimately must be subjected to testing and found to be reproducible to be accepted.[7] The critical factor in determining whether something is science is whether, at least in theory, it is falsifiable.[8] In other words, in theory the hypothesis could be disproved by an experimental result.[9] Law, on the other hand, by its very nature deals with human behavior,[10] which is profoundly more difficult to subject to falsification through experimentation.[11] Another critical distinction is that

4. For analysis of some barriers separating law and science, see generally DAVID L. FAIGMAN, LEGAL ALCHEMY: THE USE AND MISUSE OF SCIENCE IN THE LAW (1999) (focusing on the law's impatience with the limitations of scientific methods); STEVEN GOLDBERG, CULTURE CLASH: LAW AND SCIENCE IN AMERICA (1994) (discussing the paradoxical contrast between the United States' vigorous support for scientific research and its slow and sporadic implementation of the results of that research); STEVEN GOLDBERG & LAWRENCE O. GOSTIN, LAW AND SCIENCE (2006) (evaluating the relationship between law and science, particularly with regard to genetics, nuclear energy, medicine, and computers); Joseph F.C. DiMento & Helen Ingram, *Science and Environmental Decision Making: The Potential Role of Environmental Impact Assessment in the Pursuit of Appropriate Information*, 45 NAT. RESOURCES J. 283 (2005) (reviewing alternative explanations of the sometimes troubled relationship between science and environmental decision making); Richard V. Pouyat, *Science and Environmental Policy—Making Them Compatible*, BIOSCIENCE, Apr. 1999, at 281, 281 (describing some of the most challenging barriers separating ecological and biological science and public policy); Carol M. Rose, *Environmental Law Grows Up (More or Less), and What Science Can Do to Help*, 9 LEWIS & CLARK L. REV. 273 (2005) (assessing the role of science in a maturing, modern environmental law).

5. *See* SHEILA JASANOFF, SCIENCE AT THE BAR: LAW, SCIENCE, AND TECHNOLOGY IN AMERICA 5–11 (1995) (contrasting the cultures of legal and scientific inquiry by noting that "fact-finding in the law is always contingent on a particular vision of . . . delivering social justice," while "science is ordinarily seen as set apart from all other social activities by virtue of its institutionalized procedures for overcoming particularity and context dependence and its capacity for generating claims of universal validity").

6. GOLDBERG, *supra* note 4, at 7; *see* Daniel J. McGarvey, *Merging Precautions with Sound Science Under the Endangered Species Act*, BIOSCIENCE, Jan. 2007, at 1, 1 (describing how hypothesis tests aim to minimize type I errors (false positives), whereas the goal of environmental decision making typically is to prevent type II errors (false negatives)).

7. GOLDBERG, *supra* note 4, at 7.

8. *Id.* at 8.

9. *Id.*

10. *Id.* at 13.

11. *See id.* at 14 ("Human history does not lend itself to the running of controlled experiments.").

while science emphasizes cumulative progress in understanding the world—each experiment builds on previous ones to increase cumulative knowledge—law emphasizes "process."[12] In other words, law's primary purpose is to resolve human disputes rather than to continually add to a body of testable knowledge.[13]

One of the biggest challenges of the legal system is to be able to address the uncertainty inherent in science, which may result from a lack of data, inconsistent data, or conflicts in the interpretation of data.[14] Many gaps and uncertainties exist in the scientific information relied upon to make environmental policy decisions.[15] Some of the gaps are due to the fact that many areas simply have not been fully studied as a result of limited funding for environmental studies, the low likelihood of being able to reap future profits from environmental studies, or mere lack of interest.[16] Other areas that have been studied may still present uncertainty because studies may have inconsistent results or because experts who review the studies may have conflicting interpretations of the quality, meaning, and significance of the studies.[17] Finally, many scientific studies in the environmental arena are influenced by political pressure, business pressure, or the impacts of advocacy science that are inevitable when profit-making motives are pitted against environmental or public-health protection.[18]

Although a significant amount of literature exists examining the often uneasy relationship between law and science, the vast majority of it focuses on the use of science in the courtroom.[19] Specifically, much of the literature

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12. *Id.* at 13–20.

13. *Id.*

14. *See* Holly Doremus, *The Purposes, Effects, and Future of the Endangered Species Act's Best Available Science Mandate*, 34 ENVTL. L. 397, 438–39 (2004) (stating that uncertainty in science is unavoidable); Daniel A. Farber, *Probabilities Behaving Badly: Complexity Theory and Environmental Uncertainty*, 27 ENVIRONS ENVTL. L. & POL'Y J. 145, 148–52 (2003) (describing some of the uncertainties that exist in current environmental science); John M. Volkman, *Managing Uncertainty in Species Conservation Policy*, 74 WASH. L. REV. 719, 723–24 (1999) (stating that there is much uncertainty in species-conservation policy); Wendy E. Wagner, *Commons Ignorance: The Failure of Environmental Law to Produce Needed Information on Health and the Environment*, 53 DUKE L.J. 1619, 1625–33 (2004) (describing the lack of scientific research and data on environmental problems); Vern R. Walker, *Keeping the WTO from Becoming the "World Trans-science Organization": Scientific Uncertainty, Science Policy, and Factfinding in the Growth Hormones Dispute*, 31 CORNELL INT'L L.J. 251, 258–62 (1998) (describing the kinds of scientific uncertainty prevalent in risk assessments).

15. Wagner, *supra* note 14, at 1625–30.

16. *Id.* at 1631–33.

17. *See* Doremus, *supra* note 14, at 438 ("Choices of how to interpret equivocal data and what to do in the face of uncertainty are not 'scientific' as the public understands that term, although they are familiar to scientists and indeed are an unavoidable part of the scientific enterprise.").

18. *See, e.g.*, Wagner, *supra* note 14, at 1631–32. ("[Private] actors vastly prefer ignorance over research because most documentation of externalities will ultimately affect them negatively. Thus, rather than contribute to enlightenment, actors seem more willing to contribute to, and even invest in, the perpetuation of ignorance.").

19. *See, e.g.*, DAVID S. CAUDILL & LEWIS H. LARUE, NO MAGIC WAND: THE IDEALIZATION OF SCIENCE IN LAW, at xiii (2006) ("Our focus in this book is on the current use of science in the

involves the use of expert witnesses and the challenges judges and juries face in determining the quality of scientific evidence.[20] In the courtroom setting, the role of science has been limited by the "gatekeeping" role assigned to judges to determine the reliability of the scientific evidence. The fallout of the 1993 case *Daubert v. Merrell Dow Pharmaceuticals, Inc.*,[21] which solidified this gatekeeping role, has been to create a high hurdle that must be overcome before expert scientific testimony will be permitted in the courtroom. Moreover, judicial proceedings require that, in most civil cases, scientific issues be demonstrated by the party bearing the burden of proof by a preponderance of the evidence, just like any other factual matters must be.[22] Accordingly, for a party, such as an environmental regulatory agency or environmental organization, to overcome the *Daubert* hurdle and to demonstrate by a preponderance of the evidence that its scientific position should prevail is extremely challenging.[23] Another obvious reason why law and science have such an uneasy relationship in the courtroom is that the great majority of judges and juries are not educated in the hard sciences and do not have the technical expertise necessary to fully understand, interpret, and apply scientific evidence.[24] Moreover, the rapid technical advances in the sciences make it difficult for even those so inclined to keep up with new developments.[25] It is no wonder that courts are loathe to accept new cutting-edge scientific developments.

In the administrative-rulemaking arena, it is relatively easy to incorporate new or different scientific ideas as compared to the courtroom setting. If an agency, such as the Environmental Protection Agency (EPA), decides to utilize a new scientific approach, very few legal barriers or challenges exist. There is no *Daubert*-type requirement that the approach be shown to be reliable before it will be allowed.[26] To the extent anyone is playing a gatekeeping role, it is the agency itself. Moreover, if the agency promulgates a rule based on a new or different scientific approach, the

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courtroom."); JASANOFF, *supra* note 5, at xiii ("My purpose is to explore how . . . science and the courts[] interact with each other . . . .").

20. JASANOFF, *supra* note 5, at xiii.

21. 509 U.S. 579 (1993). A recent Westlaw search of law review articles containing the word "Daubert" in their titles found 547 such articles.

22. *See Daubert*, 509 U.S. at 593 n.10 (noting that, when determining the admissibility of scientific evidence, factual issues "should be established by a preponderance of proof"); JASANOFF, *supra* note 5, at 10 ("In order to prevail the plaintiff must prove his claim by a 'preponderance of the evidence'—in other words more than 50 percent of the evidence must be in the plaintiff's favor.").

23. *See, e.g.*, JASANOFF, *supra* note 5, at 120 ("It is difficult to establish by a preponderance of the evidence that such commonly occurring complaints as leukemia, birth defects, loss of fertility, and neurological or psychological disorders resulted from contact with one or another toxic substance.").

24. *Id.* at 5.

25. *Id.* at 7.

26. Wendy E. Wagner, *Importing* Daubert *to Administrative Agencies Through the Information Quality Act*, 12 J.L. & POL'Y 589, 591–92 (2004).

standard of review of the agency action generally will be the arbitrary and capricious standard—barring agency action for which there is no reasonable rationale—which at least in theory should be hard to meet.[27]

Due to the ease with which agencies should be able to incorporate new scientific ideas into their rule and policy development, at least from a purely legal perspective, it is unclear why agencies such as EPA have not taken advantage of the many potentially beneficial scientific ideas that have come out of universities and other research institutions in the United States and throughout the world. The arbitrary and capricious standard of judicial review should in theory result in courts being highly deferential to agency rulemaking and policy development, including in the area of incorporating new or different scientific ideas into agency decision making. However, as other scholars have demonstrated, courts have expanded their role in arbitrary and capricious review via the "hard look" doctrine, which has contributed to regulatory ossification.[28] As explained by Professors Lynn Blais and Wendy Wagner elsewhere in this Issue, the fear that courts will scrutinize and strike down their decisions has contributed to the reluctance on the part of agencies to develop new rules or to revise existing rules to take into account new technological developments.[29] Likewise, such fears are likely to inhibit agencies from attempting to utilize new scientific ideas. Of course, agencies are subject to political pressures that may influence their willingness to look to the world of science for new ideas. Moreover, it is possible that simple bureaucratic inertia makes agencies slow to adopt new or different ideas. Nevertheless, regardless of the political leanings of a particular administration or the general slow pace of government action,

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27. *See* 5 U.S.C. § 706 (2000) (setting standards for judicial review of agency action); *see also* Motor Vehicles Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co., 463 U.S. 29, 43–44 (1983) (requiring that agencies take a "hard look" at the data, arguments, and alternatives before making a final decision); Citizens to Pres. Overton Park, Inc. v. Volpe, 401 U.S. 402, 419–20 (1971) (requiring an agency to base its decision on the whole record, not on "merely post hoc rationalizations").

28. Thomas O. McGarity, *The Courts and the Ossification of Rulemaking: A Response to Professor Seidenfeld*, 75 TEXAS L. REV. 525, 527–29 (1997); Thomas O. McGarity, *Some Thoughts on "Deossifying" the Rulemaking Process*, 41 DUKE L.J. 1385, 1410–12 (1992); *see also* Thomas O. McGarity & Wendy E. Wagner, *Legal Aspects of the Regulatory Use of Environmental Modeling*, 33 Envtl. L. Rep. (Envtl. Law Inst.) 10,751, 10,770 (2003) (analyzing thirty years of judicial challenges to EPA rulemakings to identify the types of constraints the court imposed under the Administrative Procedure Act).

29. Lynn E. Blais & Wendy E. Wagner, *Emerging Science, Adaptive Regulation, and the Problem of Rulemaking Ruts*, 86 TEXAS L. REV. 1701, 1706 (2008); *see also* Wagner, *supra* note 26, at 603–04 (stating that placing stricter scientific burdens on agencies will cause them to avoid promulgating new regulations). Scholars have also identified the increased oversight role of the Bush Administration's Office of Management and Budget (OMB) and its "sound science" crusade as a major factor in regulatory ossification. *See, e.g.*, Roni A. Neff & Lynn R. Goldman, *Regulatory Parallels to* Daubert*: Stakeholder Influence, "Sound Science," and the Delayed Adoption of Health-Protective Standards*, 95 AM. J. PUB. HEALTH (SUPPLEMENT I) S81, S87 (2005) (describing how the charade of "sound science" hampers the government's ability to safeguard the public's health and well-being).

agencies are receptive to some new scientific ideas, but they curiously appear to be reluctant to consider other scientific developments that may help address the many difficult challenges faced by the agencies.

IV. The Use of Science in Environmental Law (How We Have)

Although for the foregoing reasons the relationship between science and environmental law has been strained, historically the law has readily incorporated certain scientific ideas, developments, or approaches, while completely ignoring or even shunning others. For example, risk assessment is a scientific approach that has found a home in many aspects of environmental law and policy. Other scientific ideas, such as adaptive management, while widely discussed in the legal academic literature, have not yet found a strong foothold in the law and are put to limited use in only certain aspects of environmental decision making. Emergy synthesis, a scientific idea whose origins date back more than fifty years, is widely accepted in the scientific academic community, holds great promise as a tool to inform environmental decision making, and yet has barely shown up as a small blip on the environmental law and policy radar screen. This Article asks the question: Why are some scientific ideas embraced by the legal and policy world, while others that appear to be of equal if not greater utility, such as emergy synthesis, are ignored? To attempt to find some patterns, this Article looks at the history of three scientific ideas—risk assessment, adaptive management, and emergy synthesis—to attempt to discern patterns relating to acceptance by the legal and policy communities.

A. Emergy Synthesis

Emergy analysis was developed by Howard T. Odum as part of a broad theory regarding the role of energy in systems derived from Alfred Lotka's "maximum power principle" from the 1920s.[30] It appears that Odum's first foray into the concept of emergy began in the 1950s when he, along with his brother Eugene, defined the crucial role of energetics in ecology.[31] As part of their work on energetics, the Odum brothers acknowledged that the "quality" and not merely the "quantity" of energy is significant.[32] The Odums' recognition that there was a need for a "common denominator" for describing different kinds of energy led H.T. Odum to use the term

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30. *See* HOWARD T. ODUM, ENVIRONMENTAL ACCOUNTING: EMERGY AND ENVIRONMENTAL DECISION MAKING 15–21 (1996) (introducing the concept of emergy and citing to Lotka's maximum power principle); Alfred J. Lotka, *Contribution to the Energetics of Evolution*, 8 PROC. NAT'L ACAD. SCI. 147, 147–49 (1922) (presenting the maximum power principle).

31. *See generally* EUGENE P. ODUM & HOWARD T. ODUM, FUNDAMENTALS OF ECOLOGY (1953).

32. Mark T. Brown & Sergio Ulgiati, *Energy Quality, Emergy, and Transformity: H.T. Odum's Contributions to Quantifying and Understanding Systems*, 178 ECOLOGICAL MODELLING 201, 201–02 (2004). Energetics is "a branch of mechanics that deals primarily with energy and its transformations." MERRIAM-WEBSTER'S COLLEGIATE DICTIONARY 413 (11th ed. 2003).

"embodied energy" to mean the amount of one kind of energy required to make the same amount of another.[33] Odum abandoned the term "embodied energy" because it was being used by others for some different purposes and instead adopted the term "emergy."[34] Emergy is now commonly understood to capture the idea of energy memory, or in other words, how much of one type of energy is required to make another.[35]

During the 1970s, H.T. Odum refined his ideas and developed the concept that is now known as "emergy synthesis,"[36] which has been further expanded and refined by other scholars over the past thirty years.[37] Emergy synthesis provides a methodology to value resources or services based on their "intrinsic" value rather than based on consumer preferences.[38] Emergy synthesis is considered a "donor" value system because it is based on the principle that the energy that goes into creating a resource or service determines its value.[39] Although emergy synthesis has reached a high level of sophistication and is accepted and used by scientists worldwide,[40] to date it has not found a place in the legal or policy arena.[41]

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33. Brown & Ulgiati, *supra* note 32, at 202–03.

