Bottlenecks and Baselines: Tackling Information Deficits in Environmental Regulation

Bradley C. Karkkainen*

The first generation of statutory and regulatory environmental law in this country naively assumed that information would be abundant and cheap to acquire. Nowhere is this assumption clearer, perhaps, than in the National Environmental Policy Act[1] (NEPA), the statute that signaled the onset of the "environmental decade" of the 1970s.[2]

NEPA famously requires federal agencies, prior to undertaking any action that "significantly affects" environmental quality, to produce and publicly disclose a "detailed statement" of the environmental impacts of the proposed action, evaluating it side-by-side with a range of alternatives.[3] This open-ended information requirement, reflecting a mid-twentieth century faith in "comprehensive bureaucratic rationality,"[4] places enormous demands on agency resources.[5] A full-scale environmental impact statement (EIS) typically is hundreds or even thousands of pages in length, and takes millions of dollars and months, if not years, to complete.[6] Even when completed, however, the informational value of an EIS may be dubious.[7] Litigation-averse agency officials, loath to be sued for failure to consider relevant information, are inclined to cram an EIS full of every scrap of data and analysis available, regardless of quality, resulting in bloated, indiscriminate documents.[8]

Moreover, the principal conclusions in an EIS are typically predictive judgments. Since NEPA does not require follow-up monitoring or verification, in most cases we will never know if an EIS was correct.[9] The few follow-up empirical studies that have been done are not encouraging: they

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* Professor and Henry J. Fletcher Chair, University of Minnesota Law School.

1. 42 U.S.C. §§ 4321–4370 (2000).

2. Bradley C. Karkkainen, *Toward a Smarter NEPA: Monitoring and Managing Government's Environmental Performance*, 102 COLUM. L. REV. 903, 904 (2002).

3. 42 U.S.C. § 4332(2)(C) ("[A]ll agencies of the Federal Government shall . . . include in every recommendation or report on proposals . . . affecting the quality of the human environment, a detailed statement by the responsible official on . . . the environmental impact of the proposed action . . . [and] alternatives to the proposed action . . . .").

4. Karkkainen, *supra* note 2, at 912.

5. *Id.* at 911–12, 925–27.

6. *See id.* at 917–19 & nn.64–67 (citing studies that show an average length of over 200 pages and an average completion time of up to 5 years).

7. *See id.* at 921 (noting that the open-endedness of NEPA's requirements often leads to the production of reports with low information quality).

8. *Id.* at 922.

9. *Id.* at 927.

suggest that many predictive judgments in EISs are framed too imprecisely to be empirically tested, and where subsequent monitoring does allow verification of more precise predictions, the principal conclusions are wrong even about the direction of environmental change in a disturbingly large percentage of cases, and wrong about its magnitude in a large part of the rest.[10]

The situation, however, is not entirely bleak. Facing the costs and delays associated with EIS production, agency officials have taken matters into their own hands. In the vast majority of cases, agencies now employ a simplified, streamlined analytical device known as an environmental assessment (EA), typically leading to a finding of no significant impact (FONSI).[11] Because NEPA requires a full EIS only when the environmental impacts of the proposed action are judged to be "significant," agencies now endeavor to design programs and projects in such a way that they can plausibly be characterized as falling below that threshold.[12] Alternatively, agencies can add on just enough mitigation measures to plausibly push the environmental impact of their programs below the EIS-triggering "significant" level—a gambit known as the "mitigated FONSI."[13] While critics contend these stratagems amount to a massive subversion of the NEPA regime,[14] the case can be made that they are in fact salutary developments. Through the indirect and unintended backdoor route of EAs, FONSIs, and mitigated FONSIs, NEPA is arguably prompting agencies to design and implement environmentally benign projects, programs, and mitigation measures in a manner that avoids the statute's most onerous paperwork requirements.[15] Indeed, it is tempting to conclude that whenever the costs of minimizing or mitigating adverse environmental impacts fall below the costs of EIS production, rational agency managers will elect to minimize or mitigate the impacts. Thus, whatever we sacrifice in information disclosure, we more than make up for in environmental benefits.

Yet this analysis is too facile. Once again, our confidence is tested by NEPA's failure to require follow-up monitoring.[16] At the end of the day, we have little more than the agency's written assurance in the EA and FONSI that, as so designed or mitigated, the program or project will not produce significant environmental impacts. The agency's predictions, however, may be predicated upon faulty or incomplete baseline data, incomplete or

10. *See id.* at 928–29 (citing ex post verification studies showing that half or less of the measurable predictions contained in EISs were "accurate" as to both the direction and magnitude of environmental change).

11. Bradley C. Karkkainen, *Whither NEPA?*, 12 N.Y.U. ENVTL. L.J. 333, 347 (2004).

12. *See id.* at 347–48 (stating that federal agencies produce approximately 50,000 EAs that lead to FONSIs annually but only about 500 full-scale EISs).

13. *Id.* at 348.

14. Karkkainen, *supra* note 2, at 933–34.

15. Karkkainen, *supra* note 11, at 348–49.

16. *Id.* at 349.

inconclusive science, or simple misjudgments about the direction and magnitude of change in complex, nonlinear, dynamic, and interdependent ecological settings. If the agency turns out to be wrong, we will never even know it, much less be in a position to hold the agency accountable.[17] For agencies, the consequences of being wrong under NEPA are approximately nil.

I begin with this NEPA example not to single out NEPA for harsh criticism. Indeed, for all its limitations, NEPA remains one of our most important and foundational environmental laws. It opened agency decision making to an unprecedented level of public scrutiny, forced agencies to take environmental costs into consideration in their decision making, and very likely produced substantial but unquantified (and presently unquantifiable) improvements in government's environmental performance.[18]

But NEPA also usefully illustrates a more general problem in environmental regulation: to a remarkable degree, information failures pervade environmental law and policy. And worse, we have failed to think about these information problems head-on and strategically. We continue to muddle through with statutory and regulatory frameworks predicated upon outdated and erroneous mid-twentieth-century assumptions about the ease of acquiring and processing the information required for sound environmental decision making.

In previous work, I have described the phenomenon of information failure in environmental regulation as a single problem.[19] The basic insight here is that doing environmental regulation and natural-resources management well—or in some cases acting at all—requires a good deal of information. Other things being equal, we want these decisions to be based on high-quality information. Typically, we place the burden of acquiring or producing information, and then managing, analyzing, and evaluating that information, on the government—more particularly, on the responsible regulatory or resource-management agencies.[20] Additionally, we generally require more than just the amassing of information; we demand also that the regulatory or resource-management agency glean from the amassed information a justification, not just for some kind of action with respect to the problem at hand, but also for the particular course of action chosen as against a range of possible alternatives.[21] Finally, we demand that this justification be robust enough to withstand judicial review.[22]

17. *See* Karkkainen, *supra* note 2, at 938 (suggesting a system of postdecision monitoring to give the government and the public the chance to hold the agency accountable for wrong predictions).

18. *See id.* at 904–06 (summarizing the many positive aspects of NEPA).

19. Bradley C. Karkkainen, *Information as Environmental Regulation: TRI and Performance Benchmarking, Precursor to a New Paradigm?*, 89 GEO. L.J. 257 (2001).

20. *Id.* at 266.

21. *See* Corrosion Proof Fittings v. EPA, 947 F.2d 1201, 1217 (5th Cir. 1991) (holding that EPA, under the Toxic Substances Control Act (TSCA), was required to evaluate less burdensome

Less widely appreciated, however, is that the information burdens we place on regulatory and resource-management agencies can sometimes themselves represent a significant constraint on the agencies' capacity to act. Indeed, sometimes these information burdens can be crushing, debilitating, or broadly distorting of policy outcomes.[23]

The result is that in many areas we get a suboptimal output of agency decisions—problems go unaddressed, regulatory solutions come too late in the day to be optimally effective, or old decisions hold sway long after they have outlived their usefulness—because, at least in part, the burden of information required to justify change and make it stick is simply too great.[24]

The problem, then, broadly stated, is that we have not thought carefully or strategically enough about these information burdens. We do not have well-designed policies about exactly what information should be required, how and to whom the burden of producing that information should be assigned, and what the burden of persuasion should be on the basis of that information. We have not done nearly enough clear thinking about what kinds of unintended side consequences and incentives that assignment of both the burden of production and the burden of persuasion creates for the agency to whom it is assigned and for nongovernmental parties—industry, first and foremost, but also environmental and public-health NGOs, academic experts, independent scientists, and so on.