34. *Id.* at 203.

35. *Id.* at 205 ("Emergy is the availability of energy (exergy) of one kind that is used up in transformations directly and indirectly to make a product or service.").

36. A partial list of Dr. H.T. Odum's emergy publications includes H.T. ODUM, ENERGY, ENVIRONMENT AND PUBLIC POLICY: A GUIDE TO THE ANALYSIS OF SYSTEMS (1988); HOWARD T. ODUM ET. AL., ENVIRONMENT AND SOCIETY IN FLORIDA (1998); HOWARD T. ODUM, ENVIRONMENTAL ACCOUNTING: EMERGY AND ENVIRONMENTAL DECISION MAKING (1996); HOWARD T. ODUM & ELISABETH C. ODUM, A PROSPEROUS WAY DOWN: PRINCIPLES AND POLICIES (2001); Howard T. Odum, *Embodied Energy, Foreign Trade and Welfare of Nations*, *in* INTEGRATION OF ECONOMY AND ECOLOGY—AN OUTLOOK FOR THE EIGHTIES 185–99 (A.M. Jansson ed., 1984); Howard T. Odum, *Folio #2: Emergy of Global Processes*, *in* HANDBOOK OF EMERGY EVALUATION: A COMPENDIUM OF DATA FOR EMERGY COMPUTATION ISSUED IN A SERIES OF FOLIOS (2000); Howard T. Odum, *Self-Organization, Transformity, and Information*, 242 SCIENCE 1132 (1988).

37. The emergy Web site at the University of Florida alone lists more than 300 publications by University of Florida faculty and graduate students related to emergy synthesis. *See* Emergy Systems.org, Publieations, http://www.emergysystems.org/ publications.php (last updated Jan. 26, 2008).

38. Mark T. Brown & Sergio Ulgiati, *Emergy Evaluation of the Biosphere and Natural Capital*, 28 AMBIO 486, 487 (1999).

39. *Id.*

40. Jorge L. Hau & Bhavik R. Bakshi, *Promise and Problems of Emergy Analysis*, 178 ECOLOGICAL MODELLING 215, 216 (2004).

41. During the early years of emergy research, at least one lawmaker considered using emergy in environmental or energy decision making. For example, in his book, ENVIRONMENTAL ACCOUNTING, Odum states:

> In 1975 our initiatives through Senator M. Hatfield of Oregon caused a federal law to be introduced requiring "net energy analysis" of new projects. Because the words "energy" and "embodied energy" were not clearly defined, the implementation of the law became confused and its purpose of preventing wasteful projects was circumvented. While noting the illegal substitution of economic analysis for energy analysis, the U.S. General Accounting Office (GAO, 1982) reviewed energy analysis methods describing three approaches: process analysis; input–output analysis; and our approach, which they called "ecoenergetics." They wrote:

One potential benefit of emergy synthesis over currently used methodologies is that it eliminates the need to employ neoclassical-economic approaches to value resources or services. Whether, or how, to assign economic value to natural resources and systems has been one of the most controversial areas of environmental law for decades.[42] Economics plays a role in many areas of environmental law. For example, most environmental regulatory statutes impose a requirement that either cost–benefit balancing or feasibility analysis be used to determine pollution-control standards.[43] In addition, economic analyses, such as cost–benefit balancing, are often used to choose between competing project sites or project alternatives.[44] Recently, with the development of ecosystems-services payment programs, economics has taken on an even greater role.[45] However, the use of economics in

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> Ecoenergetics has broad appeal in its emphasis on the fullest possible measurement of the embodied energy of labor, environmental systems, and solar energy, but its analytical boundaries are more extensive than seems appropriate for the analysis of alternative energy technologies, as we explain at greater length [elsewhere]. Moreover, a set of consistent quantitative methods has yet to be developed for it. Therefore we chose not to use ecoenergetics.

ODUM, *supra* note 30, at 277–78 (alteration in original) (emphasis omitted); *see also* U.S. GEN. ACCOUNTING OFFICE, GAO/IPE-82-1, DOE FUNDS NEW ENERGY TECHNOLOGIES WITHOUT ESTIMATING POTENTIAL NEW ENERGY YIELDS, at summary (1982), *available at* http://archive.gao.gov/f0102/119139.pdf ("GAO recommends that the Congress require DOE to consider the potential net energy yields of proposed technologies and to provide the analytie support needed to implement net energy analysis.").

42. *See, e.g.*, DANIEL A. FARBER, ECO-PRAGMATISM: MAKING SENSIBLE ENVIRONMENTAL DECISIONS IN AN UNCERTAIN WORLD 9 (1999) ("I argue for a pragmatic approach to environmental problems, in which economic analysis is useful, but not controlling. . . . [T]he dichotomy between economics and value judgments turns out to be a false one."); SIDNEY A. SHAPIRO & ROBERT L. GLICKSMAN, RISK REGULATION AT RISK: RESTORING A PRAGMATIC APPROACH 1–2 (2003) (describing U.S. environmental, health, and safety laws as historically based on preventative risk regulation and noting the many critics who find risk regulation irrational because it often leads to solutions whose economic costs are much greater than their economic benefits).

43. *See* FARBER, *supra* note 42, at 7 (noting that President Reagan issued an order in 1981 requiring all government agencies to base their decisions on cost–benefit analysis except when prohibited from doing so by statute); *see also id.* at 119 (noting that feasibility analysis is employed in certain EPA regulations that direet a particular firm to achieve the specific level of pollution control it considers feasible).

44. *See, e.g.*, NAT'L CTR. FOR ENVTL. ECON., EPA, ENVIRONMENTAL ECONOMIC RESEARCH AT EPA § 3.4 (2008), http://yosemite.epa.gov/ee/epalib/ord1.nsf/77e34926d19d5664852565a500501ed6/6f63dca022f9544585256625006ccdc8!OpenDocument ("When economic information cannot be used to set the regulatory goal, policy makers at a minimum would like that their regulations achieve the goal at least cost. In a great many cases, [EPA] does have the discretion to select the most cost-effective approach from among regulatory approaches that yield equivalent outcomes.").

45. *See* J.B. Ruhl, *Ecosystem Services and the Common Law of "The Fragile Land System,"* NAT. RESOURCES & ENV'T, Fall 2005, at 3, 69 (describing an ecosystems approach based on proof of economic harm); James Salzman, *A Field of Green? The Past and Future of Ecosystem Services*, 21 J. LAND USE & ENVTL. L. 133, 135–36 (2006) (discussing the economic problems associated with public goods and collective action as one barrier to creating markets in ecosystems services); James Salzman, *Creating Markets for Ecosystem Services: Notes from the Field*, 80 N.Y.U. L. REV. 870, 870 (2005) ("In recent years, an increasing number of initiatives around the world have sought to create markets for [ecosystem] services, some dependent on government intervention and some created by entirely private ventures."); James Salzman, *The Promise and Perils of Payment for*

environmental law is not without controversy.[46] The criticism of the use of economics in environmental law is in large part attributable to the fact that it relies on neoclassical economics to value ecological resources and services.[47]

The shortcomings of using neoclassical-economic analysis in environmental law have been well documented.[48] One of the most significant shortcomings is the difficulty of assigning a dollar value to many environmental resources and services using neoclassical-economic methods. Most ecological resources and services are not bought and sold on the market and consequently do not have a market value.[49] Neoclassical economics attempts to place a dollar value on such nonmarket resources by using "contingent valuation" to determine consumers' willingness to pay for that resource or service.[50] Many criticize the use of contingent valuation because many question its assumption that environmental values are significant only to the extent that consumers are willing to pay to preserve them.[51] The problems with assuming that a resource's value is only determined by how much a consumer is willing to pay are manifold. First, contingent valuation assumes that consumers have perfect information and adequate technical

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Ecosystem Services, 1 INT'L J. INNOVATION & SUSTAINABLE DEV. 5, 5 (2005) (identifying different types of ecosystems-service markets and examining the challenges posed by each).

46. *See, e.g.*, FARBER, *supra* note 42, at 6–8 (describing the argument over how best to protect the environment between proponents of cost–benefit analysis and proponents of environmental values).

47. John M. Heyde, *Is Contingent Valuation Worth the Trouble?*, 62 U. CHI. L. REV. 331, 332 (1995); *see also* HERMAN E. DALY & JOSHUA FARLEY, ECOLOGICAL ECONOMICS: PRINCIPLES AND APPLICATIONS 24–26 (2003) (describing the circular flow model—the pre-analytic vision of standard economics—and its shortcomings); FARBER, *supra* note 42, at 52–53 (noting criticisms of basing environmental policy on market preferences that highlight the "stark division between the interests people have as private consumers and those they have as citizens").

48. *See* FARBER, *supra* note 42, at 35 (noting that "[m]uch of the environmental scholarship of the past twenty years has been dominated by the struggle between" political and economic approaches).

49. Because there are no significant markets for most environmental services, cost–benefit analyses, preparation of environmental impact statements, wetlands mitigation banking, Superfund remediations, and oil-spill cleanups often ignore these services. James Salzman, Barton H. Thompson, Jr. & Gretchen C. Daily, *Protecting Ecosystem Services: Science, Economics, and Law*, 20 STAN. ENVTL. L.J. 309, 311–12 (2001).

50. *See* FARBER, *supra* note 42, at 49 (noting that "some economists advocate the use of 'contingent valuation' studies to measure how much people are willing to pay for nonuse values"); Heyde, *supra* note 47, at 339 ("Contingent valuation is a public opinion surveying technique: surveyors ask members of a sample group how much they would be willing to pay to restore a resource to its undamaged state. The results are then aggregated . . . to provide a statistical picture of how much society as a whole values the resource in question.").

51. *See* FARBER, *supra* note 42, at 49 ("There is a great deal of dispute about whether contingent valuation, even if done carefully, provides a genuine measure of preferences. . . . [C]ritics doubt that people actually have preferences about specific environmental sites or that their responses reflect considered efforts to assess such preferences."); Heyde, *supra* note 47, at 333 ("Courts and natural resource trustees should abandon contingent valuation. . . . [O]bsession with the 'perfect' damages figure tends to commodify our understanding of natural resources, thereby undermining the proper relationship that society should have with these resources.").

understanding to determine how much money they would be willing to pay for an ecological resource or service, even one as complex and as little understood as, for example, nutrient cycling. In addition, researchers have demonstrated that the concept of "willingness-to-pay" typically used in contingent valuation is inherently skewed toward valuing the right to use resources rather than the right to preserve resources,[52] and that generally, the amount that consumers are willing to pay to protect a resource is only about one-half of the amount that the same consumer would be willing to accept to allow the resource to be exploited.[53] Perhaps, most significantly, however, many have argued that consumer preference has nothing to do with the importance of the ecological resource or service for sustaining life on earth.[54] Many ecological goods and services are not assigned any value by neoclassical-economic analysis and thus are rarely included in any meaningful way in traditional cost–benefit analysis. Scientists have been working to develop alternative methods for assigning a value to ecological resources and services for many years.[55] Emergy synthesis is one of these alternative valuation methodologies, which provides a valuation methodology that relies on science rather than on consumer preferences.

Emergy synthesis has numerous advantages over neoclassical-economic systems of assigning value to resources and services. Emergy synthesis is based on the principle that the energy embodied in a resource or service determines its value. As such, it relies on the intrinsic value of resources and services. Emergy synthesis rejects contingent valuation, a measure of what emergy proponents characterize as a "receiver" system of value, in favor of a donor system of value. A donor system of value based on solar energy required to produce things rejects the underlying assumption of neoclassical-economic valuation, which suggests that value stems only from utilization by humans.[56]

Scientific scholars have analyzed emergy synthesis and have found it to have a number of benefits over traditional approaches.[57] For example,

52. FARBER, *supra* note 42, at 99–101.

53. *Id.* at 100.

54. Brown & Ulgiati, *supra* note 38, at 493.

55. *See, e.g.*, DALY & FARLEY, *supra* note 47, at 29 (arguing that consideration of the linear throughput of resources in an economy should be added to the traditional circular flow model).

56. Brown & Ulgiati, *supra* note 38, at 486.

57. CHARLES O. HOLLIDAY, JR. ET AL., WALKING THE TALK: THE BUSINESS CASE FOR SUSTAINABLE DEVELOPMENT 83–85 (2002) (describing the benefits of "eco-efficiency," a methodology similar to emergy synthesis in that eco-efficiency recognizes the inherent value of natural resources and seeks to minimize the amount of that value used in producing goods and services). For discussions of the benefits of other concepts that comprise emergy synthesis, see Kenneth Arrow et al., *Economic Growth, Carrying Capacity, and the Environment*, 268 SCIENCE 520, 521 (1995) (arguing that traditional economic policy is not an adequate substitute for environmental policy that takes into account the planet's carrying capacity); Bhavik R. Bakshi, *A Thermodynamic Framework for Ecologically Conscious Process Systems Engineering*, 24 COMPUTERS & CHEMICAL ENGINEERING 1767, 1767–68 (2002) (arguing that traditional process engineering considers environmental objectives as secondary to economic objectives but that

emergy synthesis has been lauded in that it provides a bridge that connects economic and ecological systems.[58] Since emergy can be quantified for any system, its economic and ecological aspects can be compared on an objective basis that is independent of its monetary perception.[59] Emergy synthesis compensates for the inability of money to value nonmarket inputs in an objective manner.[60] Moreover, emergy synthesis has been praised for being scientifically sound and sharing the rigor of thermodynamic methods, for utilizing a common unit which allows all resources to be compared on a fair basis, for rccognizing the different qualities of energy, and for providing a more holistic alternative to many existing methods of environmentally conscious decision making.[61]

Although criticisms have been leveled at emergy synthesis, they are primarily based on a lack of understanding on the part of the critics, on insufficient communication of emergy theory outside of the scientific world by emergy scholars, on a lack of clear links with related concepts in other disciplines, and on the types of general criticisms that are often directed at new, groundbreaking ideas.[62]

One of the fundamental benefits of emergy synthesis is that it represents a new model for a new science that, rather than bridging multiple disciplines, incorporates those disciplines in itself. Emergy synthesis integrates economic and scientific values into one metric.[63] Moreover, emergy values resources and services in an objective scientific manner that does not rely on consumer preferences.[64] Accordingly, emergy synthesis appears to provide a very useful methodology that could inform the difficult decisions that must be made in the face of less-than-perfect data.

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emergy theory properly accounts for both objectives); Paul Ekins et al., *A Framework for the Practical Application of the Concepts of Critical Natural Capital and Strong Sustainability*, 44 ECOLOGICAL ECON. 165, 166 (2003) (stating that traditional economic models do not properly account for nonpriced, eommon-property environmental resources).

58. *See* Bakshi, *supra* note 57, at 1767 (stating that emergy combines the benefits of both economic and ecologieal analysis).

59. Hau & Bakshi, *supra* note 40, at 218.

60. *Id.*

61. *Id.*

62. *Id.* at 223 (reviewing criticisms of emergy and concluding that many of the criticisms apply not just to emergy analysis but to all methods that employ a holistie view). Publications that provide criticism of emergy analysis include: DANIEL T. SPRENG, NET ENERGY ANALYSIS AND THE ENERGY REQUIREMENTS OF ENERGY SYSTEMS 289 (1988); Cutler J. Cleveland et al., *Aggregation and the Role of Energy in the Economy*, 32 ECOLOGICAL ECON. 301, 313 (2000) (stating that econometric analysis of energy use reveals a strong correlation between energy use and economic output and demonstrates that economic performance is not decoupled from energy use); B.Å. Mansson & J.M. McGlade, *Ecology, Thermodynamics and H.T. Odum's Conjectures*, 93 OECOLOGIA 582, 588–92 (1993) (criticizing the use of energy as a curreney to describe ecology).

63. Mary Jane Angelo & Mark T. Brown, *Incorporating Emergy Synthesis into Environmental Law: An Integration of Ecology, Economics, and Law*, 37 ENVTL. L. 963, 974 (2007).

64. *Id.* at 984–85.

Among the most promising uses of emergy synthesis are as a way to inform decision making on the severity of environmental impacts on an ecosystem, and as a way to choose which is the most environmentally efficient of two or more proposed options for development or restoration.[65] Analyzing all of the emergy inputs and outputs to the ecosystem under each option can tell us which option results in the most emergy loss or gain.

Emergy synthesis can provide an objective measure of inherent value that does not rely on consumer preferences. However, emergy synthesis should not be viewed as a panacea. The information resulting from emergy synthesis, while extremely useful, should not be viewed as providing any absolute answers. The emergy value of a resource or a service, in itself, does not tell you whether that resource or service is good or bad, merely that it possesses a certain level of embodied energy and therefore would require that level of energy to replace.[66] The question of whether that resource or service is good or bad is a matter of policy. For example, a pesticide such as DDT, which is made from fossil fuels and requires a large amount of energy to make, has a relatively high emergy level; however, this fact does not say anything about whether DDT is good or bad. The fact that DDT has a high emergy level, however, does provide useful information. High-emergy substances have the ability to have high levels of impacts.[67] Thus, a high-emergy substance, such as DDT, has the potential to have a high impact to an ecosystem.[68] Whether that impact is something desirable, such as controlling pests, or undesirable, such as bioaccumulation in the food chain, however, is a matter of public policy.

To date, emergy synthesis has only been used in a very sporadic, ad hoc manner in environmental decision making. Although the emergy accounting procedure has not been used by environmental regulators in the United States, the United Nations Environment Programme bas used emergy synthesis as part of a project to restore West African drylands and improve rural livelihoods.[69] Researchers have also used emergy synthesis in a wide variety of case studies.[70] Although emergy synthesis has not been integrated

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65. *Id.* at 974–75.

66. *Id.* at 981.

67. *Id.*

68. *Id.*

69. U.N. ENV'T PROGRAMME, AN ECOSYSTEM APPROACH TO RESTORING WEST AFRICAN DRYLANDS AND IMPROVING RURAL LIVELIHOODS THROUGH AGROFORESTRY-BASED LAND MANAGEMENT INTERVENTIONS 8–9 (2005), *available at* http://www.worldagroforestry.org/wadrylands/resources/West%20African%20Drylands%20Project.pdf.

70. In one case, researchers evaluated three alternative sources of water supply for Windhoek, Namibia: aquifer water, Okavango River water, and desalination. *See* Andrés A. Buenfil, *Emergy Evaluation of Water Supply Alternatives for Windhoek, Namibia*, *in* INT'L INST. FOR APPLIED SYS. ANALYSIS, POPULATION-DEVELOPMENT-ENVIRONMENT IN NAMIBIA: BACKGROUND READINGS 187 (Ben Fuller & Isolde Prommer eds., 2000), *available at* http://www.iiasa.ac.at/Research/POP/pde/docs/IR-00-031.pdf. The study demonstrated that the use of aquifer water was the preferable alternative primarily due to the environmental and economic costs of desalination and the

into the culture of EPA, it is interesting to note that EPA offers a two-week emergy short course[71] and that in 2005 EPA published a report entitled *Environmental Accounting Using Emergy: Evaluation of the State of West Virginia*.[72] Perhaps not surprisingly, the EPA employee responsible for the course and the report is a former graduate student of Dr. Odum.

Given the potential benefits of emergy synthesis to many areas of environmental decision making—coupled with the fact the emergy synthesis has been in existence for decades, has reached a high level of sophistication, is accepted and used by scientists throughout the world, and has been used in the international arena—it is curious that U.S. environmental agencies such as EPA have not undertaken a serious evaluation of the idea.

B. Risk Assessment

Risk assessment entails "evaluation of scientific information on the hazardous properties of environmental agents and on the extent of human exposure to those agents."[73] Risk assessment provides information for use in risk management. Risk assessment is comprised of two components, hazard and exposure,[74] and is a four-step process.[75] First, the hazard is identified to

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downstream environmental impacts to the Okavango Delta wetlands and wildlife should water from the Okavango River be diverted. *Id.* In another case study, researchers evaluated three effluent treatment alternatives for wastewater discharge from an existing pulp and paper mill in Florida: constructing a pipeline to pipe wastewater from the mill to the Gulf of Mexico; piping water to the headwaters of an existing wetland for treatment by the existing wetland system; or constructing a new wetland strand between the mill and the Gulf of Mexico, through which wastewater would be discharged. EMERGY EVALUATION OF ENVIRONMENTAL ALTERNATIVES 6–35, http://www.emergysystems.org/downloads/PowerPoints/Lecture10_EnvEvaluation.ppt. Finally, Dr. Odum conducted an emergy synthesis evaluating two alternatives for cooling-water disposal from a nuclear power plant in Crystal River, Florida: (1) the construction and operation of cooling towers, and (2) discharging the hot waters to the adjacent estuarine ecosystem. Taking into account a number of factors—including the ecological costs of impacts to zooplankton and juvenile fish, and reduction in ecological metabolism—and comparing these to the emergy costs of construction, maintenance, and operation of the cooling tower, the emergy analysis demonstrated that direct discharge of cooling water into the bay was the better alternative. *Id.* at 36–39.

71. ATL. ECOLOGY DIV., EPA, EMERGY, http://www.epa.gov/aed/html/collaboration/emergycourse/presentations/index.html.

72. DANIEL E. CAMPBELL & SHERRY L. BRANDT-WILLIAMS, EPA, ENVIRONMENTAL ACCOUNTING USING EMERGY: EVALUATION OF THE STATE OF WEST VIRGINIA (2005), *available at* http://epa.gov/nheerl/publications/files/wvevaluationposted.pdf.

73. COMM. ON RISK ASSESSMENT OF HAZARDOUS AIR POLLUTANTS, NAT'L RESEARCH COUNCIL, SCIENCE AND JUDGMENT IN RISK ASSESSMENT 25–26 (1994) [hereinafter SCIENCE AND JUDGMENT IN RISK ASSESSMENT] (defining risk assessment).

74. Keith J. Jones, *Endocrine Disruptors and Risk Assessment: Potential for a Big Mistake*, 17 VILL. ENVTL. L.J. 357, 370 (2006) ("Environmental risk assessment is usually described in terms of two components—hazard and exposure."). *See also* MARY O'BRIEN, MAKING BETTER ENVIRONMENTAL DECISIONS 17–25 (2000) (describing hazard and exposure in further detail).

75. COMM. ON THE INSTITUTIONAL MEANS FOR ASSESSMENT OF RISKS TO PUB. HEALTH, COMM'N ON LIFE SCIS., NAT'L RESEARCH COUNCIL, RISK ASSESSMENT IN THE FEDERAL GOVERNMENT: MANAGING THE PROGRESS (the "Red Book") 19–20 (1983) [hereinafter RED BOOK] (dividing risk assessment into four major steps). Alternatively, some approach risk assessment as a three-step process. Nicklas A. Akers, *New Tools for Environmental Justice: Articulating a Net*

determine the qualitative nature of the adverse consequence.[76] Examples of such identified hazards include death, cancer, neurological effects, reproductive effects, and birth defects. Hazard identification is done using toxicological, epidemiological, and other scientific tests.[77] The second step is to determine the relationship between levels of exposure and probable adverse consequences.[78] In the case of chemical risk assessment, this step involves determining the adverse effect expected from exposure to a certain dose of the chemical.[79] The third step is quantification of exposure.[80] The amount of the contaminant or other hazard that individuals and populations are likely to be exposed to is determined in this step.[81] Finally, the hazard information and exposure information are combined to characterize the risk in probabilistic terms. For example, the risk may be described as 1×10^{-6}, meaning that if one million people are exposed to the chemical, one will contract cancer.[82]

Risk assessment has been used by federal agencies in their decision making since before the creation of EPA.[83] In fact, the term *risk assessment*, in its broadest sense, encompasses any attempt, whether quantitative or qualitative, to evaluate and weigh the likelihood of a particular hazard occurring. Under this broad view of risk assessment, it can be said that risk assessment dates back to early man. In its more commonly recognized form in environmental law, however, modern risk assessment dates back to the mid-1970s and grew out of techniques used by the Food and Drug Administration (FDA) to assess health risks from food additives beginning in the 1940s and 1950s.[84] To carry out its mission of evaluating the safety of food additives under the Food Drug and Cosmetic Act,[85] FDA developed a number of risk-quantification techniques that form the basis of modern

Health Effects Challenge to Emissions Trading Markets, 7 HASTINGS W.-NW. J. ENVTL. L. & POL'Y 203, 214 (2001) ("Risk assessment can be conceived of as a three-part process."); *see also* Elaine M. Faustman & Gilbert S. Omenn, *Risk Assessment*, *in* CASARETT & DOULL'S TOXICOLOGY: THE BASIC SCIENCE OF POISONS 107 (Curtis D. Klaassen ed., 7th ed. 2008) (discussing risk assessment generally).

76. RED BOOK, *supra* note 75, at 19.

77. *See id.* at 20, 22–23 (discussing epidemiological data, animal-bioassay data, short-term studies, and comparisons of molecular structure in hazard identification).

78. *Id* at 19–20.

79. *See id.* at 23–24 (discussing analysis of chemical exposure in dose–response assessment).

80. *Id.*

81. *Id.*

82. *Id.*

83. *See* SCIENCE AND JUDGMENT IN RISK ASSESSMENT, *supra* note 73, 29–30 (discussing the historical roots of risk assessment).

84. *See id.* (noting that the origins of risk assessment are found in the practices of toxicologists in the 1940s and that the concept was then adopted by FDA scientists in the 1950s).

85. 21 U.S.C. §§ 301–397 (2000).

environmental risk assessment.[86] Starting in the early 1940s, toxicologists began studying how to establish limits on exposure to hazardous substances to protect human health.[87] The rationale behind establishing exposure limits was that "all substances could become harmful under some conditions of exposure—when the so-called threshold dose was exceeded—but . . . human health could be protected as long as those exposure conditions were avoided."[88] Occupational-health scientists began establishing acceptable exposure limits based on short-term toxicity observations in highly exposed work.[89] However, scientists were not sure how to set threshold doses for large, diverse human populations and widely varying chemicals.[90]

Quantitative risk assessment gained a foothold at EPA starting in the mid-1970s, as EPA was tasked to make risk-based determinations under the plethora of new environmental statutes adopted by Congress.[91] By the 1980s a number of federal agencies had begun to employ quantitative risk assessment.[92] Several factors contributed to the widespread use of risk assessment beginning in the 1980s.

First, the large number of new environmental and health-protective statutes passed by Congress in the 1970s and early 1980s forced agencies such as EPA to develop methodologies to evaluate risk in their decision making. The possibility that carcinogenic substances might act through nonthreshold mechanisms, where exposure to even one molecule is associated with a small but non-zero increased risk of tumor induction, led to

86. *See, e.g.*, SCIENCE AND JUDGMENT IN RISK ASSESSMENT, *supra* note 73, at 30 (noting two FDA scientists' work to establish "acceptable daily intakes (ADIs)[] for dietary pesticide residues and food additives").

87. *Id.* at 29.

88. *Id.*

89. *Id.* at 30. For example, threshold limit values (TLVs) were first published by the American Conference of Governmental Industrial Hygienists in the 1950s. *Id.* In the early 1950s, a procedure known as acceptable daily intakes (ADIs) for dietary pesticide residues and food additives was proposed by two FDA scientists, O.G. Fitzhugh and A. Lehman. *Id.* This procedure is based on the above stated threshold hypothesis and—originally—on identification of a ehemical's no-observed-effect level (NOEL). *Id.* The response levels used today are no-observed-adverse-effect level (NOAEL) and lowest-observed-adverse-effect level (LOAEL). *Id.* The FDA scientists established the safety factor of 100 when they cited data "suggesting that 'average' human sensitivities might be up to 10 times tbose of laboratory animals and that some members of a large and diverse human population might be up to 10 times more sensitive than the 'average' person." *Id.* A chemical-specific ADI was derived by dividing the experimental NOEL by 100. *Id.* However, the FDA scientists who established this safety-factor method of risk assessment never claimed that an ADI was risk-free, but that it carried "reasonable certainty of no harm." *Id.* (citation omitted). Margin of safety, which is a variation of the safety-factor approach, involves a judgment of whether an estimated ratio of the NOEL to actual exposures is acceptable. *Id.* The procedure for setting ADIs is still the basic procedure for establisbing exposure limits today. *Id.* at 31. This method was recommended by National Resource Council committees in 1970, 1977, and 1986 and adopted by the Joint Food and Agriculture Organization and World Heath Organization expert committees on food additives and pesticide residues in 1965 and 1982. *Id.* at 30–31.

90. *Id.* at 29–30.

91. *Id.* at 32.

92. *Id.* at 33.

the use of dose–response models.[93] Scientists avoided identifying "acceptable" levels of carcinogen intakes through the 1960s and 1970s.[94] However, by the mid-1970s, a systematic approach for regulating carcinogens was clearly needed.[95] At that time, federal agencies, particularly FDA and EPA, began adopting methods for quantifying low-dose risks associated with chemical carcinogen exposure.[96]

By the late 1970s, the increased trend of risk assessment in carcinogen regulation led to several agencies working together as the Interagency Regulatory Liaison Group (IRLG) to create risk-assessment guidelines.[97] The participating agencies made no commitment to adopt risk assessment but would use the approach in the IRLG guidelines if they did decide to use risk assessment.[98] By the 1980s, risk assessment had taken on an importance in regulatory agencies that caught the attention of industry.[99] The Supreme Court's decision in *Industrial Union Department, AFL-CIO v. American Petroleum Institute*[100] (*Benzene*) was an impetus for the development of risk assessment by signaling that some form of quantitative risk assessment was required as a prerequisite to deciding whether a risk was large enough to merit regulation.[101] Thus, in 1981, the National Research Council (NRC) was instructed to undertake a study of federal agency use of risk assessment.[102] This study was more of a synthesis of the earlier work of federal agencies, including EPA, and did not recommend a specific method of risk assessment.[103] Many of the recommendations made by the study have been implemented by EPA, including maintaining a clear conceptual distinction between risk assessment and risk management and developing

93. *Id.* at 31. The National Research Council promoted these models in its series of reports entitled *Biological Effects of Ionizing Radiation*. *Id.* The Nuclear Regulatory Commission later incorporated these models into its regulatory decision making. *Id.* The earliest legislative acknowledgment of the possibility that carcinogens may act through nonthreshold mechanisms was the "Delaney clause" of the Food Additive Amendments of 1958. *Id.*

94. *Id.*

95. *Id.* at 32. Carcinogenicity testing began increasing rapidly in the late 1960s, regulators began dealing with many newly identified carcinogens in commercial products in the 1970s, and analytic chemists began identifying carcinogens at lower and lower concentrations. *Id.*

96. *Id.*

97. *Id.*; *see also* Work Group on Risk Assessment, Interagency Regulatory Liaison Group, *Scientific Bases for Identification of Potential Carcinogens and Estimation of Risks*, 63 J. NAT'L CANCER INST. 241, 258–65 (1979) (describing mathematical models and analytical methods for quantifying human cancer risk).