Yet a closer examination reveals that although information deficits are commonplace throughout environmental regulation, they are not all of a single type. This Article represents a first attempt to establish a typology, identifying four distinct types of information failure that characterize present-day environmental law and policy. These are as follows: Part I addresses the problem of asymmetrically held information, especially as it concerns industrial processes. Industries generally hold an advantage over regulators with respect to their understanding of the production processes and pollution-control technologies available to them, but arguably have a disincentive to share that information with regulatory agencies that might use it as a basis for regulation. Part II discusses the sheer burden of information required to establish health-based environmental standards given the incomplete state of medical and scientific knowledge and the regulatory pathologies that follow. Part III focuses on the absence of good baseline information and data on environmental conditions and stressors. Finally, Part IV examines the

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regulatory alternatives and show that those alternatives were less effective than the proposed harsher regulatory scheme).

22. *See* Karkkainen, *supra* note 2, at 907 (noting that NEPA makes judicial review available to force an agency to change its justification if its initial study is not sufficiently comprehensive).

23. *See* Karkkainen, *supra* note 19, at 266–68 (describing the way in which information barriers negatively impact regulatory agencies' ability to place pollutants under effective regulatory control).

24. *See id.* at 277 (noting that the difficulty and expense involved in revising ineffective regulations pressure agencies to issue effective regulations the first time, but also act as a bar to further regulatory change).

problems of uncertainty and scientific gaps with respect to complex and dynamic ecosystem processes and functions that stand in the way of our achieving the elusive goal of integrated ecosystem management.

For each of these four types of information failure, however, we can also identify some promising alternatives to the standard regulatory approaches of the 1970s. None of these alternatives is as yet fully developed, and each exhibits significant limitations. But taken together, these alternatives might suggest a way forward in the direction of a more conscious and directed approach toward information policy in the context of environmental regulation.

I. Technology-Based Regulation and Information Asymmetries

Critics of "command-and-control" approaches to environmental regulation generally train their sights on technology-based regulations. These, they claim, are inefficient, rigid, straitjacketing, one-size-fits-all approaches that tend not to fit anyone particularly well.[25] Technology-based regulations typically ignore variations within and across industry sectors that distribute compliance costs unevenly.[26] Generally, these regulations are predicated upon add-on, end-of-the-pipe pollution-control technologies, and once promulgated, they tend to freeze those technologies in place because industry has little incentive to develop alternative pollution-reduction strategies and technologies.[27] Moreover, the administrative costs of technology-based regulations can be staggering.[28] Under the Clean Water Act,[29] for example, EPA has had to develop technology-based effluent-limitation standards for literally hundreds of industries and dozens of pollutants by examining a variety of industry-specific pollution-control technologies.[30] These complex engineering evaluations are costly and time-

25. *See* Bruce A. Ackerman & Richard B. Stewart, *Reforming Environmental Law*, 37 STAN. L. REV. 1333, 1335–37 (1985) (criticizing the best available technology (BAT) strategy used by EPA); Daniel A. Farber, *Environmental Protection as a Learning Experience*, 27 LOY. L.A. L. REV. 791, 794 (1994) (stating that because "EPA cannot fully master the economics and technologies of dozens of industries," it is "bound to make mistakes in both directions: asking more than some industries can reasonably achieve and letting others off too lightly").

26. Ackerman & Stewart, *supra* note 25, at 1335 (stating that technology-based regulations "waste many billions of dollars annually by ignoring variations among plants and industries in the cost of reducing pollution" (footnote omitted)).

27. *See id.* at 1336 (stating that technology-based regulations "do not . . . provide strong incentives for the development of new, environmentally superior strategies, and may actually discourage their development").

28. *See id.* at 1336–37 (stating that the "centralized determination of complex scientific, engineering, and economic issues" involved in technology-based regulations "impose[s] massive information-gathering burdens on administrators").

29. 33 U.S.C. §§ 1251–1387 (2000).

30. *See* Ackerman & Stewart, *supra* note 25, at 1335 ("Under the Clean Water Act's [technology-based regulation] strategy, the EPA adapts nationally uniform effluent limitations for some 500 different industries."); *see also* 33 U.S.C. § 1311(b)(2)(A) (2000) (requiring "application of the best available technology economically achievable" to each category or class of industry).

consuming, typically taking many months to perform.[31] Highly competitive, dynamic, and innovative industrial sectors in particular complain that by the time a new technology-based regulatory standard is promulgated, it may be technologically obsolete, because industry has moved on to new product lines and new production technologies.[32]

These criticisms may be exaggerated, but they bear a kernel of truth. At bottom, the problem is one of information. Current statutes assign to regulatory agencies the burden of assembling the relevant information necessary to promulgate literally thousands of industry-specific, pollutant-specific, and technology-specific standards. That, in turn, requires thousands of hours of evaluation and analysis. Even a careful and good-faith effort on the regulator's part will typically lead to a standard that is at best an approximate fit for the multiple players in a single industry.[33] For its part, industry has little initial incentive to cooperate in the production of this information. Since the default assumption in our legal order is that there is no regulation until and unless the regulatory agency, acting under appropriate statutory authority, has made a reasoned case for a particular regulatory standard, industry foot-dragging will only delay the onset of regulation.[34] Again, as with NEPA,[35] the Congresses that enacted these statutes appear to have assumed that the information necessary to promulgate regulations would be readily available and cheap to acquire. Instead, the cost and difficulty of acquiring this information stand as major barriers to the timely promulgation of effective, efficient, and well-tailored regulatory standards.

An important but generally underappreciated element in this equation is that information on industrial technologies tends to be held asymmetrically. Generally, industries know more about their own production technologies and cost curves, and are better positioned than regulatory agencies to

31. *See* Ackerman & Stewart, *supra* note 25, at 1336–37 (noting the "massive information-gathering burdens" administrators face in promulgating technology-based regulations); *see also* Richard B. Stewart, *Models for Environmental Regulation: Central Planning Versus Market-Based Approaches*, 19 B.C. ENVTL. AFF. L. REV. 547, 552 (1992) (noting the "slow, unresponsive, and costly" decisions made as a result of the large amount of centralized planning needed for technology-based regulations).

32. ROSEMARY O'LEARY ET AL., MANAGING FOR THE ENVIRONMENT: UNDERSTANDING THE LEGAL, ORGANIZATIONAL, AND POLICY CHALLENGES 332 (1999) (stating that technology-based regulation often fails to keep pace with rapid technological and process changes in dynamic industries, so that proposed rules are sometimes obsolete before they are promulgated).

33. *See supra* note 25 and accompanying text.

34. *Cf.* Mary Lyndon, *Information Economics and Chemical Toxicity: Designing Laws to Produce and Use Data*, 87 MICH. L. REV. 1795, 1813–14 (1989) (stating that manufacturers of chemical products have an incentive to avoid production and disclosure of toxicity and exposure data on their products because such information could lead to regulatory restrictions); Wendy E. Wagner, *Commons Ignorance: The Failure of Environmental Law to Produce Needed Information on Health and the Environment*, 53 DUKE L.J. 1619, 1631–32 (2004) (stating that, regarding health and environmental impacts, industry actors "vastly prefer ignorance over research" because the information they produce may lead to regulation).

35. *See supra* notes 1–8 and accompanying text.

determine the nature and extent of their waste byproducts (whether or not they actually pay attention to them) and to evaluate the cost, effectiveness, and unintended consequences of applying particular pollution-control technologies to their own industrial processes.[36] It seems a curious mismatch, then, to assign primary responsibility for investigating and evaluating industrial technologies to a regulatory agency that, regardless of its engineering expertise, enters the game at such an informational disadvantage. Seen in that light, long regulatory lead times, inefficiencies, rigidity, and regulatory mismatches appear to be a predictable consequence.

At this point, some commentators argue for some form of industry self-regulation;[37] others argue for negotiated regulatory solutions mutually agreed upon between industry and regulator, either on a case-by-case or industry-wide basis.[38] The problem with self-regulation, however, is accountability: industry's incentive will always be to seek the least-cost solution—the least cost to industry itself—even if it means externalizing costs (like excessive levels of pollution) to society.[39] Predictably, then, self-regulation will tend toward regulating with an exceedingly light hand, and this tendency will be compounded by a lack of transparency and accountability in the decision-making process.

For these reasons, negotiated solutions—for example, negotiated rulemaking,[40] Project XL-type individualized waivers,[41] and sector-by-sector

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36. Wagner, *supra* note 34, at 1643–45; *see* Cary Coglianese, Richard Zeckhauser & Edward Parson, *Seeking Truth for Power: Informational Strategy and Regulatory Policymaking*, 89 MINN. L. REV. 277, 286–87 (2004) (stating that manufacturing firms "almost always know much more than government about the risks associated with their products, technologies, and processes" and are in a better position to evaluate the effectiveness and costs of alternative pollution control strategies).

37. *See generally* David W. Case, *Changing Corporate Behavior Through Environmental Management Systems*, 31 WM. & MARY ENVTL. L. & POL'Y REV. 75 (2006) (discussing possible advantages of corporate self-management through environmental management systems (EMSs), but concluding that purely voluntary programs suffer from low participation rates and lack of transparency); Daniel A. Farber, *Triangulating the Future of Reinvention: Three Emerging Models of Environmental Protection*, 2000 U. ILL. L. REV. 61, 68–72 (2000) (discussing the "unilateralism" model of industry self-regulation).