98. SCIENCE AND JUDGMENT IN RISK ASSESSMENT, *supra* note 73, at 32; Work Group on Risk Assessment, Interagency Regulatory Liaison Group, *supra* note 97, at 245.

99. SCIENCE AND JUDGMENT IN RISK ASSESSMENT, *supra* note 73, at 33.

100. 448 U.S. 607 (1980).

101. SCIENCE AND JUDGMENT IN RISK ASSESSMENT, *supra* note 73, at 33.

102. *Id.* at 33; *see* RED BOOK, *supra* note 75. This study, known as the "Red Book," continues to be the basis for EPA's risk-assessment paradigm. *See, e.g.*, 1 U.S. PRESIDENTIAL/CONG. COMM'N ON RISK ASSESSMENT AND RISK MGMT., FRAMEWORK FOR ENVIRONMENTAL HEALTH RISK MANAGEMENT 23–28 (1997) (detailing current risk-assessment strategy at EPA).

103. SCIENCE AND JUDGMENT IN RISK ASSESSMENT, *supra* note 73, at 33.

guidelines detailing the scientific basis of risk assessment.[104] In 1983, when President Reagan appointed William Ruckelshaus as EPA Administrator, Ruckelshaus made risk assessment a top priority, and under his direction, risk assessment became an integral part of virtually every program administered by the Agency.[105]

After the release of the 1983 NRC Report, the Office of Science and Technology Policy (OSTP) issued a comprehensive review of the scientific basis of risk assessment of chemical carcinogens in 1985.[106] This review adopted the risk-assessment framework recommended in the 1983 NRC Report and provided federal agencies a basis for developing the guidelines also recommended by NRC.[107] EPA was the only federal agency to adopt a set of carcinogen risk-assessment guidelines as recommended.[108] In 1986 and 1987, EPA published risk-assessment guidelines for mutagenicity, developmental toxicity, effects of chemical mixtures, and human exposure.[109] In 1988, EPA published risk-assessment guidelines for female reproductive risk, male reproductive risk, and exposure-related measurements.[110] Finally, revised guidelines for development toxicity and revised guidelines for human exposures were published by EPA in 1991 and 1992, respectively.[111] It was

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104. *Id.* at 34.

105. Nicholas Bagley & Richard L. Revesz, *Centralized Oversight of the Regulatory State*, 106 COLUM. L. REV. 1260, 1319 (describing Ruckelshaus's push for EPA "to formulate a set of agency-specific generic cancer guidelines" and his support for standardized, science-based risk-assessment assumptions); *see also* William D. Ruckelshaus, *Risk, Science, and Democracy*, ISSUES SCI. & TECH., Spring 1985, at 19, 28–29 ("The explicit and open codification suggested by the NRC will . . . offer[] the possibility that one day all the protective agencies of government will speak with one voice when they address risks, so that estimates of risk will be comparable among agencies and the public at last will be able to make a fair comparison of the individual risk-management decisions of separate agencies."); Interview by Dr. Michael Gorn with William D. Ruckelshaus, Adm'r, EPA (Jan. 1993), *available at* http://www.epa.gov/history/publications/ruck/21.htm (last updated Sept. 21, 2007) ("To the extent I began the process of risk-based decisionmaking within the agency, I consider this a major achievement. I believe it started when we embraced the [1983 NRC Report]. We began to use its principles in establishing priorities in the agency, and in managing the major risks society faced and EPA attempted to regulate.").

106. SCIENCE AND JUDGMENT IN RISK ASSESSMENT, *supra* note 73, at 34.

107. *Id.*

108. Guidelines for Carcinogen Risk Assessment, 51 Fed. Reg. 33,992 (Sept. 24, 1986); SCIENCE AND JUDGMENT IN RISK ASSESSMENT, *supra* note 73, at 34.

109. SCIENCE AND JUDGMENT IN RISK ASSESSMENT, *supra* note 73, at 34–35; *see* Guidelines for Mutagenicity Risk Assessment, 51 Fed. Reg. 34,006 (Sept. 24, 1986); Guidelines for the Health Risk Assessment of Chemical Mixtures, 51 Fed. Reg. 34,014 (Sept. 24, 1986); Guidelines for the Health Assessment of Suspected Developmental Toxicants, 51 Fed. Reg. 34,034 (Sept. 24, 1986); Guidelines for Estimating Exposures, 51 Fed. Reg. 34,042 (Sept. 24, 1986).

110. SCIENCE AND JUDGMENT IN RISK ASSESSMENT, *supra* note 73, at 35; *see* Proposed Guidelines for Assessing Female Reproductive Risk, 53 Fed. Reg. 24,834 (June 30, 1988); Proposed Guidelines for Assessing Male Reproductive Risk and Request for Comments, 53 Fed. Reg. 24,850 (June 30, 1988); Proposed Guidelines for Exposure-Related Measurements and Request for Comments, 53 Fed. Reg. 48,830 (Dec. 2, 1988).

111. SCIENCE AND JUDGMENT IN RISK ASSESSMENT, *supra* note 73, at 35; *see* Guidelines for Developmental Toxicity Risk Assessment, 56 Fed. Reg. 63,798 (Dec. 5, 1991); Guidelines for Exposure Assessment, 57 Fed. Reg. 22,888 (May 29, 1992).

at this time that EPA also published its groundbreaking report, *Reducing Risk: Setting Priorities and Strategies for Environmental Protection.*[112]

Today, EPA's National Center for Environmental Assessment (NCEA) is responsible for providing guidance on how pollutants may impact human health and the environment.[113] Additionally, NCEA administers the Global Change Research Program and the Integrated Risk Information System Program.[114]

Currently, risk assessment is used in virtually every area of environmental law. EPA uses risk assessment to guide decisions covered by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA), the Toxic Substances Control Act (TSCA), the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), and the Clean Air Act (CAA).[115] Its most significant role is in establishing dose–response relationships for chemical substances, such as pesticides, contaminants in drinking water, and air pollutants.[116] Such dose–response relationships are critical to characterize and quantify risk for subsequent risk-management decisions.

C. Adaptive Management

Adaptive management is defined as an "iterative, incremental decision making process built around a continuous process of monitoring the effects of decisions and adjusting decisions accordingly."[117] Adaptive management is iterative in that it relies on adjusting actions based on new information

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112. *See* SCI. ADVISORY BD., EPA, REDUCING RISK: SETTING PRIORITIES AND STRATEGIES FOR ENVIRONMENTAL PROTECTION (1990).

113. National Center for Environmental Assessment, EPA, NCEA Basic Information, http://cfpub.epa.gov/ncea/cfm/aboutncea.cfm?ActType=AboutNCEA (last updated June 18, 2007). For a listing of current risk-assessment guidelines, see National Center for Environmental Assessment, EPA, Risk Assessment Guidelines, http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm? deid=55907 (last updated Aug. 23, 2006).

114. National Center for Environmental Assessment, EPA, NCEA Basic Information, *supra* note 113.

115. *See* SCIENCE AND JUDGMENT IN RISK ASSESSMENT, *supra* note 73, at 35–36 (highlighting EPA's adoption of risk assessment as a guide to decisions under various statutory schemes); Matthew D. Adler, *Against "Individual Risk": A Sympathetic Critique of Risk Assessment*, 153 U. PA. L. REV. 1121, 1156–59 (2005) (noting the use of risk assessment under CERCLA and FIFRA); *see also* Federal Insecticide, Fungicide, and Rodenticide Act of 1976, 7 U.S.C. §§ 136–136y (2000); Toxic Substances Control Act, 15 U.S.C. §§ 2601–2692 (2000); Resource Conservation and Recovery Act of 1980, 42 U.S.C. §§ 6901–6992k (2000); Clean Air Act, 42 U.S.C. §§ 7401–7671q (2000); Comprehensive Environmental Response, Compensation, and Liability Act, 42 U.S.C. §§ 9601–9675 (2000).

116. *See* SCIENCE AND JUDGMENT IN RISK ASSESSMENT, *supra* note 73, at 39–40 (noting that once a chemical is found to be potentially hazardous, the next step is to use risk assessment to establish dose–response relationships).

117. J.B. Ruhl, *Regulation By Adaptive Management—Is It Possible?*, 7 MINN. J. L. SCI. & TECH. 21, 28 (2005).

gleaned through monitoring.[118] It strives to characterize uncertainty though multi-model inference and Bayesian inference.[119]

The concept of adaptive management was developed in the 1970s and 1980s by two ecologists, C.S. Holling and Carl Walters, at the University of British Columbia.[120] Later, Holling, while the director of the International Institute for Applied Systems Analysis (IIASA) in Vienna, Austria, further developed the approach.[121] Although the adaptive management concept originated from the works of Holling and Walters in the 1970s and 1980s,[122] it can be traced back to Charles E. Lindblom's article, *The Science of "Muddling Through,"* published in 1959.[123] Holling incorporated the concept of resilience into policy design as an alternative to environmental assessment,[124] which he found to be a "reactive approach" that "[would] inhibit laudable economic enterprises as well as violate critical environmenttal constraints."[125] Holling described adaptive management as "integrat[ing] environmental with economic and social understandings at the very beginning of the design process, in a sequence of steps during the design phase, and after implementation."[126]

Walters described adaptive management as a way to deal with scientific uncertainty when managing renewable resources, especially since resource managers had begun relying on quantitative modeling as a tool to predict

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118. *Id.* at 30.

119. Wikipedia, Adaptive Management, http://en.wikipedia.org/wiki/Adaptive_Management (last modified Mar. 1, 2008).

120. *See generally* INT'L INST. FOR APPLIED SYS. ANALYSIS, ADAPTIVE ENVIRONMENTAL ASSESSMENT AND MANAGEMENT (C.S. Holling ed., 1978); CARL WALTERS, ADAPTIVE MANAGEMENT OF RENEWABLE RESOURCES (1986).

121. *See generally* INT'L INST. FOR APPLIED SYS. ANALYSIS, *supra* note 120 (exemplifying Holling's work on adaptive management while at IIASA).

122. Warren T. Coleman, *Legal Barriers to the Restoration of Aquatic Systems and the Utilization of Adaptive Management*, 23 VT. L. REV. 177, 186 (1998); *see also* INT'L INST. FOR APPLIED SYS. ANALYSIS, *supra* note 120, at 1–2 (proposing adaptive environmental assessment and management as an alternative to traditional environmental assessment); WALTERS, *supra* note 120; Bradley C. Karkkainen, *Adaptive Ecosystem Management and Regulatory Penalty Defaults: Toward a Bounded Pragmatism*, 87 MINN. L. REV. 943, 948–56 (2003) (identifying a number of distinct variants on the concept of adaptive management, including scientific-hypothesis testing, macro-adaptation, and adaptive management as used by federal agencies).

123. 19 PUB. ADMIN. REV. 79 (1959) (advocating the successive limited comparisons method as an alternative to the rational comprehensive method of decision making by public administrators).

124. INT'L INST. FOR APPLIED SYS. ANALYSIS, *supra* note 120, at 19–20. The concept of resilience, as an overall criterion for policy design, embraces variability:

> The more that variability in partially known systems is retained, the more likely it is that both the natural and management parts of the system will be responsive to the unexpected. The very process and techniques we recommend, while aimed in part at reducing uncertainty, are designed as a changing adaptive process of policy design.

Id.

125. *Id.* at 1.

126. *Id.*

responses to alternative harvesting policies.[127] According to Walters, renewable-resource scientists had made major errors by not putting greater emphasis on socioeconomic dynamics in their research and management and in their approach to dealing with scientific uncertainty.[128] Instead of cautiously regulating harvests while seeking better understanding through more and more detailed analyses, Walters suggested using an adaptive management process "where management activities themselves are viewed as the primary tools for experimentation."[129]

The need for an adaptive approach to management became apparent in light of a new understanding of ecosystems as being "dynamic and stochastic rather than in equilibrium."[130] Since then, government agencies have been trying to account for the disparity between science and environmental law and to formulate a system that can adjust to confront scientific uncertainty.[131] However, environmental regulation that can provide "feedback loops to update regulatory efforts as information increases" is "counterintuitive for the American legal system, which puts a premium on firm rules of law."[132] Thus, adaptive management has not been seriously incorporated into environmental law.[133]

Environmental law often requires that regulation be based upon the "best available scientific knowledge," which is a principle of ecosystem management.[134] According to J.B. Ruhl, "[e]cosystem management is exactly what it sounds like—managing ecosystem-level problems through ecosystem-level approaches—and it almost always calls for creative and adaptive use of policy instruments as varied as inflexible commands at one

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127. WALTERS, *supra* note 120, at vii.

128. *Id.* at 2.

129. *Id.* at 2–3.

130. Timothy H. Profeta, *Managing Without a Balance: Environmental Regulation in Light of Ecological Advances*, 7 DUKE ENVTL. L. & POL'Y F. 71, 71 (1996); *see also* A. Dan Tarlock, *The Nonequilibrium Paradigm in Ecology and the Partial Unraveling of Environmental Law*, 27 LOY. L.A. L. REV. 1121, 1122–23 (1994) ("[T]he equilibrium paradigm has been rejected in ecology and replaced with a complex, stochastic nonequilibrium one.").

131. Thomas T. Ankersen & Richard Hamann, *Ecosystem Management and the Everglades: A Legal and Institutional Analysis*, 11 J. LAND USE & ENVTL. L. 473, 493 (1996) ("The law tends to encourage regulatory inaction in the face of uncertainty."). Adaptive management is being recognized and adopted in varying degrees by federal government agencies responsible for managing natural resources, including the National Forest Service, the Fish and Wildlife Service (FWS), the Department of the Interior, the Bureau of Reclamation, the Army Corps of Engineers, and the Bureau of Land Management. Coleman, *supra* note 122, at 187. Federal agencies have been using adaptive management for the restoration of critical ecosystems, such as the Pacific Northwest Forests, the Colorado River, and the Everglades. *Id.*

132. Profeta, *supra* note 130, at 86.

133. *Id.*; *see also* Coleman, *supra* note 122, at 178 ("The legal challenge is to maintain enough flexibility for institutions to manage systems that are in a constant state of flux, while providing the legal certainty required to satisfy procedural and substantive due process.").

134. Ankersen & Hamann, *supra* note 131, at 492.

extreme to generous incentives at the other."[135] Adaptive management, also a principle of ecosystem management,[136] "increasingly has become synonymous" with ecosystem management.[137] Although the concept of adaptive management has not yet been integrated into environmental regulatory programs, it has been used in a number of resources-management programs. For example, the Columbia River Basin Fish and Wildlife Program, considered the first application of adaptive management in resource management,[138] was the world's largest biological-restoration program in 1986.[139] Intensive management of the Columbia River Basin began with the listing of several Snake River salmon populations as endangered.[140] Congress passed the Pacific Northwest Electric Power Planning and Conservation Act,[141] which established the Pacific Northwest Electric Power and Conservation Planning Council (the Council).[142] The Act mandated that "[t]he Council shall promptly develop and adopt . . . a program to protect, mitigate, and enhance fish and wildlife . . . . [T]he program, to the greatest extent possible, shall be designed to deal with that river and its tributaries as a system."[143] The Act also requires that fish and wildlife are accorded "equitable treatment" with the multiple purposes of the

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135. J.B. Ruhl, *Taking Adaptive Management Seriously: A Case Study of the Endangered Species Act*, 52 U. KAN. L. REV. 1249, 1250 (2004). Edward Grumbine provided the following working definition of ecosystem management: "Ecosystem management integrates scientific knowledge of ecological relationships within a complex sociopolitical and values framework toward the general goal of protecting native ecosystem integrity over the long term." R. Edward Grumbine, *What is Ecosystem Management?*, 8 CONSERVATION BIOLOGY 27, 31 (1994) (emphasis omitted).

136. Ankersen & Hamann, *supra* note 131, at 492.

137. J.B. Ruhl, *Thinking of Environmental Law as a Complex Adaptive System: How to Clean Up the Environment by Making a Mess of Environmental Law*, 34 HOUS. L. REV. 933, 999 (1997). "[V]irtually every collection of domestic ecosystem management principles, however varied, explicitly incorporates adaptive management as a guiding principle." Ankersen & Hamann, *supra* note 131, at 494. Grumbine found that adaptive management was one of the dominant themes emerging from a review of ecosystem-management articles in peer-reviewed journals up to 1993. Grumbine, *supra* note 135, at 29–31.

138. Ankersen & Hamann, *supra* note 131, at 495.

139. Kai N. Lee & Jody Lawrence, *Adaptive Management: Learning from the Columbia River Basin Fish and Wildlife Program*, 16 ENVTL. L. 431, 431–33 (1986). *See generally* John M. Volkman & Willis E. McConnaha, *Through a Glass, Darkly. Columbia River Salmon, the Endangered Species Act, and Adaptive Management*, 23 ENVTL. L. 1249 (1993) (discussing the proposal and implementation of adaptive management principles in the Columbia River Basin Fish and Wildlife Program).

140. Profeta, *supra* note 130, at 91.

141. Pub. L. No. 96-501, 94 Stat. 2697 (codified as amended at 16 U.S.C. §§ 839–839h (2000)).

142. 16 U.S.C. § 839b(a) (2000); Lee & Lawrence, *supra* note 139, at 435. *See generally* Northwest Power Planning Council, http://www.nwcouncil.org/Default.htm (describing the mission and purpose of the Northwest Power Planning Council and providing updates on its progress).

143. 16 U.S.C. § 839b(h)(1)(A).

hydroelectric projects.[144] Finally, the Act requires that the "best available scientific knowledge" be used.[145]

The Council adopted an adaptive-management policy as part of its action plan. Agencies involved included the Federal Energy Regulatory Commission, the Bureau of Reclamation, and the Army Corps of Engineers.[146] Professor Kai Lee, a member of the Council, suggested adaptive management in 1984.[147] The Council found that using adaptive management as a policy framework "recognizes biological uncertainty, while accepting the congressional mandate to proceed on the basis of the 'best available scientific knowledge.'"[148]

In 1992, NRC conducted a study on the use of adaptive management for the restoration of aquatic ecosystems.[149] The study has been cited as an example of how legal academics view adaptive management in terms of how resource management should be conducted.[150] The study suggested using the adaptive environmental assessment (AEA) developed by C.S. Holling as an appropriate "process for involving scientists, resource managers, policy analysts, and decision makers interactively in designing resource management problems."[151] In formulating its national restoration strategy, the NRC established adaptive management as a principle for priority setting

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144. Lee & Lawrence, *supra* note 139, at 436–37; *see* 16 U.S.C. § 839b(h)(11)(A)(i) (providing that fish and wildlife proteeted by the Act receive equitable treatment from the federal agencies responsible for operating or regulating hydroelectric facilities on the Columbia River or its tributaries).

145. 16 U.S.C. § 839b(h)(6)(B).

146. Lee & Lawrence, *supra* note 139, at 436–37; *see* 16 U.S.C. §§ 839b(h)(11)(A) ("Federal agencies responsible for managing, operating, or regulating Federal or non-Federal hydroelectric facilities located on the Columbia River or its tributaries shall . . . tak[e] into account at each relevant stage of decisionmaking processes to the fullest extent practicable, the program adopted by the Council . . . .").

147. Volkman & McConnaha, *supra* note 139, at 1255.

148. Lee & Lawrence, *supra* note 139, at 435. Another example of the use of adaptive management is with the Glen Canyon Dam. The Glen Canyon Dam serves to store water and generate power. Tarlock, *supra* note 130, at 1143. The construction of the dam altered the flow of the river below the dam, resulting in decreased sediment deposits that build canyon beaches; decreased river temperature; and fluctuating releases of water—all of whieh threaten listed indigenous fish. *Id.* The resulting political pressure forced the Bureau of Reclamation to prepare $88 million worth of scientific studies, which then forced the Departments of the Interior and Energy to prepare environmental impact statements (EISs) for the operation of the dam. *Id.* The operating agencies have adopted adaptive management in order to be able to experiment with flow regimes and satisfy the NEPA EIS requirement. *Id.* (citation omitted).

149. *See* COMM. ON RESTORATION OF AQUATIC ECOSYSTEMS, NAT'L RESEARCH COUNCIL, RESTORATION OF AQUATIC ECOSYSTEMS: SCIENCE, TECHNOLOGY, AND PUBLIC POLICY 357–58 (1992) [hereinafter RESTORATION OF AQUATIC ECOSYSTEMS] (deseribing the adaptive-management methodology); Tarlock, *supra* note 130, at 1140 ("A recent National Researeh Council-National Academy of Sciences study captures the essence of adaptive management . . . .").

150. *See, e.g.*, Coleman, *supra* note 122, at 187 (citing a description of adaptive management from the 1992 NRC study).

151. RESTORATION OF AQUATIC ECOSYSTEMS, *supra* note 149, at 345.

and decision making in the face of scientific uncertainty.[152] The example used by NRC was Chesapeake Bay's nutrient-management strategy, in which the initial goal was set to reduce nutrient loading by 40%.[153] The policy makers committed to a continuous study of the goal itself, as well as the cost and effectiveness of the chosen means.[154] As a result, both the goals and approaches of the nutrient-management strategy are subject to revision over time.[155]

Federal agencies have used adaptive management in a number of resource-management and restoration programs. For example, the U.S. Forest Service expressly adopted adaptive management in its plan governing federal lands in Oregon, Washington, and northern California.[156] As part of the Everglades restoration program, the Army Corps of Engineers adopted adaptive management.[157] The Army Corps of Engineers used adaptive management as a tool to confront the ecological uncertainties in deciding what a restored Everglades ecosystem should look like.[158] Moreover, the congressional mandate to experiment with water deliveries to the Everglades National Park from the Central and Southern Flood Control Project is cited as one example of "legislative authorization to pursue an adaptive management policy."[159] A final example is the Army Corps of Engineers' 2001 adoption of the concept of adaptive management that was published in the Revised Draft Environmental Impact Statement (RDEIS) for the *Missouri River Master Water Control Manual* (*Master Manual*).[160]

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152. *Id.* at 357.

153. *Id.* at 358. Concerns over declining fisheries and rising pollutants in the bay arose in the 1970s. Profeta, *supra* note 130, at 89. In 1975, Congress authorized a five-year study of threats to the Bay, and in 1983, Congress formed a structure to govern the ecosystem. *Id.* at 89–90. These efforts to protect the Bay eventually evolved to incorporate adaptive management in order to fill informational gaps. *Id.* at 90. The program had some success but failed to identify the exact relationship between water-quality levels and habitat health. *Id.*

154. RESTORATION OF AQUATIC ECOSYSTEMS, *supra* note 149, at 358.

155. *Id.*

156. Profeta, *supra* note 130, at 91. The goal of the plan was to resolve the conflicts arising between the protection of the spotted owl as an endangered species and timber harvesting. *Id.*; *see also* Ankersen & Hamann, *supra* note 131, at 495 (describing many efforts to reconcile biodiversity protection with industry in the Pacific Northwest). The plan designates adaptive management areas (AMAs) and regulates on the basis of ecosystem units. Profeta, *supra* note 130, at 91–93. The governance of the AMAs eventually evolved into a decentralized system in order to address ecosystem complexity and allow public input. *Id* at 93.

157. Ankersen & Hamann, *supra* note 131, at 492.

158. *Id.*

159. Ankersen & Hamann, *supra* note 131, at 498. "The 1984 legislation authorized the Corps, in conjunction with the water management district, to experiment with deliveries of water to the Everglades National Park based on a concept referred to as the 'rainfall plan.'" *Id.* The goal of the experiment was to develop an optimum water-delivery plan for the Everglades National Park. *Id.* at 498–99. The Army Corps selected a "modified rain-driven plan" and initiated consultation with FWS under § 7 of the Endangered Species Aet. *Id.* at 499. FWS authorized the Army Corps of Engineers' preferred alternative through an incidental-take permit. *Id.*

160. John H. Davidson & Thomas Earl Geu, *The Missouri River and Adaptive Management: Protecting Ecological Function and Legal Process*, 80 NEB. L. REV. 816, 819 (2001). The *Master*

During the 1990s the idea of adaptive management became much discussed in both the scientific and legal literature. Although adaptive management is widely touted in both, its role in environmental law to date has been very limited. Thus far, adaptive management has been used primarily as a resource-management tool in such areas as fisheries management or public-land management.[161] Although often proposed as a needed component of environmental regulation, adaptive management has not yet been integrated into environmental regulatory programs. Adaptive management is not yet pervasively used in environmental law. It has only been expressly adopted in four statutes.[162] The Department of the Army, the Army Corps of Engineers, the Forest Service, and EPA have all expressly incorporated adaptive management into their regulations.[163] Although the success of adaptive management as a component of environmental regulation is still uncertain, it has still proven to be an effective approach for the management of complex ecosystems.

V. Why Some Scientific Ideas Stick and Spread

A useful framework for evaluating what conditions are significant for a scientific idea to gain currency in the law and policy arenas is found in

Manual is a system of written instructions for the operation of the Missouri River Basin. *Id.* at 834. The *Master Manual* was originally prepared in 1960. *Id.* In 1989, the Corps agreed to revise the *Master Manual*. *Id.* This was the first time the *Master Manual* would be subject to review under NEPA. *Id.* During the NEPA review process, the Corps of Engineers asked the FWS for formal consultation under the Endangered Species Act. *Id.* at 841. It is important to note that in 1994 FWS had announced a policy change that all of its regulatory and other functions would be guided by the concept of ecosystem management. *Id.* at 837. One of the Reasonable and Prudent Alternatives suggested by FWS in its biological opinion was the recommendation to adopt adaptive management. *Id.* at 842. FWS recommended two components of this new adaptive management process: establishment of an interagency coordination team, and implementation of a monitoring program. *Id.* All five alternatives in the RDEIS were to be "buttressed by a process known as adaptive management." *Id.* at 843. The Army Corps of Engineers planned to refine the adaptive management process in the RDEIS after it received the NRC report entitled *Missouri River Ecosystem: Exploring the Prospects for Recovery*. *Id.* at 844.

161. *See, e.g.*, Samuel P. Hays, *The Future of Environmental Regulation*, 15 J.L. & COM. 549, 579 (1996) (discussing the use of adaptive management in the Clinton forest program in the Pacific Northwest as a new direction for public-land management); Volkman & McConnaha, *supra* note 139, at 1255–56 (describing the introduction of adaptive management into fisheries management in the mid-1980s).

162. Southwest Forest Health and Wildfire Prevention Act of 2004, 16 U.S.C. §§ 6701–6707 (Supp. V 2005); Estuaries and Clean Waters Act of 2000, 33 U.S.C. § 2903 (2000); Water Resources Development Act of 2007, Pub. L. No. 110-114, § 2031, 121 Stat. 1041, 1082 (to be codified at 42 U.S.C. § 1962-3); Energy Independence and Security Act of 2007, Pub. L. No. 110-140, § 633, 121 Stat. 1492, 1686 (to be codified at 42 U.S.C. § 17212).

163. Environmental Analysis of Army Actions, 32 C.F.R. § 651.5(d)(10)(v) (2008); National Forest System Land Management Planning, 36 C.F.R. § 219.3 (2008); Programmatic Regulations for the Comprehensive Everglades Restoration Act, 33 C.F.R. § 385.3 (2008); Criteria and Standards for the National Pollutant Discharge Elimination System, 40 C.F.R. § 125.93 (2006) (suspended by 72 Fed. Reg. 37,107 (July 9, 2007)).

Malcolm Gladwell's 2000 bestselling book, *The Tipping Point*.[164] The significance of the who, what, where, and when of the development of a scientific idea to its adoption in the law parallels the significance of these factors to determining whether and to what extent any new idea or trend is adopted and spread. Sociologists have studied various factors that contribute to new ideas or trends gaining currency.[165] Many of the ideas gleaned from these studies have been integrated into Gladwell's book.[166] This book explores the phenomenon of how what Gladwell describes as "social epidemics" work.[167] The term "social epidemic" encompasses a large range of phenomena, including the emergence of fashion trends, crime waves, books becoming bestsellers, and a variety of other social trends that emerge and rapidly spread throughout our culture.[168] According to Gladwell, one critical characteristic of social epidemics is that, rather than occurring gradually, change happens "at one dramatic moment," which he describes as the "tipping point."[169] Three factors appear to be critical in creating a social epidemic: (1) the law of the few, (2) the stickiness factor, and (3) the power of context.[170] The "law of the few" holds that in any given situation, a very few people will have the most influence.[171] The "stickiness factor" relates to the specific characteristics that make a particular idea memorable enough to be adopted and spread.[172] The "power of context" is based on the idea that human beings are much more sensitive to their environment than they may seem, and thus, contextual circumstances can have significant influence over individuals' actions.[173] These three rules explain the circumstances under which social epidemics typically occur and provide a roadmap for how to promote future social epidemics.[174]

To attempt to identify possible reasons why some scientific developments, such as risk assessment, find a home in the law, I began by looking at each of the three scientific developments discussed in this Article in terms of the who, what, where, and when. First, I examined who developed the idea and whether the position or stature of the person or persons who developed the idea (the "who") impacted the acceptance of the idea by the legal and policy community. Next, I examined the nature of the

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164. GLADWELL, *supra* note 3.

165. *See, e.g.*, *id.* at 282 endnote (listing several sociological studies of diffusion and collective behavior).

166. *See id.* (noting that the *Tipping Point* model has been described in several classic works of sociology).

167. *See id.* at 21 (introducing the concept of social epidemics).

168. *See id.* at 14 (describing the variety of phenomena covered by the *Tipping Point* concept).

169. *Id.* at 9.

170. *Id.* at 29.

171. *Id.* at 22.

172. *Id.* at 25.

173. *Id.* at 28–29.

174. *Id.* at 29.

scientific idea (the "what") to see if any pattern emerged. As to the "where," I looked to see where the idea first got a foothold—in the general public debate or in the law itself—to see if one tends to follow from the other. Finally, I considered the time at which the idea was developed to see if the timing of the development of the idea correlated with other events that may have facilitated the movement of the idea into the legal and policy realm. These factors fit neatly into the *Tipping Point* framework.

A. The Law of the Few (The Who)

The "law of the few" holds that in any given situation, a very few people will have the most influence.[175] Research into the origins of social epidemics reveals that they are driven by the influences of a very few exceptional people.[176] In *The Tipping Point*, Gladwell explains how word of mouth, as opposed to concerted advertising or sales approaches, is one of the most important factors in the spreading of an idea or trend.[177] The success of the spread of an idea is therefore largely dependent on the social abilities of those few individuals who influence the word-of-mouth spreading of an idea.[178] Gladwell groups these exceptionally socially gifted people into three categories:[179] (1) connectors, people who have special gifts in bringing together others from different social and professional circles,[180] (2) mavens, people who are obsessed with collecting information and have the desire to share their knowledge with others,[181] and (3) salesmen, people who have the skills necessary to persuade others of their views.[182]

The need for connectors, mavens, and salespeople to turn an idea into a social epidemic also applies to getting scientific ideas to be accepted and widely used in the law. An examination of the roles that scientists and policy makers have played in developing and disseminating the three scientific ideas discussed in this Article suggests that where environmental agencies, such as EPA, fail to employ connectors, mavens, or salespeople in key positions, a scientific idea is not likely to catch on in the Agency.