38. Farber, *supra* note 37, at 76–79 (discussing a variety of bilateral "bargaining" approaches to negotiated environmental regulation).

39. *See id.* at 71 (stating that skepticism about environmental self-regulation is rooted in the fundamental economic principle that "firms are rational maximizers of profits" and that "environmental harms are externalities that do not enter into firms' profitability").

40. Negotiated rulemaking is authorized by the Negotiated Rulemaking Act of 1990, 5 U.S.C. §§ 561–570 (2000). *See generally* Cary Coglianese, *Assessing Consensus: The Promise and Performance of Negotiated Rulemaking*, 46 DUKE L.J. 1255 (1997) (explaining negotiated rulemaking and offering a generally skeptical assessment).

41. Project XL was a Clinton-era EPA program that sought to relieve regulated entities of onerous regulatory requirements on a negotiated, case-by-case basis in return for pledges of "superior environmental results." EPA, What is Project XL?, http://www.epa.gov/projectxl/file2.htm (last updated May 14, 2008); *see* Dennis D. Hirsch, *Project XL and the Special Case: EPA's Untold Success Story*, 26 COLUM. J. ENVTL. L. 219, 224, 229 (2001) (describing Project XL and offering a generally positive assessment of its usefulness in addressing "special cases" where conventional regulatory standards are a "bad fit"). *See generally* Lawrence E. Susskind & Joshua

bargaining as in the Dutch model[42]—might at first blush appear more promising. But here again, industry self-interest coupled with asymmetrically held information remains a threat. At the margins, industries will have an incentive to exaggerate the costs and technological difficulties of achieving a high level of environmental performance and to understate the prospects for environmental progress. Regulators may push for tougher standards and challenge industry's factual assertions, but the informational playing field is not level; industry will often have both the opportunity and the motive to "game" the negotiations.[43]

What, then, is to be done?

One currently fashionable solution is to bring in market-based incentives, either cap-and-trade programs[44] or Pigouvian taxes.[45] The idea is to get industry to bring pollution under control on its own initiative by providing appropriate financial incentives to do so. These incentives may be either positive, in the form of profits to be made by generating and selling pollution allowances in a cap-and-trade system, or negative, in the form of avoiding the costs of a volume-based pollution tax.[46] Economists argue that incentive-based approaches are more economically efficient than the

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Secunda, *The Risks and Advantages of Agency Discretion: Evidence from EPA's Project XL*, 17 UCLA J. ENVTL. L. & POL'Y 67 (1999) (offering a generally positive assessment of Project XL as a device to introduce flexibility and adaptive-learning capacity into the regulatory system, but cautioning that clearer legal authorization, changes in agency culture, and procedural safeguards would be needed to ensure its success).

42. *See generally* Daniel J. Fiorino, *Toward a New System of Environmental Regulation: The Case for an Industry Sector Approach*, 26 ENVTL. L. 457, 485–88 (1996) (urging adoption of a performance-based, industry-sector model of environmental regulation in which environmental performance objectives are negotiated and periodically revised on a sector-by-sector basis); Michael P. Vandenbergh, *An Alternative to Ready, Fire, Aim: A New Framework to Link Environmental Targets in Environmental Law*, 85 KY. L.J. 803, 867–81 (1997) (describing and offering a generally positive assessment of the Dutch model in which sector-based environmental performance targets are periodically negotiated within the framework of national goals and targets).

43. This threat is also at play in conventional regulatory standard-setting. *Cf.* Wagner, *supra* note 34, at 1649–59 (describing a variety of methods available to industry to obfuscate and "manufacture uncertainty" so as to disrupt the regulatory process).

44. Under "cap-and-trade" or "emissions-trading" schemes, a regulatory agency sets an overall pollution "budget" and assigns individual quotas to regulated entities. *See* T.H. TIETENBERG, EMISSIONS TRADING 7–9 (1985) (describing emissions-trading programs and explaining why they are economically efficient). If an entity reduces pollution below the authorized level, it generates an "allowance" which it can bank to credit against future regulatory requirements or sell on the open market to an entity that finds it cheaper to purchase the allowance than to reduce its own emissions. *Id.*

45. A Pigouvian tax, named for the English economist Arthur Cecil Pigou, attempts to correct social externalities (e.g., pollution) by taxing them at a rate that reflects the externalized cost. A Pigouvian pollution tax thus creates an incentive to eliminate pollution wherever it is economically efficient to do so, that is, wherever the cost of eliminating pollution is less than the cost imposed by the pollution. DAVID A. ANDERSON, ENVIRONMENTAL ECONOMICS AND NATURAL RESOURCE MANAGEMENT 298–99 (2004); RICHARD C. PORTER, THE ECONOMICS OF WASTE 7 (2002).

46. *See supra* notes 44–45.

alternatives.[47] Because industrial firms and facilities are better positioned than distant government bureaucrats to identify and evaluate least-cost pollution-reduction strategies, regulatory approaches that "put a price on pollution" translate pollution control into an ordinary, profit-motivated business decision.[48] Firms then will implement those pollution-reduction measures that are available to them at a cost below the prevailing price of pollution (the market price of allowances in a cap-and-trade system or the price set by the tax in a Pigouvian approach).[49] Consequently (in theory), all and only the least-cost pollution-control measures will be undertaken.[50]

Notice, however, that these market-based mechanisms are also efficient from an information-policy perspective. The burden of evaluating the effectiveness and costs of pollution-control strategies and technologies falls squarely on industry, the party best positioned to make those evaluations; the regulator need only determine how many allowances to issue or where to set the tax, and monitor closely to prevent, punish, and deter cheating.[51] Under this model, industry has a strong incentive to get those evaluations right, as accuracy translates directly into dollars earned or saved.[52] Asymmetrically held information, in short, is no longer the enemy of regulatory efficiency, but instead is its driver.

There are, however, important limitations to market-based incentive approaches. Cap-and-trade works best where we are truly indifferent to the location of the pollution source, that is, where we are not concerned with localized concentrations.[53] That is true of greenhouse gases and ozone-

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47. *See, e.g.*, Ackerman & Stewart, *supra* note 25, at 1341–42 (arguing that allowing polluters to buy and sell pollution permits would "bring about a least-cost allocation of control burdens, saving many billions of dollars annually"); Robert W. McGee & Walter E. Block, *Trading Permits as a Form of Market Socialism and the Search for a Real Market Solution to Environmental Pollution*, 6 FORDHAM ENVTL. L. REV. 51, 51–52 (1994) (stating that the "quasi-market forces" of tradeable pollution permits lead to a more efficient allocation of resources than traditional command-and-control regulations); Richard B. Stewart, *A New Generation of Environmental Regulation?*, 29 CAP. U. L. REV. 21, 99–100 (2001) (emphasizing the advantages of pollution taxes and trading-quota systems over traditional command-and-control regulation).

48. *See* James E. Krier, *Marketable Pollution Allowances*, 25 U. TOL. L. REV. 449, 452 (1994) ("Both [pollution taxes and cap-and-trade systems] put a price on pollution and then leave decisions about control up to the sources . . . provided only that they pay."); Stewart, *supra* note 47, at 99 ("Sources that succeed in such innovation can reduce the price that they pay for residuals generated and thereby gain a competitive advantage, making environmental protection a profit center.").

49. *See* Stewart, *supra* note 47, at 99 ("Each source will tend to limit residuals to the level where its marginal cost of limitation equals the price that it must pay on its remaining residuals.").

50. *See id.* at 99–100 (summarizing the theoretical economic advantages of Pigouvian taxes and cap-and-trade systems over other forms of regulation).

51. *Id.* at 100.

52. *See id.* ("Unlike government officials, sources generally have strong incentives to achieve residuals limitations at the least cost.").

53. *See id.* at 100–02 (stating that, in principle, either pollution taxes or emissions-trading systems could be adjusted to reflect localized differentials in pollution impact, but this would add substantial administrative complexity and transaction costs and might impede the functioning of efficient markets).

depleting substances, but precious little else.[54] Even for sulfur oxides, the pollutants regulated under the Clean Air Act's widely heralded acid-rain cap-and-trade program,[55] indifference to the location of the pollution source is little more than a convenient fiction. Beyond the damage they cause to lakes and forests, sulfur oxides can be a serious health hazard in local concentrations.[56] Ex post cost–benefit analyses laud the acid-rain trading program for bringing about unanticipated health dividends,[57] but the program was not designed as a public-health measure,[58] and there is reason to doubt that we would have allowed such free interlocational trading if we had contemplated it might mean trading off adverse health effects in some locations (such as Cleveland) for improved health in others (such as Long Island).[59]

It has long been understood that even for purpose of controlling acid rain in the Adirondacks, New England, and eastern Canada—the problem the acid-rain-trading program was designed to cure—emissions from the heavily coal-dependent Ohio Valley, immediately upwind of the affected areas, are far more important than those in other regions.[60] For this and other reasons,

54. *See* Krier, *supra* note 48, at 454 ("The problem is minimized to the degree that the pollutant in question has no local effects but is of importance only as it mixes in a larger atmospheric space.").

55. The Clean Air Act was amended in 1990 to add a national cap-and-trade program for sulfur oxide emissions from electric generating stations. 42 U.S.C. §§ 7651–7651o (2000).

56. The EPA lists sulfur dioxide (SO_2) as one of six high-priority "criteria pollutants" under the Clean Air Act because of its adverse effects on human respiratory systems. National Primary Ambient Air Quality Standards for Sulfur Oxides (Sulfur Dioxide), 40 C.F.R. § 50.4 (2007). *See generally* EPA, How Sulfur Dioxide Affects the Way We Live, http://www.epa.gov/air/urbanair/so2 ("SO_2 dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment.").

57. *See, e.g.*, Dallas Burtraw et al., *The Costs and Benefits of Reducing Acid Rain* 13–14 tbl.2 (Res. for the Future, Discussion Paper No. 97-31-REV, 1997), *available at* http://www.rff.org/documents/RFF-DP-97-31-REV.pdf (finding that the "dominant source of benefits" from the national sulfur oxide emissions-trading system "is reduced human mortality risk," the value of which exceeds the program's costs by an order of magnitude).

58. *See id.* at 27 (acknowledging the public policy debate leading to enactment of the emissions-trading program "centered on the problem of acidification ('acid rain')[,] with particular concern for its [e]ffect on water and soil chemistry and ultimately ecological systems").

59. Some analysts argue that the acid-rain-trading program has actually tended to reduce localized concentrations of sulfur oxide emissions because the largest reductions have generally come from the largest sources. *See, e.g.*, Byron Swift, *Allowance Trading and SO2 Hot Spots—Good News from the Acid Rain Program*, 31 Daily Env't Rep. (BNA) 954 (May 12, 2000). If so, however, this is a fortuitous development and not a designed feature of the program. *Cf.* Richard Toshiyuki Drury et al., *Pollution Trading and Environmental Injustice: Los Angeles' Failed Experiment in Air Quality Policy*, 9 DUKE ENVTL. L. & POL'Y F. 231, 269–70 (2001) (criticizing Los Angeles' RECLAIM emissions-trading program in volatile organic compounds (VOCs) on the ground that it allowed development of toxic "hot spots").

60. *See, e.g.*, Noah D. Hall, *Transboundary Pollution: Harmonizing International and Domestic Law*, 40 U. MICH. J.L. REFORM 681, 715 (2007) (stating that pollution originating in Midwestern states causes acid rain in the Northeast and New England); *see also* JAMES L. REGENS & ROBERT W. RYCROFT, THE ACID RAIN CONTROVERSY 42–47 (1988) (describing the complexities of tracing the source of acid rain from where the effects of such rain are observed).

while the cap-and-trade program has clearly ratcheted down national sulfur oxide emissions in a cost-efficient manner, it has not brought about as much improvement to the acidifying northeastern lakes and forests as was initially promised.[61]

For their part, Pigouvian taxes suffer from the general aversion to taxation that currently infects domestic American politics[62]—although they are widely used in Europe.[63] This political constraint represents a severe impediment to implementation of a tax-based approach to environmental protection in the United States.[64] In addition, there may be practical limits to how many pollution taxes we might expect industry to keep track of (Five? Thirty? One hundred or more?), potentially making it difficult to administer a tax-based approach to environmental protection at a sufficiently fine resolution. Despite these limitations, market-based approaches do represent one promising family of solutions to at least some of the most important information problems that pervade environmental regulation.

They are not, however, the only solutions. A class of regulatory measures that I have elsewhere dubbed "regulatory penalty defaults" might be another sensible idea.[65] The idea of a penalty default—a term borrowed from contract theory, and specifically from Ayres and Gertner's pioneering work in the field[66]—is that by setting a harsh rule as the default and then permitting parties to bargain around that default to a mutually agreed outcome, we can (at least sometimes) induce the party holding asymmetrical information to reveal that information so as to advance the bargaining

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Some early proposals to address acid rain called for a focused effort to reduce Midwestern and Ohio Valley emissions, but these proposals were defeated by politically influential Midwestern, Appalachian, and Western members of Congress who feared adverse impacts on their coal and electric-utility industries. *See* Arnold W. Reitze Jr., *The Legislative History of U.S. Air Pollution Control*, 36 HOUS. L. REV. 679, 714–15 (1999) (detailing the efforts of Midwestern, Appalachian, and Western states to block air-pollution legislation that might affect the coal and electric-utility industries).

61. NAT'L SCI. & TECH. COUNCIL, EXECUTIVE OFFICE OF THE PRESIDENT, NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM REPORT TO CONGRESS: AN INTEGRATED ASSESSMENT 36–43 (2005) (reporting that while lakes, rivers, and forest ecosystems in some regions are showing modest improvements, New England and the Blue Ridge region are essentially unchanged).

62. *See* Nathaniel O. Keohane et al., *The Choice of Regulatory Instruments in Environmental Policy*, 22 HARV. ENVTL. L. REV. 313, 354–55 (1998) (describing political barriers to environmental taxes in the United States, including nearly universal industry opposition and environmentalists' skepticism).

63. *See* Johan Albrecht, *The Use of Consumption Taxes to Re-launch Green Tax Reforms*, 26 INT'L REV. L. & ECON. 88, 89 (2006) (noting that in 2001 environmental taxes in the EU totaled € 286 billion, or 6.5% of total tax and "social charge" revenues).

64. *See, e.g.*, Keohane et al., *supra* note 62, at 354–55 (explaining why environmentalists may be opposed to pollution taxes).

65. Bradley C. Karkkainen, *Adaptive Ecosystem Management and Regulatory Penalty Defaults: Toward a Bounded Pragmatism*, 87 MINN. L. REV. 943, 944 (2002) [hereinafter Karkkainen, *Adaptive Ecosystem Management*]; Bradley C. Karkkainen, *Information-Forcing Environmental Regulation*, 33 FLA. ST. U. L. REV. 861, 861 (2006) [hereinafter Karkkainen, *Information-Forcing*].

66. Ian Ayres & Robert Gertner, *Filling Gaps in Incomplete Contracts: An Economic Theory of Default Rules*, 99 YALE L.J. 87, 91 (1989).

process.[67] A type of penalty-default approach is embedded in California's Proposition 65,[68] discussed in subpart II(B) *infra*. Another inadvertent example can be discerned in NEPA's onerous procedural requirements, discussed in the Introduction, which constitute such a harsh penalty default that agencies are induced to investigate more environmentally benign ways of implementing projects and programs.[69] Because the information asymmetries with respect to industrial technologies are so pronounced, one might expect technology-based pollution control to be another area rife with opportunities to employ a penalty-default approach. Yet thus far I have been unable to discern clear examples of penalty default rules being used to advance industry self-regulation of this kind. The time is ripe, perhaps, to begin thinking about what such an approach might look like in practice.

II. Health-Based Regulation and the Burden of Uncertainty

A. The "No-Regulation" Default and Its Consequences

Not all environmental regulation is technology-based. Some is health-based: the statutes mandate that regulatory agencies set standards at levels necessary to protect public health. The Clean Air Act,[70] for example, requires EPA to set national ambient-air-quality standards (NAAQSs) for ubiquitous air pollutants at levels "requisite to protect the public health" with "an adequate margin of safety" without consideration of economic cost.[71] Other variants include health-based, but feasibility-limited, standards, such as the Safe Drinking Water Act's[72] mandate that drinking-water maximum contaminant levels (MCLs) be set at levels coming as close as possible to purely health-based maximum contaminant level goals (MCGLs)[73] while still being economically and technologically feasible.[74] A related approach is risk–benefit balancing, as in the Toxic Substance Control Act[75] (TSCA), which authorizes EPA to regulate toxic substances as necessary to eliminate

67. *Id.* at 94.

68. CAL. HEALTH & SAFETY CODE §§ 25249.5–.13 (West 2006).

69. 42 U.S.C. § 4332(2)(C) (2000).

70. 42 U.S.C. §§ 7401–7449 (2000).

71. *Id.* § 7409 (requiring the EPA Administrator to set primary and secondary ambient-air-quality standards for "criteria" air pollutants, and defining primary air-quality standards as those "the attainment and maintenance of which in the judgment of the Administrator, based on such criteria and allowing an adequate margin of safety, are requisite to protect the public health"); *see also* Whitman v. Am. Trucking Ass'ns, 531 U.S. 457, 471 (2000) (reaffirming the courts' longstanding interpretation that the Clean Air Act "unambiguously bars cost considerations from the NAAQS-setting process").

72. 42 U.S.C. § 300g (2000).