As described above, risk assessment was initially developed primarily by the FDA and later refined by EPA with considerable input from the NRC, whereas both adaptive management and emergy synthesis were developed by university scientists. Adaptive management was developed by scientists at the University of British Columbia and subsequently refined when C.S. Holling directed the IIASA in Vienna. H.T. Odum, a professor of

175. *Id.* at 33.
176. *Id.* at 19–22.
177. *Id.* at 32.
178. *Id.* at 33.
179. *Id.* at 34.
180. *Id.* at 38.
181. *Id.* at 67.
182. *Id.* at 70.

environmental engineering sciences at the University of Florida, developed emergy analysis. The subsequent expansion and refinement of emergy synthesis resulted primarily from the work of researchers at the University of Florida or researchers who received all or part of their graduate education at the university under the guidance of Dr. Odum and his protégés. Of the three scientific developments discussed in this Article, risk assessment alone has become an important part of environmental law and policy. Unlike the developers of emergy and adaptive management, who were university researchers, the individuals who were critical to the development and spread of risk assessment were government employees.

In *Tipping Point* parlance, researchers such as Dr. Odum and Dr. Holling would be considered the mavens. These researchers were driven to gather information, develop ideas, and solve problems. They sought to help society by finding ways to address its problems with scientific solutions. They may have even been skilled at communicating their ideas to others. However, for an idea to spread, it is not sufficient to merely rely on mavens: connectors and salespeople are equally important. Unlike emergy synthesis and adaptive management, risk assessment appears to have had connectors and salespeople involved in spreading its virtues. For example, agency scientists and policy makers at the FDA and EPA appear to have played the role of connector, reaching out to the research community to find ideas that they could bring back to the agencies and tailor to fit the agencies' needs.[183] Moreover, it could be said that EPA Administrator William Ruckelshaus played the role of salesperson, praising the virtues of risk assessment and persuading his staff and others that risk assessment was the proper tool for answering the difficult risk-based questions EPA faced.[184] Emergy synthesis and adaptive management do not appear to have had clear connectors showing agencies how these scientific ideas could be used. Nor do they have salespeople, such as a Ruckelshaus, with the credibility, stature, and persuasive ability to sell the ideas. Perhaps emergy synthesis and adaptive management would have gained more traction had there been connectors and salespeople championing these ideas. As described in more detail below, part of the reason for the lack of connectors may be related to the cultural shift that has occurred in regulatory agencies such as EPA since the privatization and outsourcing trends began.

Because risk assessment was sought out and developed by the federal agencies themselves, it was easily incorporated and quickly spread throughout the legal and policy arena. Moreover, Ruckelshaus's commitment to risk assessment and his leadership integrating risk assessment into virtually every program within EPA appears to be a critical factor in risk assessment's ubiquity.[185] Courts also played a role in encouraging the

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183. *See supra* subpart IV(B).

184. *See supra* note 105 and accompanying text.

185. *See supra* note 105 and accompanying text.

widespread use of risk assessment. In the 1980 case *Benzene*, the court invalidated an Occupational Safety and Health Administration (OSHA) rule lowering the acceptable level of benzene exposure because OSHA had not demonstrated "significant risks."[186] To determine whether a significant risk exists, it is necessary to engage in some type of assessment to measure risk. Consequently, OSHA and other agencies began to focus on more quantitative risk-assessment methodologies that would assist them in withstanding judicial scrutiny.[187] Finally, in 1983, NRC issued a report on risk assessment that helped to standardize the methodology and that established risk assessment as a mainstay of environmental and health policy.[188] The confluence of these events in the early 1980s appears to have firmly planted quantitative risk assessment in the environmental and health decision-making processes throughout the federal government.

Neither adaptive management nor emergy synthesis has been sought out by federal agencies to address any pressing need resulting from new congressional or judicial mandates. Likewise, neither idea has had a champion such as Ruckelshaus within the high ranks of government. Instead, both were developed in universities by research scientists on their own initiatives.[189] Thus, although both ideas have the potential to greatly improve environmental decision making, agencies have not taken ownership of the ideas.

Both the late Dr. Odum and Dr. Holling are internationally renowned scholars. In fact, Dr. Odum and his brother Eugene commonly are thought of as the fathers of modern ecology, and their names are known to virtually everyone who has ever taken a college ecology course.[190] Nevertheless, Odum and Holling's ideas have not been adopted by environmental agencies for incorporation into environmental decision making. The fact that a scientific development comes out of a well-respected research institution or from an internationally renowned researcher appears to be of little import.

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186. Indus. Union Dep't, AFL-CIO v. Am. Petroleum Inst. (*Benzene*), 448 U.S. 607, 653–55 (1980).

187. *See* David Michaels & Celeste Monforton, *Scientific Evidence in the Regulatory System: Manufacturing Uncertainty and the Demise of the Formal Regulatory System*, 13 J.L. & POL'Y 17, 25 (2005) (stating that in order to meet the Supreme Court's mandate in *Benzene*, OSHA had spent considerable time preparing detailed quantitative risk assessments related to its health standards); Charles F. Mills III, *Global RBCA: Its Implementation, Foundation in Risk-Based Theory, and Implications*, 22 J. LAND USE & ENVTL. L. 101, 110–11 (2006) (discussing judicial affirmation of OSHA's use of quantitative risk assessment post-*Benzene*).

188. *See supra* notes 102–04 and accompanying text.

189. *See supra* notes 30–37 and accompanying text (discussing the origins of emergy synthesis); *supra* notes 120–29 and accompanying text (discussing the origins of adaptive management).

190. Sholto Maud & Dino Cevolatti, *Realising the Enlightenment: H.T. Odum's Energy Systems Language* qua *G.W.v Liebniz's* Characteristica Universalis, 178 ECOLOGICAL MODELLING 279, 283 (2004) (referring to H.T. Odum as the "'father' of systems ecology"); Ari L. Goldman, *Eugene P. Odum Dies at 88; Founded Modern Ecology*, N.Y. TIMES, Aug. 14, 2002, at A21 (referring to Eugene Odum as "the father of modern ecology").

Of the three scientific approaches discussed in this Article, risk assessment, the only of the three that was not developed by an internationally respected researcher, has become used widely in environmental decision making. As described above, risk assessment was developed primarily by federal regulatory agencies, such as FDA and EPA, both of which were in need of a methodology to evaluate risks under their statutory mandates from Congress. Both agencies were actively looking for a methodology to use and were supported by the work of NRC, which further developed the methodology. It appears that one of the most important factors in determining whether a scientific idea will be incorporated into the law is whether the regulatory agency is actively seeking a scientific methodology or approach to address a specific concern or to answer a specific question, particularly when ordered to do so by Congress. University scientists may toil in laboratories or in the field for decades developing extremely useful ideas, but unless the agencies are looking for such ideas, they are unlikely to be embraced.

B. Stickiness (The What)

The second factor identified in *The Tipping Point* as being necessary for an idea to catch on is referred to as the "stickiness factor." "Stickiness" is a characteristic of successful ideas.[191] In order for an idea to catch on and spread, it must be "sticky," meaning that the idea must be memorable and must move people to act.[192] The idea of "stickiness" has been further developed in the recent book *Made to Stick: Why Some Ideas Survive and Others Die*.[193] This book posits that while some ideas are inherently interesting and others are not, there is something more at work that determines why some interesting ideas fail to catch on.[194] The book identifies six principles of "sticky" ideas: (1) simplicity, which depends on stripping an idea to its core; (2) unexpectedness, which suggests that an idea must be counterintuitive to generate interest and curiosity; (3) concreteness, which requires that an idea be explained in terms of human action using concrete images; (4) credibility, which requires that the ideas themselves carry their own credentials; (5) emotion, which suggests that the idea must make people feel something; and (6) stories, which suggests that using stories is a way to motivate people to act.[195]

Applying these stickiness factors to the three examples of scientific ideas suggests that risk assessment is stickier than either adaptive management or emergy synthesis. First, at least on its face, risk assessment is simpler than the other ideas. Second, risk assessment is easier to describe

191. GLADWELL, *supra* note 3, at 91.

192. *Id.* at 25.

193. CHIP HEATH & DAN HEATH, MADE TO STICK: WHY SOME IDEAS SURVIVE AND OTHERS DIE 12–13 (2007).

194. *Id.* at 8–10.

195. *See id.* at 14–18 (introducing the six principles of sticky ideas).

in terms of concrete examples. Third, risk assessment, at least as it has been presented to the public, seems to carry with it an air of credibility in that it appears to be highly objective and quantitative and to result in clear-cut answers. Finally, because risk assessment is used to analyze human risks from dreaded diseases, such as cancer, it can be presented via real-life stories that evoke emotional responses.

One reason why risk assessment may have been so readily integrated into legal policy is that, at least on its face, it is easy to understand and appears to be a relatively straightforward method to provide clear answers to technical questions. However, although relatively easy to explain and to understand, it is rife with difficulties, prone to error, and yields often uncertain results.[196] Most of the difficulties of risk assessment occur during the second and third steps of the process. During the second step, where the relationship between the dose and the probability of harm is determined, complexity and uncertainty result from the fact that results must be extrapolated from animal tests to humans, or from tests on one species of animal to another species of animal. Not only is there uncertainty over whether species-to-species extrapolation is valid, but even within species, individual variability and susceptibility also make extrapolation inherently suspect.[197] Moreover, due to the nature of laboratory animal testing, results from tests conducted with extremely high dosing must be extrapolated to lower dosing.[198] To account for these problems inherent in animal testing, "safety" factors are applied to ensure that results are sufficiently conservative.[199] With rcgard to the third step in risk assessment, uncertainty arises from the huge variability in exposure that is likely to result in different locations, with different lifestyles, and because of other variables. Risk assessment is considered by critics to be overly quantitative and reductive.[200] Finally, perhaps the least understood issue with the method: risk assessment does not tell us anything about what level of risk is acceptable as a matter of policy, how to reduce risks to acceptable levels, or how to take into account economic or other social costs in deciding how to manage risk.[201] Risk

196. RED BOOK, *supra* note 75, at 48–49.

197. *See id.* (noting the "clear disadvantage" of animal studies in risk assessment due to species differences betwcen anımals and humans, and further acknowledging that "[d]ifferences among anınal species . . . can account for toxicıty differenccs").

198. *See ıd.* at 60–62 (describıng the extrapolation of threshold-level doses eliciting toxic responses ın lab anımals to humans in dose–response models for noncanccr toxic effects); *see also* Work Group on Risk Assessment, Interagency Regulatory Liaison Group, *supra* note 97, at 260–62 (describing mathematical models "proposed to deal with the problem of low-dosc extrapolation").

199. *See id* at 62–63 (describing the use of the "uncertainty-factor" approach to estımate "safe" exposure).

200. *See* David E. Adelman, *The False Promise of the Genomics Revolutıon for Environmental Law*, 29 HARV. ENVTL. L. REV. 117, 124–27 (2005) (discussing multiple critiques of risk assessment).

201. *See, e.g.*, Jeffrey J. Hayward, *The Same Mold Story?: What Toxic Mold Is Teaching Us About Causation in Toxic Tort Litigation*, 83 N.C. L. REV. 518, 550 (2005) (distinguishing between

assessment, in itself, merely provides a way to determine the amount of risk posed in a given situation, which can inform policy decisions regarding risk management. Thus, although risk assessment on its face is easily understood and has a superficial appeal, it is rife with complexity and uncertainty and provides only limited information. Nevertheless, despite its shortcomings and complexities, risk assessment has been embraced by the law.[202]

By contrast, adaptive management and emergy synthesis do not have the superficial appeal of risk assessment. By their very nature, they acknowledge the complexity of natural systems. Adaptive management also is based on the concept that natural systems are constantly changing, adding another layer of complexity.[203] Neither attempts to hide behind a veil of simplicity by being highly reductive, like risk assessment. Moreover, adaptive management, in particular, unabashedly embraces uncertainty, whereas risk assessment attempts to eliminate uncertainty by imposing overly simplistic "safety" factors to disguise what are inherently uncertain results.[204] Consequently, these complex and difficult-to-understand ideas are not easily integrated into a legal system that seeks simplicity and certainty. Agencies do not appear to be looking for new methodologies that further complicate their jobs and that are not easily translated to nonexpert government leaders and the public. Emergy synthesis is not easily understood by nonexperts. This is perhaps due to the fact that most laypeople are not comfortable with concepts like thermodynamics, which is at the root of emergy synthesis. Finally, it is interesting to note that the term "emergy" is not a commonly used term and is often considered to be a typographical error. Thus, it is possible that the name itself has made the approach less accessible and less attractive to those who might benefit from its use.

In addition to the simplicity factor, risk assessment appears to be stickier than the other models due to the fact that it can be described in more concrete terms using more concrete examples than can the other ideas. For example, risk assessment can be described as a way to determine how many people exposed to a certain dose of a chemical substance will contract cancer. Examples to help illustrate can be given using laypeople's everyday experiences. For instance, risk assessment can be presented in terms of what

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"[s]cientifically determined threshold effect levels" resulting from risk assessment and the "regulatory standards" of risk management, "which incorporate[s] significant policy considerations such as the notion of 'acceptable' exposure levels") (citing 2 PRESIDENTIAL/CONG. COMM'N ON RISK ASSESSMENT AND RISK MGMT., RISK ASSESSMENT AND RISK MANAGEMENT IN REGULATORY DECISION-MAKING 55, 84–85 (1997)).

202. *See, e.g.*, RISK ASSESSMENT FORUM, EPA, FRAMEWORK FOR CUMULATIVE RISK ASSESSMENT 92 (May 2003), *available at* http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?Deid =54944 (providing guidance for assessing risk from environmental stressors).

203. *See* INT'L INST. FOR APPLIED SYSTEMS ANALYSIS, *supra* note 120, at 33 ("Ecological systems are not static but are in continual change . . . and this dynamic change determines part of the structure, diversity, and viability of ecological systems.").

204. *Id* at 8–9.

percentage of people who get into car accidents not using their seat belts will die, or what percentage of people who smoke cigarettes are likely to get lung cancer. These concrete examples are part of our everyday lives and therefore immediately connect with most people. Not only are these concrete examples easy to relate to, but they also provide a clear, concrete action that individuals can take to reduce their risk, e.g., wearing seat belts or quitting smoking. Such simple, concrete examples for adaptive management and emergy synthesis, on the other hand, are not as easy to come by. It is more difficult to explain to a layperson via concrete examples what emergy is, why it matters, and what specific actions they should take in response to a particular emergy synthesis. Likewise, adaptive management by its very nature is not particularly concrete because it is concerned with the changing nature of systems and the iterative process that should be used to address changing circumstances and changing information. Despite these difficulties, however, it is possible to present these ideas in more concrete ways with clearer paths of action. For example, emergy synthesis could be explained in terms of a fifty-year-old tree in a backyard, which could be valued in a number of ways. You could burn the tree and measure its energy output and assign a market value to the number of BTUs of output. Alternatively, you could sell the tree to a lumber company and assign a value based on the price the lumber company is willing to pay for the tree. Using emergy synthesis, you could determine all of the energy that went into creating the tree and the services it provides, including fifty years of solar energy, water, nutrients, and human labor in pruning the tree. The value of the tree from this perspective is likely to be dramatically higher than the value based on the amount of energy released from burning the tree or the price a lumber company would be willing to pay for the tree. Such an analysis could be used to demonstrate that there is great value in allowing the tree to stand rather than cutting it down for a relatively small amount of money. To date, emergy and adaptive-management scientists have not been successful at packaging their ideas in simple, concrete ways or using concrete examples that prompt people to take action.