73. *Id.* § 300g-1(b)(4)(A) (requiring "maximum contaminant level goal" to be set at "the level at which no known or anticipated adverse effects on the health of persons occur and which allows an adequate margin of safety").

74. *Id.* § 300g-1(b)(4)(B) (requiring "maximum contaminant level" to be set "as close to the maximum contaminant level goal as is feasible").

75. 15 U.S.C. §§ 2601–2629 (2000).

"unreasonable risks."[76] The courts have construed TSCA's unreasonable-risk standard to require the Agency to balance risks against benefits to determine whether a given risk is unreasonable in light of its magnitude and probability, as weighed against the costs of eliminating it.[77]

What all these approaches have in common is that they require the regulatory agency to begin with a comprehensive evaluation of the medical and scientific case for bringing a particular pollutant (or substance) under regulatory control, and to justify the choice of a particular mode or degree of regulatory control on the basis of medical and scientific evidence (coupling that justification with technological and economic factors in the feasibility-limited and risk-benefit-balancing variants).[78] Again, the burden of information production and the burden of persuasion rest squarely on the regulatory agency, and the default position is that there is no regulation unless and until the agency can establish, by "reasoned elaboration" capable of withstanding judicial review, a convincing scientific and medical justification not only for regulation in general, but for also the particular regulatory standard selected.[79]

Part I described the difficulties of establishing technology-based regulatory standards, but these pale in comparison with the informational demands placed upon agencies seeking to establish health-based regulatory standards. For sound ethical reasons, direct human-subject experimentation is usually out of the question.[80] Instead, researchers must rely on animal studies, tissue studies, and epidemiological studies—all fairly indirect methods of evaluating the human-health effects of particular pollutants or substances, producing evidence that may be suggestive but is rarely unambiguous or conclusive.[81] Typically a great deal of extrapolation is required to derive dose–response curves from these varied sets of indirect

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76. *See id.* § 2605(a) (directing the EPA Administrator to regulate toxic substances upon a finding that "there is a reasonable basis to conclude that the manufacture, processing, distribution in commerce, use, or disposal of a chemical substance or mixture . . . presents or will present an unreasonable risk of injury to health or the environment . . . to the extent necessary to protect adequately against such risk using the least burdensome requirements").

77. *See, e.g.*, Corrosion Proof Fittings v. EPA, 947 F.2d 1201, 1222–23 (5th Cir. 1991) (holding that in order to determine whether a risk is "unreasonable," EPA "must balance the costs of its regulations against their benefits").

78. *See generally* John S. Applegate, *The Perils of Unreasonable Risk: Information, Regulatory Policy and Toxic Substances Control*, 91 COLUM. L. REV. 261, 277–84 (1991) (describing the information burdens on regulatory agencies in setting risk-based regulatory standards).

79. *See id.* at 282–84 (surveying the strict standard imposed on the regulatory agencies); *see, e.g.*, Town of Orangetown v. Gorsuch, 718 F.2d 29, 35 (2d Cir. 1983) (mandating that the agency's assessment be a "reasoned elaboration" of the agency's determination).

80. *See* Wendy E. Wagner, *The Science Charade in Toxic Risk Regulation*, 95 COLUM. L. REV. 1613, 1621 & n.24 (1995) (describing the moral constraints on human experimentation).

81. *See* Troyen A. Brennan, *Causal Chains and Statistical Links: The Role of Scientific Uncertainty in Hazardous-Substance Litigation*, 73 CORNELL L. REV. 469, 501–12 (1988) (describing the principal investigatory methods in toxicology and their associated uncertainties); Applegate, *supra* note 78, at 285–89 (noting the deficiencies in current testing methods).

data.[82] Epidemiological studies tend to be costly and slow, requiring a large sample size, a lengthy time frame, and precise information on exposure levels; multiple studies may produce confounding or inconsistent results.[83] Worse, most substances released into the air, water, and ground have never been subjected even to the most basic screening for potential toxicity, much less to a full battery of rigorous testing that would be required to promulgate regulatory standards.[84]

The central information problem in this arena is not asymmetrically held information, but the simple fact that medical and scientific information tends to be scarce, incomplete, inconclusive, ambiguous, or uncertain.[85] Ordinary industrial polluters are, in most cases, not likely to possess such information about the pollutants they emit, which are simply waste byproducts of their activities, nor are they likely to possess the in-house expertise that would uniquely suit them to produce the desired information.[86] Therefore, for reasons of scale efficiencies and their superior capacity to concentrate financial and technical resources on the task, it would appear to be a sensible assignment to require centralized, expert government agencies to assemble and analyze, or where necessary, to undertake or commission the necessary medical and scientific investigations.[87]

An important exception, however, is that large chemical manufacturers and other producers of novel substances or products (for example, nanotechnology) are likely to be more familiar with the physical and chemical properties of the substances they are producing than are the

82. *See* Mark Eliot Shere, *The Myth of Meaningful Environmental Risk Assessment*, 19 HARV. ENVTL. L. REV. 409, 433–38 (explaining the use of dose–response curves and criticizing them as meaningless).

83. *See* Brennan, *supra* note 81, at 511–12 & n.214 (stating that confidence intervals are wide in small-sample-size epidemiological studies, those in which exposures occur at low doses, and those in which precise exposure data are not available); Carl F. Cranor, *Discerning the Effects of Toxic Substances: Using Science Without Distorting Law*, 38 JURIMETRICS J. 545, 548 (1998) ("Generating information about any harmful effects tends to be case-by-case and science-intensive, relying on slow and costly animal or human epidemiological studies.").

84. *See* David Roe, *Ready or Not: The Coming Wave of Toxic Chemicals*, 29 ECOLOGY L.Q. 623, 627–28 (2002) (stating that studies by the nonprofit organization Environmental Defense, EPA, and the chemical industry all concluded that even preliminary toxicity-screening data were not available for more than 90% of high-volume chemicals in U.S. commerce).

85. *See* Applegate, *supra* note 78, at 264–66 (describing multiple sources of uncertainty about the toxic effects of chemicals and other potentially hazardous substances).

86. This stands in stark contrast to their position relative to the costs and effectiveness of process changes or technological fixes, which the polluters are likely to be in a superior position to assess. *See supra* note 36 and accompanying text.

87. *See* Daniel C. Esty, *Revitalizing Environmental Federalism*, 95 MICH. L. REV. 570, 614–15 (1996) (arguing that such highly technical tasks as "data collection and quality control, fate and transport studies, epidemiological and ecological analyses, and risk assessments" are more appropriately assigned to a central regulatory agency that can accumulate the necessary technical capacity and achieve economies of scale).

regulators charged with their oversight.[88] Therefore, from an information-management perspective, it would seem to be a sensible assignment of responsibilities to require the producer of the novel product to investigate not only its potentially useful applications (which it will do on its own accord, driven by the profit motive), but also its potentially adverse consequences, including possible toxicological effects. Absent legal requirement, producers may not be inclined to study these effects because that sort of investigation adds costs and could lead to regulatory controls or additional tort liability that may limit the manufacturer's profits.[89]

But curiously, this way of apportioning responsibility is inconsistently applied. The Food, Drug, and Cosmetic Act generally prohibits the introduction of food additives, drugs, and medical devices until they have been subjected to testing and evaluation, and demonstrated to meet minimum health and safety standards.[90] An expert administrative agency, the FDA, weighs the evidence and makes the final call.[91] Under this scheme, the developer of a new product has a clear incentive to study its health effects because until it has done so, the product cannot be marketed and its developer can make no profits.

Similarly, new motor fuels and fuel additives are subject to a product registration scheme under the Clean Air Act, this time with EPA weighing the medical and scientific evidence and acting as traffic cop. It will only authorize the marketing of fuels and additives that neither pose a public-health threat nor interfere with emissions-control systems.[92] Pesticides are also subject to a product-registration scheme under the Federal Insecticide,

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88. *See* Applegate, *supra* note 78, at 299 ("[I]ndustries that produce and use chemicals ordinarily are in the best position to provide or obtain toxicity and exposure data most cheaply and accurately . . . [They] have the greatest familiarity with their products' characteristics and the occasions for exposure to them.").

89. *See id.* (discussing the reasons manufacturers have an incentive not to know and not to disclose environmental health risks); Lyndon, *supra* note 34, at 1810 (stating that producers have a disincentive to research toxicology because it is uncertain if the results obtained will have any cost-saving benefits).

90. 21 U.S.C. §§ 301–397 (2000). FDCA approval standards vary for different categories of products. Drugs and medical devices, for example, must be shown to be both effective and safe. *See id.* § 355(b) (requiring an applicant to submit information demonstrating, inter alia, that the drug or device is "safe" and "effective"); *id.* § 355(d) (requiring the Secretary to deny approval for any drug or device not adequately demonstrated to be, inter alia, safe and effective). For food additives, the applicant must show that the "proposed use of the food additive, under the conditions of use to be specified in the regulation, will be safe." *Id.* § 348(c)(3)(A).

91. *See* Richard A. Merrill, *FDA's Implementation of the Delaney Clause: Repudiation of Congressional Choice or Reasoned Adaptation to Scientific Progress?*, 5 YALE J. ON REG. 1, 13 (1988) ("Regulation of chemicals used in food production and processing, such as pesticides and packaging materials, has for decades depended on the capacity of FDA inspectors to measure residues and thereby enforce health-based limits on their enforcement.").

92. 42 U.S.C. § 7545(a)–(c) (2000); *see id.* § 7545(c)(1) (requiring registration of motor fuels and motor-fuel additives and authorizing the EPA Administrator to regulate or prohibit any fuel that "causes, or contributes to, air pollution which may reasonably be anticipated to endanger the public health or welfare" or that "will impair to a significant degree the performance of any emission control device or system").

Fungicide, and Rodenticide Act[93] (FIFRA). Manufacturers must submit data showing that the pesticide will be effective for its intended use and will not harm public health or pose unreasonable risks to the environment, and registered pesticides must be sold under an EPA-approved label describing its permissible uses.[94]

Outside of these specialized and fairly narrow categories of products, however, the general rule is that new products, including new chemicals or particles, may be introduced with little or no public-health and environmental testing. Under the Toxic Substances Control Act[95] (TSCA), chemical manufacturers must notify EPA prior to introducing new chemicals into commerce ("premanufacture notice" or "PMN")[96] and, in conjunction with this notice, they must submit any data they have relating to the chemical's health and environmental effects.[97] In addition, EPA may require additional testing of chemicals that in its judgment warrant further investigation.[98] EPA conducts its own screening evaluation of a chemical within a ninety-day window provided by the statute, basing its assessment on the manufacturer's data submissions (if any) as well as published literature on structurally similar chemicals,[99] but if EPA takes no action within that period, the applicant may proceed to manufacture.[100] Because thorough toxicity screening and testing are not routinely required, however, this structure arguably creates a perverse incentive for chemical manufacturers not to engage in extensive screening or testing of chemicals prior to submitting their PMN.[101] Such tests can be costly and time consuming, and the results might raise questions about the chemical's safety that could lead EPA to demand further testing, thereby delaying the product's introduction or possibly leading to regulatory restrictions.

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93. 7 U.S.C. §§ 136–136y (2000).

94. *Id.* § 136a(a)–(c); *see id.* § 136a(c)(5)(D) (permitting registration of pesticides upon a finding by the EPA Administrator that "when used in accordance with widespread and commonly recognized practice," the pesticide will not cause "unreasonable adverse effects on the environment").

95. 15 U.S.C. § 2604 (2000).

96. *Id.* § 2604(a).

97. *Id.* § 2604(b) (requiring submission of test data).

98. *Id.* § 2604(e) (authorizing the EPA Administrator to prohibit or restrict manufacture of a new chemical upon a finding that "the information available to the Administrator is insufficient to permit a reasoned evaluation of the health and environmental effects"); *see also id.* § 2603(a) (authorizing the EPA Administrator to require testing of new or existing chemicals if, inter alia, "there are insufficient data and experience upon which the effects . . . of such substance . . . on health or the environment can reasonably be determined or predicted").

99. *See* U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-05-458, CHEMICAL REGULATION: OPTIONS EXIST TO IMPROVE EPA'S ABILITY TO ASSESS HEALTH RISKS AND MANAGE ITS CHEMICAL REVIEW PROGRAM 10–11 (2005) [hereinafter GAO, OPTIONS] (describing and criticizing EPA's screening methodology).

100. JOHN APPLEGATE ET AL., THE REGULATION OF TOXIC SUBSTANCES AND HAZARDOUS WASTES 611 (2000).

101. EPA estimates that only 15% of new chemical PMNs are accompanied by health and safety test data of any kind. *See* GAO, OPTIONS, *supra* note 99, at 11.

In addition to the limited scrutiny of new chemicals, EPA also faces a backlog of thousands of chemicals already in production that have never been adequately screened or tested for toxicity or environmental effects.[102] Under TSCA § 4, EPA has authority to require chemical manufacturers to test these existing chemicals,[103] but EPA has always exercised this authority sparingly, usually in situations in which it already has some evidence indicating a cause for concern about the substance's health or environmental effects.[104] In recent years, EPA and the chemical industry have attempted to address this backlog though a voluntary industry-supported program calling for toxicity screening for some 2,800 "high production volume" (HPV) chemicals produced in quantities of one million pounds per year or more annually.[105]

Therefore, despite these measures, we still operate under the burden of a great deal of "toxic ignorance." We do not fully understand the health and environmental effects of thousands of new and existing chemicals in production. We probably understand even less about toxic pollutants—the byproducts of a wide variety of industrial, commercial, and consumer activities—and these are regulated, if at all, under a bewildering array of statutory frameworks, including, inter alia, the Clean Air Act[106] (hazardous air pollutants), the Clean Water Act[107] (toxic water pollutants), the Resource Conservation and Recovery Act[108] (RCRA) (hazardous wastes), the Comprehensive Environmental Response, Compensation, and Liability Act[109] (CERCLA) (hazardous substances), the Safe Drinking Water Act,[110]

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102. *See* Lyndon, *supra* note 34, at 1824 n.9 (noting that, in 1984, "[o]f the existing backlog of thousands, only 76 chemicals were reviewed" by EPA).

103. *See* 15 U.S.C. § 2603(a)(1)(A)(ii) (allowing the Administrator to require testing); *see also* GAO, OPTIONS, *supra* note 99, at 18 (stating that EPA can require testing when it determines that the chemicals warrant such testing).

104. GAO, OPTIONS, *supra* note 99, at 18 (reporting that EPA has ordered additional testing of only 200 of the 62,000 chemicals currently in commerce, and has performed its own internal reviews on only 2% of these chemicals).

105. *Id.*

106. 42 U.S.C. § 7412 (2000) (specifically listing 188 "hazardous air pollutants," authorizing revisions to the list based on assessment of "adverse health and environmental effects," and requiring regulation of new and existing sources under maximum achievable control technology standards).

107. 33 U.S.C. § 1311(b)(2) (2000) (requiring effluent limitations for point sources of toxic pollutants based on "best available technology economically achievable"); *id.* § 1317(a) (listing toxic pollutants by incorporation and authorizing revisions to the list "tak[ing] into account toxicity of the pollutant, its persistence, degradability," and its effects on aquatic organisms).

108. 42 U.S.C. § 6903(5) (2000) (defining "hazardous waste" as a "solid waste" that may cause or contribute to "an increase in mortality or . . . serious, irreversible, or incapacitating reversible, illness" or "pose a substantial present or potential hazard to human health or the environment"); *id.* § 6921(a)–(b) (providing for identification and listing of hazardous wastes "taking into account toxicity, persistence, and degradability in nature, potential for accumulation in tissue, and other related factors such as flammability, corrosiveness, and other hazardous characteristics").

109. 42 U.S.C. § 9601(14) (2000) (defining "hazardous substance" and incorporating by reference substances regulated under relevant portions of the Clean Water Act, Clean Air Act, RCRA, and TSCA); *id.* § 9602(a) (authorizing the EPA Administrator to designate additional

the Occupational Safety and Health Act[111] (OSHA) (workplace exposures), each using unique definitions; approaches; standards; and monitoring, reporting, testing, and analytical requirements. As a consequence, a single pollutant may be subject to half a dozen or more regulatory regimes, depending on the media into which it is released, and various agencies, or multiple branches of a single agency, may be required to run parallel, complex, information-intensive investigations on the same pollutant. Such a project may appear redundant and inefficient, but is probably necessary under current statutory frameworks, which each require very different findings before a pollutant may be subjected to regulatory standards.

As a consequence of the high levels of information demanded as a prerequisite to regulation, combined with the paucity of scientific and medical data, the fragmentary nature of the regulatory enterprise, and the scarcity of agency resources, precious few toxic pollutants have been brought under regulatory standards.[112] And in general, as with the technology-based standards discussed in the preceding Part, industry has little incentive to cooperate. Industry rarely needs go out of its way to undertake toxicity screening or testing of products or pollutants, except where specifically required to do so by law—that is to say, only rarely and in specialized circumstances. Voluntarily undertaken screening and testing might lead to more agency demands for information and possibly to regulation.[113]

"hazardous substances" that "when released into the environment may present substantial danger to the public health or welfare or the environment").

110. 42 U.S.C. § 300g-1(a)–(b) (2000) (requiring listing and regulation of "contaminants" that "may have an adverse effect on the health of persons," are likely to occur in public water systems, and for which, in the judgment of the EPA Administrator, there is "a meaningful opportunity for health risk reduction").