Similarly, with regard to the credibility and emotion components of stickiness, risk assessment has been an easier sell. Despite the complexities and uncertainties associated with risk assessment, it is typically presented as a very scientific, objective, and quantitative method in which information is fed into the assessment and "the answer" is spit out. Of course, this is a great oversimplification, but because risk assessment has been presented in this overly simplified way, it brings with it an air of credibility. Emergy synthesis and adaptive management, on the other hand, embrace complexity. Neither emergy synthesis nor adaptive management purports to provide "the answer." As described above, a determination that a resource or service has a high emergy value says nothing about whether it is a positive value or negative value. Such determinations must be made at the policy-making level. Similarly, adaptive management inherently recognizes uncertainties and changes in our understanding of the world. Accordingly, both emergy and adaptive management appear to be less objective, quantitative, and absolute, which probably undermines the credibility afforded them.

Finally, because risk assessment came about in response to the concern that certain environmental exposures cause cancer in humans, it has been shrouded in human emotion from the beginning. Cancer is a dreaded, insidious disease that often leads to death and for which the medical treatment itself can be devastating. Emergy synthesis and adaptive management, both of which typically are used to evaluate effects on natural systems and methods to minimize or manage such effects, do not carry with them that type of direct, human emotional charge. Accordingly, emergy synthesis and adaptive management appear to be intrinsically less sticky and less easily made to be sticky than risk assessment.

C. The Power of Context (The Where & The When)

The Tipping Point describes the "power of context" as the third factor that determines whether an idea will catch on.[205] The power of context relates to the fact that social epidemics are sensitive to the social environment in both the time and the place in which they occur.[206] For an idea to catch on and spread, the circumstances must be right. In other words, the idea must be in the right place at the right time. As described below, risk assessment came into its own during a time and under circumstances that were not only amenable, but desperate, for it. To date, the circumstances do not appear to be ripe for emergy synthesis or adaptive management.

1. The Where.—One variable to consider in determining the extent to which a scientific idea gets picked up by the law is the extent to which it is widely known by the public at large. To attempt to get a sense of the relationship between a scientific idea's prevalence in general and its prevalence in the legal scholarship, judicial decisions, and administrative arena, I conducted the following computer search on Google, Westlaw, and ISI Knowledge Web.[207]

205. GLADWELL, *supra* note 3, at 139.

206. *Id.*

207. *See* ISI Web of Knowledge, http://portal.isiknowledge.com.

Figure 1: Relative Prevalence of Scientific Ideas

Search Term	Google	ISI Knowledge Web	Westlaw: Journals & Law Reviews	Westlaw: Federal Cases	Westlaw: Federal Register	Westlaw: C.F.R.
"Risk Assessment"	10,200,000	78,429	9,245	1,188	9,843	308
"Risk Assessment" & Environment	978,000	3,032	6,630	504	4,919	101
"Adaptive Management"	495,000	598	604	80	1,045	21
"Adaptive Management" & Environment	458,000	61	551	57	386	12
"Emergy"	84,300*	128*	22**	19***	61***	0
"Emergy" & Environment	41,500	34	0	0	0	0

* The relatively few hits using the term "emergy" may be due to the fact that, although the methodology has been in existence for decades, the term "emergy" itself has only been used since the early 1990s. Prior to that, various terms, including "embodied energy" and "ecoenergetics," were used.

** Of the twenty-two "emergy" hits, all but one were either a proper noun denoting a person or company or a typographical error, typically where either the word "energy" or "emerge" appeared to be intended.

*** All of which were a proper noun denoting a person or company name.

Although the number of hits from Google and Westlaw searches is admittedly an extremely crude metric, it does provide some sense of the acceptance and use of the respective scientific approaches in the law and in the broader public arena. In general, there appears to be a pattern in which the prevalence of a scientific idea decreases roughly proportionally as you move from a generic Google search to law reviews, legal journals, and *Federal Register* notices (which have roughly equivalent numbers of hits) to federal judicial opinions and finally to the *Code of Federal Regulations*. While such a crude analysis certainly should not be afforded too much weight, it does reveal a general trend wherein the prevalence of a scientific idea in the legal arena is a roughly proportional fraction of its prevalence in the broader public arena. One explanation for this trend could be that it takes a high level of prevalence of an idea in the general public arena before the idea will be accepted by the legal community. However, this is not the only conclusion that could be drawn. It is possible that the prevalence of a scientific idea in the legal arena leads to a situation where the idea becomes a ubiquitous part of the broader public debate. Whichever came first—the legal or the public—a relationship does exist, and perhaps more significantly, a pattern emerges wherein the prevalence of an idea in the legal scholarly literature and in the administrative-policy arena, as captured by the *Federal Register*, are proportionally greater than the prevalence of the idea in judicial opinions or codified regulations. One explanation is that it is not until a scientific development is vetted in the legal-scholarship and agency-policy arenas that the idea is ripe to be integrated into the courtroom or codified as a regulation.

2. *The When.*—Risk assessment came into its own during the heyday of the environmental era of the 1970s. According to former EPA Administrator William K. Reilly, risk assessment gained currency in environmental decision making in the 1970s and 1980s in large part because, during that time, EPA was charged with implementing a large number of programs under the newly adopted CAA, CWA, RCRA, CERLCA, and TSCA.[208] Thus, according to Reilly, "even the most idealistic and protective of the EPA staff" realized that they could not eliminate all risk and had to allocate resources in such a way as to address the most significant risks.[209] At the same time, technological advances allowed for the first time for substances to be detected in extremely minute quantities, forcing EPA to acknowledge that it could not reasonably require the elimination of all traces of chemicals in every medium and therefore had to make difficult choices regarding what level of risk would be considered acceptable. To make these decisions, a methodology for predicting levels of impact was necessary. Despite the complexities, uncertainties, and controversy surrounding it, risk assessment stepped in to fill this need and soon became the dominant approach used by EPA. Risk assessment also provided a scientific rationale for EPA to defend the decisions it made.

While both adaptive management and emergy synthesis date back to the 1970s, it was not until the 1990s that both achieved widespread acceptance in the scientific community. By the 1990s, the culture of EPA had radically changed from what it was in the 1970s. Moreover, at the time risk assessment became widespread, the focus of environmental law was media-based and human-health-based. The fact that most of the laws administered by EPA are media-based also appears to make risk assessment, wherein individual chemicals or pollutants can be tested in individual media to determine the level of risk they present, an easy fit. Adaptive management and emergy synthesis, on the other hand, are not by nature media-based. Instead, they both recognize and attempt to understand the complexity of nature systems and take a holistic approach to evaluating the impact of human activity to such systems. It was not until much later that the approach of looking at the impact of one chemical at a time in one medium (e.g., air, water) was called into question.[210]

208. Interview by Dr. Dennis Williams with William K. Reilly, Adm'r, EPA (Sept. 1995), *available at* http://www.epa.gov/history/publications/reilly/20.htm (last updated Sept. 21, 2007).

209. *Id.*

210. *See, e.g.*, Jamie A. Grodsky, *Genetics and Environmental Law: Redefining Public Health*, 93 CAL. L. REV. 171, 243 (2005) (contending that the current regulatory scheme is broadly ignorant of the effect of multiple-pollutant interaction); Thomas O. McGarity, *A Cost-Benefit State*, 50 ADMIN. L. REV. 7, 27 (1998) (arguing that single-chemical risk assessments may understate risk in some cases).

Moreover, as former EPA Administrator Douglas Costle has stated, during the early years of the Agency, EPA viewed itself as being on a learning curve, and it continued to take in new information and to adjust its activities accordingly.[211] In more recent years, the culture of the Agency appears not to be one of "learning" but instead appears to be one of "justifying."[212] Most federal environmental laws came into being during the 1970s and 1980s. Since that time, significant scientific advancements have been made, particularly in the ecological sciences. Scientists have begun to recognize the need to look more holistically at ecosystems.[213] This broader holistic approach inherently brought with it a need for approaches that deal with, rather than ignore, the complexities and uncertainties inherent in ecological systems.[214] Unfortunately, at the same time researchers were gaining a better understanding of the complex nature of ecological systems, the public and our political systems were becoming more skeptical of science and less open to incorporating new scientific developments into the law.[215] In this new anti-science environment, science frequently is used to justify predetermined results. If the scientific information does not support the predetermined result, it is ignored or discredited as being "junk science."[216] As described by Professor Holly Doremus elsewhere in this Issue, there has been a trend in recent years to politicize science either by administration officials pressuring agency scientists to alter results to support a particular policy or political agenda, or by science being criticized as junk science whenever it does not support a particular political agenda.[217] Such

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211. Interview by Dr. Dennis Williams with Douglas M. Costle, Adm'r, EPA, in Vt. and McLean, Va. (Aug. 4–5, 1995), *available at* http://www.epa.gov/history/publications/reilly/20.htm (last updated Sept. 21, 2007).

212. *See, e.g.*, CHRIS MOONEY, THE REPUBLICAN WAR ON SCIENCE 26 (2005) (decrying the substitution of political considerations over scientific considerations); Juliet Eilperin, *Ozone Rules Weakened at Bush's Behest: EPA Scrambles to Justify Action*, WASH. POST, Mar. 14, 2008, at A1 (describing how EPA recently had to justify a decision of the Bush Administration weakening ozone rules); Robert F. Kennedy, Jr., *The Junk Science of George W. Bush*, THE NATION, Mar. 8, 2004 (describing several instances where EPA was forced to justify some of its decisions).

213. *See, e.g.*, Grumbine, *supra* note 135, at 28–29 (indicating a need for a more inclusive ecosystem-management approach); Profeta, *supra* note 130, at 71–75 (arguing that ecosystems are complex and interconnected).

214. *See, e.g.*, Profeta, *supra* note 130, at 84–85 (arguing that environmental regulation must address the dynamic uncertainties present in ecosystems).

215. *See, e.g.*, Pouyat, *supra* note 4, at 281–84 (noting legislative reluctance to incorporate biological and ecological scientific developments into laws).

216. Wendy E. Wagner, *The "Bad Science" Fiction: Reclaiming the Debate over the Role of Science in Public Health and Environmental Regulation*, 66 LAW & CONTEMP. PROBS., Autumn 2003, at 63.

217. Holly Doremus, *Scientific and Political Integrity in Environmental Policy*, 86 TEXAS L. REV. 1601, 611–617 (2008); *see also* Stephen M. Johnson, *Junking the "Junk Science" Law: Reforming the Information Quality Act*, 8 ADMIN. L. REV. 37, 40–41 (2006) (suggesting that the perception that the government was using "junk science" led to the passage of the Information Quality Act); Linda A. Malone, *What Do Snowmobiles, Mercury Emissions, Greenhouse Gases and Runoff Have in Common?: The Controversy Over "Junk Science,"* 9 CHAP. L. REV. 365, 365–77 (2006) (describing the recent trend to use science to support political preferences with regard to the

politicization of science results in fewer high-quality scientists desiring to work for EPA for fear that their work will be distorted or attacked as junk science.[218] Likewise, those scientists who do stay at the agency may be more willing to bend their science to fit the political agenda rather than risk losing their jobs or having their work attacked as being junk.

During the early years of EPA, the agency was staffed with scientists and others concerned with developing and implementing regulations and policies to protect human health and the environment.[219] Starting with the Reagan administration in the early 1980s, the emphasis shifted to be one of working with industry and with an ever-greater emphasis on economic considerations.[220] Along with this shift, another shift was taking place which derided "big government" and sought to reduce the size of government in part by privatizing and outsourcing government functions. Many of the jobs, including scientific jobs, previously held by EPA and other agency employees were outsourced to private organizations. Jobs that once required scientists were filled with employees who, rather than being good at or caring about science and keeping up with new scientific developments, had good administrative skills.[221] Scientists who once staffed environmental agencies such as EPA soon found their roles changing from scientists to project managers.[222] A major culture shift occurred.

Of course, in environmental regulation, science is an important component. Nevertheless, EPA gets most of its scientific information from outside of the agency.[223] Except in its earliest years, EPA has never identified itself as a "science agency."[224] Instead it has identified itself as a regulatory and enforcement agency.[225] Since its inception, EPA has become less and less science-oriented.[226] Examples of this trend are seen in changes both in EPA's science budget and workforce makeup over the past thirty-plus

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use of snowmobiles in national parks, greenhouse gases, and mercury emissions from power plants); Kennedy, *supra* note 212.

218. MARK R. POWELL, SCIENCE AT EPA: INFORMATION IN THE REGULATORY PROCESS 64 (1999).

219. *See* William Sanjour, *In Name Only*, SIERRA, Sept. 1992 (contrasting the early years of EPA, which attracted true environmental enthusiasts to the organization, with more recent challenges of staff crossover between EPA and the very industries it aims to regulate).

220. One of the worst examples of the trend away from science during the Reagan Administration was when EPA Administrator Anne Gorsuch fired most of the scientists on EPA's Scientific Advisory Board to replace them with scientists who were "good, solid Republicans." E. Donald Elliott, *Strengthening Science's Voice at EPA*, 66 LAW & CONTEMP. PROBS., Autumn 2003, at 45.

221. *See* POWELL, *supra* note 218, at 57 ("The long-term trend for EPA's science has been downward.").

222. *See id.* at 61 ("[B]ecause much of their time is devoted to contractor management, many of EPA's scientists are unable to practice their craft.").

223. *Id.* at 57.

224. *Id.*

225. *Id.*

226. *Id.* at 57–58.

years. In 1973, approximately one-third of EPA's total budget was dedicated to its Office of Research and Development (ORD).[227] The science budget declined over the 1970s, and by 1980 only approximately 20% of EPA's budget was devoted to science.[228] This science budget suffered substantial decreases during the Reagan Administration, such that in the mid-1980s, the ORD accounted for only approximately 3–4% of EPA's total budget.[229] By the mid-1990s the ORD's budget was still only approximately 7% of the total.[230] This level of science funding is surprisingly small for an agency whose work is so heavily dependent on complex scientific issues. By contrast, FDA's scientific research budget is approximately 20% of its total budget.[231]

Although EPA has a large number of employees with scientific educations, due to decreasing emphasis on scientific research and outsourcing of scientific work, most of these employees' duties are contract management, as opposed to science.[232] Because these EPA employees with scientific education, including those with graduate degrees, do not get to practice their craft as scientists,[233] their scientific skills become rusty, and they are not as likely to keep up with scientific developments.[234] Starting in the 1980s, more and more of EPA's scientific work began to be done by contractors. By 1991, 80% of EPA's research and development budget was paid to outside science contractors.[235] Thus, EPA's overall trend has been a dramatic decline in science resources, while, at the same time, those resources devoted to science are primarily going to outside contractors. The combination of these two factors has resulted in EPA's remaining science staff spending their time on contract management and administrative work rather than scientific work.[236]

By necessity, when a job changes from being one of a scientist to being one of a project manager charged with administering a contract and overseeing the work of outsourced scientists, the role of the in-house employee becomes dramatically altered. Like an in-house corporate attorney versus an outsourced litigating attorney, the in-house employee must concern

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227. *Id.*

228. *Id.*

229. *Id.*

230. *Id.* It should be noted that looking only at the ORD's budget may not fully capture EPA's science budget because scientific resources are also devoted to scientific work in the various program offices. However, it is difficult to separate out which portion of program resources are devoted to seience. *Id.* at 60.