111. 29 U.S.C. § 652(8) (2000) (defining the "occupational safety and health standard" as one "reasonably necessary or appropriate to provide safe or healthful employment and places of employment"); *id.* § 655(b)(5) (instructing the Secretary of Labor to set standards for "toxic materials or harmful physical agents" that "most adequately ensure[], to the extent feasible, on the basis of the best available evidence, that no employee will suffer material impairment of health or functional capacity").

112. To date, EPA has banned, limited the production of, or restricted the use of only five chemical substances or families of substances under TSCA § 6. GAO, OPTIONS, *supra* note 99, at 18. The agency has also been chronically late in issuing technology-based control standards for hazardous air pollutants. *See* U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-06-669, CLEAN AIR ACT: EPA SHOULD IMPROVE THE MANAGEMENT OF ITS AIR TOXICS PROGRAM 15–18 & tbl.4 (2006) (finding that EPA met only 12 of 453 air-toxics regulatory requirements on time). Similarly, OSHA has promulgated new regulatory standards ("permissible exposure limits") for only a small handful of the chemicals to which workers are exposed. *See* Karkkainen, *supra* note 19, at 268 n.33 (showing that regulatory agencies are rarely able to add significant numbers of toxic substances to their oversight schemes in a given period). Most exposure limits currently in force come from the wholesale adoption in 1971 of recommended threshold limit values (TLVs) promulgated by the American Council of Government Industrial Hygienists (ACGIH), which were based on toxicology available in the 1960s, making these standards seriously out of date. *See* John Howard, *Setting Occupational Exposure Limits: Are We Living in a Post-OEL World?*, 7 U. PA. J. LAB. & EMP. L. 513, 521 (2005) (describing the process by which OSHA updated TLVs in the 1960s and 1970s).

113. *See supra* notes 96–101 and accompanying text.

Consequently, the safest posture for industry is usually one of willful blindness. In some cases, however, industry finds it more advantageous to attempt to disrupt the regulatory process by funding or producing studies that cast doubt on other research that tends to support regulation, thereby muddying the waters and delaying the onset of regulation;[114] by filing detailed, critical comments to which agencies must produce elaborate responses;[115] or by threatening or actually filing petitions for judicial review of newly promulgated rules—which not only delays the particular rule in question, but also tends to further ossify the rulemaking process in general as regulatory agencies, anticipating such challenges, decide they must engage in even lengthier and more elaborate exercises in analysis and justification prior to issuing new rules.[116]

Two regulatory innovations—one of recent vintage, one now more than two decades old—point to possible directions out of this morass. They are California's Proposition 65,[117] adopted by voter initiative in 1986, and the European Union's new REACH program for chemical testing and registration.[118]

B. Shifting the Burden Through a Duty to Warn: Proposition 65

A strikingly different approach to creating incentives for information production and disclosure is embodied in California's Proposition 65, the Safe Drinking Water and Toxic Enforcement Act of 1986.[119] Enacted by voter initiative in 1986, Proposition 65 requires California businesses to give a "clear and reasonable warning" to any person—whether worker, customer, or neighbor—whom the business exposes to a substance identified by the

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114. *See* Lyndon, *supra* note 34, at 1816 (stating that even when industry produces high-quality information, "deception certainly occurs," and that this information will be "undervalued unless it can be independently corroborated"); Wagner, *supra* note 34, at 1649 ("Faced with especially incriminating information on the adverse effects of a product or activity, actors may not only decline to voluntarily assist in producing additional research but may actively work to obfuscate especially damaging information produced by others.").

115. *See, e.g.*, ROBERT ESWORTHY & JAMES E. MCCARTHY, AIR QUALITY: EPA'S 2006 CHANGES TO THE PARTICULATE MATTER (PM) STANDARD 17 (2007), *available at* http://www.nationalaglawcenter.org/assets/crs/RL33254.pdf (discussing the tendency of industry to oppose more stringent regulatory standards, and specifically highlighting the more than 120,000 comments the Agency received in response to its January 2006 particulates national ambient-air-quality standards (NAAQSs)).

116. *See* Thomas O. McGarity, *The Courts and the Ossification of Rulemaking: A Response to Professor Seidenfeld*, 75 TEXAS L. REV. 525, 526–30 (1997) (discussing how private industry's backing and use of critical judicial-review doctrines, such as the "hard look doctrine," have worked to ossify the rulemaking processes of regulatory agencies).

117. Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65), CAL. HEALTH & SAFETY CODE §§ 25249.5–.13 (West 2006).

118. Council Regulation 1907/2006, Concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), 2006 O.J. (L 396) 1 (EC) [hereinafter REACH], *available at* http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:396:0001:0849:EN:PDF.

119. CAL. HEALTH & SAFETY CODE §§ 25249.5–.13.

state of California as a carcinogenic or reproductive toxin.[120] Most discussion of Proposition 65 has focused on whether the information provided in the ubiquitous warning labels it has generated is useful, misleading, or simply ignored.[121]

In the case of environmental releases, however, Proposition 65's effect is more subtle. Implementing regulations authorize mass mailings, newspaper advertisements, and the posting of signs as acceptable methods of warning,[122] but industries releasing Proposition 65-regulated substances into the environment always face residual uncertainty as to who exactly is exposed and whether the specific warnings given would be deemed by a jury to be "clear and reasonable" under the circumstances.[123] Penalties for failure to warn—or failure to warn adequately—are potentially stiff: up to $2,500 for each day of violation, enforceable by a civil action by the attorney general or by citizen suit.[124] Thus, environmental polluters face an open-ended risk of liability for failure to warn, even if they are making good-faith efforts to warn of exposures.

At this point, however, the statute throws them a life raft. Exposures "which the person responsible can show . . . pose[] no significant risk assuming lifetime exposure at the level in question" are exempt from warning requirements.[125] Meeting this evidentiary requirement on a case-by-case basis would be a daunting undertaking for most industrial polluters. However the California Environmental Protection Agency (CalEPA) is further authorized to promulgate, on a substance-by-substance basis, "no significant risk levels" (NSRLs), establishing regulatory safe-harbor thresholds below which toxic exposures will be deemed not to pose a significant risk.[126]

This approach inverts the usual incentives for potentially regulated businesses. Instead of opposing regulation or seeking to retard its onset,

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120. *Id.* § 25249.6.

121. *See, e.g.*, Clifford Rechtschaffen, *The Warning Game: Evaluating Warnings Under California Proposition 65*, 23 ECOL. L.Q. 303 (1996) (analyzing the usefulness of Proposition 65 warnings and offering recommendations to make the warnings more easily understood by and effectively communicated to the public at large); Michael Barsa, Note, *California's Proposition 65 and the Limits of Information Economics*, 49 STAN. L. REV. 1223 (1997) (criticizing the clarity and practical utility of Proposition 65 warnings and questioning whether they have resulted in safer products).

122. CAL. HEALTH & SAFETY CODE § 25249.11(f).

123. *Id.* § 25249.6.

124. *See id.* § 25249.7 (detailing the penalties for violating the warning and anticontamination portions of Proposition 65).

125. *Id.* § 25249.10.

126. *See* CAL. EPA, PROPOSITION 65 SAFE HARBOR LEVELS: NO SIGNIFICANT RISK LEVELS FOR CARCINOGENS AND MAXIMUM ALLOWABLE DOSE LEVELS FOR CHEMICALS CAUSING REPRODUCTIVE TOXICITY 1 (2006) (detailing the process by which the Office of Environmental Health Hazard Assessment (OEHHA) determines these "safe harbor" thresholds); *see also* CAL. CODE REGS. tit. 22, §§ 12705, 12805 (2008) (listing NSRLs and maximum allowable dose levels for specific pollutants).

California businesses now welcome the promulgation of regulatory safe-harbor thresholds as a shelter against the threat of open-ended liability for failure to warn.[127] By getting their toxic releases below the regulatory thresholds, they can immunize themselves against Proposition 65 liability. But first, of course, the safe-harbor thresholds must be established, and that is where the reversed incentives have their greatest effect. Instead of strategically declining to produce or disclose information that might advance the regulatory process, California businesses now have an affirmative incentive to cooperate with the regulatory agency in producing and disclosing all credible information that might assist the agency in setting safe-harbor regulatory thresholds.

And that is just what happened. Within a few months after Proposition 65 was enacted, California regulators were able to establish safe-harbor thresholds for nearly 300 carcinogens and reproductive toxins[128]—a far faster rate of regulatory output than that of the federal EPA or OSHA, which must struggle against the usual industry incentives to withhold or strategically manipulate information.[129] Published reports indicate that trade associations and individual business firms came forth with gushers of information on chemical toxicity, epidemiological studies, exposure pathways, and other relevant information in support of the regulatory effort.[130] Nor did industry have an incentive to seek to delay the onset of regulation through judicial review; without exception, the promulgated rules went unchallenged.[131]

From a certain point of view, the safe-harbor regulatory thresholds that emerge from the Proposition 65 process look a lot like conventional health-based regulations—they are fixed regulatory standards established by a centralized regulatory agency (CalEPA) on a substance-by-substance basis. Yet there are some subtle and potentially important differences. First, reduction of emissions below the regulatory thresholds is voluntary;

127. *See* David Roe, *Toxic Chemical Control Policy: Three Unabsorbed Facts*, 32 Envtl. L. Rep. (Envtl. Law Inst.) 10,232, 10,235 (2002) (detailing how, as a result of the unusual incentive structure of Proposition 65, industry associations actively cooperated with California regulators in the creation of "safe harbor" numbers).