231. *Id.* at 60.

232. *Id.* at 60–61.

233. *Id.* at 61.

234. *Id.* at 61–62.

235. *Id.* at 62.

236. *Id.* at 61–64. Another criticism of contracting out science is that it can result in agency resources being spent to hire like-minded cronies who will manipulate their work to fit the political agenda of those who are writing their paychecks. *Id.* at 38.

herself with contract matters, administrative bureaucracy, quality control, scope of work, deliverables, etc., rather than with the actual, substantive scientific issues. Scientists who desire to do real scientific work typically are not interested in project management. Those that are interested in administrative work are less likely to view themselves as scientists or to take ownership of the science and are less likely to keep up with new scientific developments or push for their inclusion in the law. At the same time, contracting firms doing scientific work for the agency have no economic or professional incentive to try new things. They are rewarded for doing what is in their scope of work and for completing the deliverables in their contract. Incentives exist to get more contracts and make more money. No incentive exists to take the time to learn about new scientific developments, to determine how they could be used by the agency, and to convince the agency to adopt them.[237] Proposals to further outsource and privatize science at EPA and other agencies continue to be made.[238]

Another potential contributor to the cultural shift at EPA is the generic tendency for ambitiousness and enthusiasm to erode in governmental and other organizations after the initial momentum from their founding push has worn off. Perhaps part of EPA's culture shift simply reflects the human and organizational reality that at some point the honeymoon ends and a less exciting, less hopeful, and more mundane reality sets in. Another related issue is that due to EPA's regulatory focus and need to respond quickly to the environmental or political crisis of the moment, even in the face of limited information, many research scientists who are more interested in long-term, quality research are not attracted to the EPA workforce, or if they are attracted, they do not stay for long.[239]

One observation regarding the timing of the introduction of risk assessment versus the other scientific approaches is that risk assessment appears to have been in the right place at the right time. During the heyday of the development of environmental law and regulation, there was tremendous pressure for a scientific methodology to make predictions about risk and to inform regulatory decision making in a way that dispelled the arguments of critics that environmentalists sought to eliminate all risk, regardless of the economic or social costs. Risk assessment stepped in to fill the need. However, in addition to being a time of pressing need, but it was also a time when environmental—particularly human health—risks were at

237. *See* POWELL, *supra* note 218, at 63 tbl.3.5 (analyzing the breakdown of EPA employees with doctorates, which as of 1993 equaled less than 10% of those with college degrees).

238. *See, e.g.*, *U.S. Researchers Fear Job Losses from Privatization Drive*, 424 NATURE 478, 478 (2003) (describing the Bush Administration's proposal to contract out federal scientific projects at EPA, National Park Service, and National Institutes of Health); Press Release, Pub. Employees for Envtl. Responsibility, U.S. Army to Contract out Environmental Staff (June 20, 2007), *available at* http://www.peer.org/news/print_detail.php?row_id=875 (describing the U.S. Army's attempt to privatize its environmental, natural, and cultural-resouree functions).

239. POWELL, *supra* note 218, at 63.

the forefront of the public's mind. During the 1970s and 1980s, with high profile hazardous-waste-contamination incidents such as Love Canal, the public became increasingly concerned with the risk of cancer from environmental contaminants. Consequently, EPA's risk assessment was primarily used as a means to evaluate cancer risk to humans.

Another important characteristic of that time period is also that the public had not yet become as jaded and skeptical of science as it is now. The post-World War II years marked a time when the public not only trusted science, but also put great hope for the future in technological and scientific advances. Americans believed that technology could solve our problems and such beliefs were fortified by scientific success stories, such as putting humans into space and ultimately on the moon. By the 1980s, however, the public became more skeptical of technology.[240] Technological developments, such as the modern products of chemistry that had improved the daily lives of average Americans, became serious problems as more and more hazardous-waste-contamination sites were discovered. Americans became weary of news reports on scientific studies that seemed to contradict each other. It seemed as though one day a certain food product was considered unhealthy and the next week that same food was considered to afford great health benefits. Public distrust of science was encouraged by politicians who manipulated science to fit their own agendas and who called into question the credibility of any scientific study that did not support their political agenda by calling it "junk science."[241] Thus, the environment for incorporating new or different scientific approaches into environmental law in the late 1980s through the 2000s became increasingly hostile. At the same time that there was a need to develop scientific approaches that could address broader issues than merely assessing the risk posed by specific doses of specific chemical substances on specific species, the door closed on science.[242]

It seems likely that many factors contribute to whether a scientific idea becomes incorporated into environmental law or policy. Moreover, using only three scientific ideas to identify patterns or reach conclusions regarding why some ideas are integrated into the law while others are not certainly is not sufficient to form any conclusive results. Nevertheless, certain patterns do emerge from the three examples, which could provide insight into how to better integrate science into law in the future.

240. *See* Jon D. Miller & Rafael Pardo, *Civic Scientific Literacy and Attitude to Science and Technology: A Comparative Analysis of the European Union, the United States, Japan, and Canada*, *in* BETWEEN UNDERSTANDING AND TRUST: THE PUBLIC, SCIENCE AND TECHNOLOGY 81, 81 (Meinolf Dierkes & Claudia von Grote eds., 2000) (noting the widespread "public awe and admiration" at scientific advances).

241. *See id.* at 82 (chronicling growing institutional cynicism and public awareness of environmental damage).

242. *See supra* note 218 and accompanying text.

VI. Lessons for the Future (How We Can)

To the extent that patterns can be discerned from this limited analysis of three scientific developments, the following factors appear to be important in determining whether scientific developments will be integrated into environmental law and policy. It appears that one of the most important factors is ensuring that EPA regains a scientific culture such that mavens, connectors, and salespeople are available to develop new ideas, reach out to the scientific-research community to find new ideas, find ways to incorporate the new ideas into law and policy, and sell the new ideas to agency staff, government leaders, and the general public. In addition, even the best ideas are not likely to catch on unless they are sufficiently "sticky." Good scientific ideas must be packaged and presented in a manner that takes advantage of the principles of "stickiness." Finally, although neither scientists nor policy makers have complete control over the particular circumstances that exist when a particular new scientific idea is developed, it is possible to ensure that circumstances within EPA are such that the agency is at least open to the possibility of using new scientific developments. To accomplish this, integrity and trust of science must be restored.

With regard to the "who," it appears that the most important factor is that the regulatory agency itself identifies a need and seeks out science to help it address that need. It appears that unless the agency is actually in the market for a new scientific idea to fulfill an identified need, it will not be open to new or different ideas despite the fact that new ideas may exist that could greatly enhance the agency's work. No matter how prestigious the researcher or how elite the research institution that develops an idea, it seems that EPA, in its current form, is generally not willing to reach out to pull in new or different scientific ideas. To create a culture at EPA in which scientists are either developing new scientific ideas to meet policy needs or keeping up with and seeking out new scientific ideas being developed at research institutions, it is necessary to ensure that there are sufficient scientific mavens and connectors who can bring together scientists and policy makers and thereby provide a bridge between the worlds of science and policy.

For new or different scientific ideas to be incorporated into environmental law and policy, high-level agency staff must be motivated to look more closely at the work being done at research universities and other research institutions to find and try out new scientific ideas. In an era where government leaders have consciously created a culture of distrust of science and have intentionally ignored or distorted science where necessary to promote their own political agendas, it is no wonder that agency personnel are not motivated to seek out new or different scientific ideas that may not support the political agenda of a given administration. For this to occur, agencies must have clear direction from above that an important goal is to seek out better scientific approaches and to use the best science available to make the best decisions possible.

To ensure that agencies such as EPA keep abreast of and seek out new scientific ideas to improve their decision making, we must restore a scientific culture to the agencies. Agencies that are asked to make decisions critical to human-health and environmental protection based on science must respect science and scientists. Science should not be outsourced such that scientists within agencies are merely contract or project managers without financial or professional incentive to keep up with new developments or to find ways to integrate them into the activities of the agencies. Instead, agencies must have scientists on staff who are rewarded for doing objective science, who have professional pride, and who are tasked with keeping up with developments and finding ways to use the best new or different scientific ideas to improve environmental policy. In *Tipping Point* parlance, we need to ensure that there are mavens, connectors, and salespeople whose skills can be used to seek out, incorporate, and spread new scientific ideas to support environmental decision making. The best way to provide mavens and connectors is to shift the culture of EPA such that it puts priority on hiring and retaining skilled scientists who are not only permitted but encouraged to conduct scientific research, participate in scientific conferences and other professional activities, and keep up with scientific developments. These mavens are necessary to ensure that the agency keeps abreast of new, useful scientific ideas. Other scientists—who, rather than being pure researchers, are those with connections to a wide circle of other scientists and policy makers and who have the social skills to bring scientists and policy makers together—will be needed to ensure that good scientific ideas find their way to the right policy people. These connectors ideally would be people with the ability to "bridge the gap" between science and policy and who have the skills to communicate with people in both disciplines to bring useful scientific ideas to the right policy people and be able to demonstrate how these new ideas might be used in the policy-and-law arena. These connectors, or "bridgers," would be able to translate legal and scientific concepts so that individuals involved in both disciplines could better understand each other. More importantly, however, the connector would have the expertise to identify areas where new scientific developments could benefit environmental decision making and could develop proposals to experiment with incorporating such ideas into law or policy.[243] Finally, to

243. Although an evaluation of EPA's existing Scientific Advisory Board (SAB) is beyond the scope of this Article, in theory the SAB could fill the role of connector. Historically, however, the SAB has had only limited success as a connector. First, SAB members are full-time researchers at universities, companies, and other institutions and therefore have only limited time to devote to EPA activities. Moreover, SAB has been criticized as being overly politicized. For a further discussion of EPA's SAB, see generally JOHN D. GRAHAM, HARNESSING SCIENCE FOR ENVIRONMENTAL REGULATION (1991) (evaluating the SAB's regulatory science activities through

ensure that useful ideas are actually used, salespeople are needed at the highest levels of the agency. Leaders such as former Administrator Ruckelshaus, who have the stature, charisma, and skills to "sell" their staff and the public on a good idea, are necessary.

One option for ensuring that EPA is able to obtain the type of scientific research needed to address problems faced by environmental regulators and policy makers is an institutional change. For example, during Doug Costle's administration at EPA, a proposal was made to create "Centers of Excellence" on human health, ecology, and technology.[244] Under the proposed model, EPA would fund research at major universities to be used partially for basic research and partially for research focused on solving specific environmental problems. Almost half of a billion dollars was set aside to fund those centers. When President Reagan took office, he cancelled the program, and it was never revived.[245] To Costle's mind this was an enormous lost opportunity to develop balanced research systematically focused on identifying and solving important environmental problems. A research institution based on this model, which responds to the needs of environmental managers while ensuring that science is conducted in a rigorous manner and is insulated as much as possible from political influence, could greatly enhance the incorporation of new scientific ideas into the law. As was the case with risk assessment, if agencies ask for research to address specific problems they are facing, it is much more likely that the resulting research will be in a form useful to the agency and much more likely that the agency will be willing to integrate the research into their rule or policy development. Others have suggested ways to improve and strengthen the role of science at EPA. These proposals have included, among other things, the following: create a high-level advocate for science, empower scientists to make policy recommendations, and organize a "science watch" NGO to represent disinterested scientists in the administrative process.[246] Another possibility is to create a nonregulatory scientific research agency, analogous to the U.S. Geological Survey (USGS), which serves as the primary source of internal scientific advice for the Department of Interior. Such an agency could be tasked with conducting research for EPA-related purposes in an environment that is independent of the political pressures asserted on EPA as a regulatory agency.[247] USGS has

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1988), and Elliott, *supra* note 220, at 45 (arguing for an increased role for science in policy making at EPA).

244. Interview by Dr. Dennis Williams with Douglas M. Costle, *supra* note 211.

245. *Id.*

246. *See* Elliott, *supra* note 220, at 53–62 (outlining three proposals to improve and strengthen the role of science at EPA).

247. Doremus, *supra* note 217, at 1626 (describing USGS as a nonregulatory agency that provides the Department of Interior with its primary source of scientific advice).

a reputation for conducting quality science in an honest and objective manner.[248]

Of course, for good scientific ideas to be integrated into environmental law and policy, the public's trust in science must be restored. Two things will need to happen for this to take place. First, to the extent possible, science must be insulated from political influence. We must go back to an approach where scientific data are as objective as possible, and where policy decisions are informed by science, not characterized as science. Second, politicians and government officials must be willing to stop the assault on science as being "junk science" merely because it does not support their particular political agendas.

With regard to the "what," it appears that for scientific ideas to catch on with EPA, as well as with the general public, the ideas need to be "sticky." Although some ideas are inherently stickier than others, most ideas can be made at least somewhat sticky. This can be accomplished by packaging and presenting scientific ideas in ways that incorporate the principles of stickiness. For example, scientific ideas such as emergy synthesis and adaptive management, although inherently complex, could be made stickier if they were boiled down to their core ideas and presented to policy makers and the public as simpler, more streamlined ideas with clear guidance on how they could be applied in a real-world setting. These ideas could also be made stickier if very concrete examples and stories are used that connect to people on an emotional level. Unfortunately, most scientists are either not adept at, or are not interested in, boiling down complex ideas to core concepts or presenting them in ways that make a strong human connection and prompt individuals into action. Academics are not necessarily rewarded for making their ideas simple and easily accessible. Even the term "emergy" itself is not sticky. The average person does not know what the term means and is unlikely to be able to glean its meaning from the word itself. The term "emergy" is frequently identified as a typographical error. Nothing in the term itself provides a concrete image that will stick in people's minds or prompt individuals to take action. Thus, one way to make emergy stickier is to change its name to something that is easily understood and conveys a clear concrete message.

The "when and where" factors are perhaps where persons interested in promoting an idea have the least power. To some extent, as seen in the case of risk assessment, the success of a scientific idea simply depends on the idea being in the right place at the right time. In other words, the timing of factors such as a new congressional or judicial mandate, or a new environmental problem or crisis, creates an environment that is ripe for new scientific ideas. Nevertheless, there are ways to change the culture of agencies like EPA such that they are more receptive to new or different scientific ideas. Perhaps the

248. *Id.*

most critical change that is needed to create such a receptive atmosphere is an administration that respects science, recognizes the benefit science can provide in informing sound decision making, and eschews political interference in science. Leadership is needed that recognizes and respects the divide between science and policy. Agency heads are needed who exert leadership in directing staff to utilize new scientific approaches as they foster an agency culture that respects scientists, hires scientists, and allows scientists to do scientific work and take professional pride in their work.

VII. Conclusion

Environmental law and policy decisions must be informed by science. While universities and other research institutions throughout the world continue to develop new scientific ideas and approaches, environmental law has failed to fully take advantage of the benefits these developments can offer. A number of factors appear to influence whether a particular scientific idea finds a home in the law. These factors can be categorized as relating to the who, what, where, and when of the particular idea. Most significantly, it appears that the environmental agencies themselves must be seeking a scientific idea to assist them in addressing a particular congressional or judicial mandate or to answer a scientific question they are grappling with. To some extent, whether a scientific idea catches on depends on whether it is packaged and presented in a manner that is memorable and that provides a clear path of action. Perhaps more importantly, however, for agencies that desire to seek out and integrate new or different scientific ideas or approaches, agencies must have strong leadership encouraging them to do so, a culture of science must exist within the agency, science must be respected by government leaders, and agency scientists must be free to engage in scientific work free from political pressure. If this could be accomplished, the environmental law and policy world could benefit substantially from the ever-growing body of scientific knowledge.

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