128. Office of Envtl. Health Hazard Assessment, OEHHA Proposition 65: Proposition 65 in Plain Language!, http://www.oehha.org/prop65/background/p65plain.html ("[California regulators] ha[ve] established safe harbor numbers for nearly 300 chemicals to date and continue[] to develop safe harbor numbers for listed chemicals.").

129. *See* Roe, *supra* note 127, at 10,235 (describing how, by shifting the burden of proof onto the industries to show levels of harm, Proposition 65 also created an unusual incentive structure that encouraged cooperation with the regulation); Applegate, *supra* note 78, at 309–10 & n.263 (noting that because of industry's help, Proposition 65 has been a more successful scheme than other EPA endeavors).

130. Roe, *supra* note 127, at 10,235–36.

131. *See* Barsa, *supra* note 121, at 1240 (noting that California promulgated nearly 300 rules "without a single legal challenge").

businesses are not legally obligated to achieve these targets.[132] If it is too costly to do so, they may elect to continue with higher levels of pollution, and assume or attempt to manage the risk of liability for failure to warn.[133] Second, because the Proposition 65 safe-harbor thresholds are purely health-based performance standards,[134] businesses remain free to experiment with whatever combination of process changes and pollution-control measures they deem most cost-effective and most suitable to their particular circumstances.[135]

Notice that by shifting the default position to one of uncertainty and risk on the part of polluters, Proposition 65 profoundly changes the dynamics of information flow. It creates unusually powerful incentives for businesses to produce and disclose information relevant to the establishment of health-based environmental standards that would otherwise be unavailable or difficult for regulators to obtain, and it creates unprecedented incentives for those same businesses to cooperate in the regulatory enterprise. It shifts the burden of producing information from the regulatory agency to the potentially regulated private parties, but it preserves a role for the regulatory agency as the centralized repository and evaluator of that information. It preserves a zone of decentralized experimentation in pollution-reducing technologies and production processes, and creates strong incentives for such experimentation to occur as businesses seek to achieve the safe-harbor thresholds.

Proposition 65 has some important limitations. Like NEPA,[136] it relies upon a blunt, heavy-handed, and onerous "penalty-default" feature—in this case, the open-ended threat of liability under a nebulous "clear and reasonable warning" standard.[137] For this reason Proposition 65 is widely reviled among California businesses,[138] and efforts by environmental NGOs to enact similar measures in other states have been derailed by vigorous

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132. *See* Karkkainen, *Information-Forcing*, *supra* note 65, at 874 (explaining that Proposition 65 provides powerful incentives for polluters to voluntarily reduce emissions but does not require them to do so).

133. *See* CAL. EPA, *supra* note 126, at 1 (stating that the California Environmental Protection Agency is authorized to set thresholds of chemical and carcinogen exposure based upon potential to cause cancer and reproductive toxicity).

134. *Id.*

135. *Cf.* Ackerman & Stewart, *supra* note 25, at 1337–38 (discussing the potential cost inefficiencies of technology-based control standards).

136. *See supra* notes 1–8 and accompanying text.

137. *See supra* notes 120–24 and accompanying text.

138. *See* Rick R. Rothman et al., *California's Prop 65 and the Boy Who Cried Wolf*, 14 NAT. RESOURCES & ENV'T 227, 227 (2000) ("Businesses expected to be crippled by the law's requirement that they provide warnings associated with exposures to levels of chemicals so low that they challenge scientific detection.").

business opposition, raising serious questions about the replicability of Proposition 65 elsewhere.[139]

Setting aside the particulars and examining the broad outlines of the incentive structure created by Proposition 65, however, reveals a pattern remarkably similar to that of NEPA. At the heart of each lies a penalty-default provision—the onerous EIS procedure in the NEPA case, and the onerous threat of civil liability in the Proposition 65 case. In each case, this penalty can be avoided only through channeled cooperation on the part of the regulatory target. Thus, the NEPA EIS penalty can be avoided if the agency identifies and adopts design alternatives or mitigation measures that keep adverse environmental impacts below the EIS-triggering threshold of "significant."[140] Similarly, the Proposition 65 civil liability penalty can be avoided if regulated entities as a class cooperate in providing the information necessary to allow the regulatory agency to set safe-harbor thresholds, and individual entities then identify and undertake strategies to reduce their own emissions below those regulatory thresholds.[141] In each case, the regulatory target is induced to produce and reveal valuable information and to undertake affirmative environmental-protection measures that otherwise would probably not occur. Yet the regulatory regime does not presume to prescribe in detail the behavior that must be undertaken or avoided by the regulated entity, avoiding the pitfalls of conventional command-style regulatory approaches. Instead, it creates incentives that induce and channel a self-designed program of voluntary improvements in environmental performance.

An important limitation on Proposition 65's effectiveness is that it reaches only those substances determined by the State of California to be carcinogens or reproductive toxins.[142] These are fairly narrow classes of pollutants: many toxic substances produce acute or chronic adverse health

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139. *See* Richard A. Lovett, *Prop 65's Non-toxic Legacy*, SACRAMENTO BEE, Nov. 30, 1997, Forum, at 1 (reporting criticisms of Proposition 65 as too harsh and rigid and noting failures to enact similar measures in other states). *See also* Paulette L. Stenzel, *Right-to-Know Provisions of California's Proposition 65: The Naïveté of the Delaney Clause Revisited*, 15 HARV. ENVTL. L. REV. 493, 494 & n.8 (1991) (indicating the early hopes of Proposition 65's backers that the measure would be replicated elsewhere and quoting the Sierra Club as developing a "generic version of Proposition 65" for other states).

140. *See* Procedures for Implementing the National Environmental Policy Act, 72 Fed. Reg. 53,662 (Sept. 19, 2007) (to be codified at 40 C.F.R. § 6.206) (requiring a description of the mitigation measures that must be adopted to ensure that an action will have no significant impacts).

141. *See* CAL. HEALTH & SAFETY CODE § 25249.10(c) (West 2006) (placing the burden on a defendant wishing to escape liability to show that exposure to the substance in question poses no significant risk at 1,000 times the level in question); REPROD. & CANCER HAZARD ASSESSMENT SECTION, CAL. EPA, PROPOSITION 65: PROCESS FOR DEVELOPING SAFE HARBOR NUMBERS 1 (2001), *available at* http://www.oehha.org/prop65/policy_procedure/pdf_zip/SafeHarborProcess.pdf (explaining the availability of a "safe harbor" under Proposition 65 and allowing the establishment of safe harbors based on risk assessments conducted by parties other than the state government).

142. *See* CAL. HEALTH & SAFETY CODE § 25249.6 (confining the scope of Proposition 65 warning requirements to "chemical[s] known to the state to cause cancer or reproductive toxicity").

effects other than cancer, birth defects, or other reproductive harms.[143] And even within these categories, the list of covered substances is limited by CalEPA's current state of knowledge concerning carcinogenic or reproductive effects. As was noted earlier, thousands of chemicals in common use have never been subjected to even the most basic toxicity screening, and Proposition 65 does nothing to advance the ball in addressing that information deficit.

C. Shifting the Burden by Mandate: REACH

The European Union recently adopted an ambitious new program to reverse these perverse incentives. Dubbed REACH (for *R*egistration, *E*valuation, *A*uthorisation, and Restriction of *Ch*emical Substances),[144] the new EU regulation requires chemical manufacturers and importers to register chemical substances (both "new" and "existing") that they produce or import in amounts of one metric ton or more per year with the European Chemicals Agency in Helsinki.[145] The registration submission must include information on the identity of the manufacturer or importer, the identity of the substance, "guidance" on its safe use, toxicity and exposure data, and proposals for additional testing.[146] For substances produced or imported in quantities of ten metric tons or more per year, a thorough "chemical safety assessment" is required.[147] Registrations must be revised and updated if there are changes in production or import volumes, changes in use, or new information on health or environmental risks.[148] The European Chemicals Agency will monitor and evaluate industry submissions for quality-control purposes,[149] require further testing and evaluation of chemicals that appear potentially hazardous,[150] and initiate regulatory proceedings that may lead to the authorization or restriction of substances "of very high concern"[151]—including carcinogens; mutagens; reproductive toxins; and persistent, bioaccumulative, and toxic (PBT) substances—prioritized in a "community rolling action plan" targeting the highest priority candidates for toxicity evaluation.[152]

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143. These include neurological disorders, developmental disorders, lung disease, skin irritations, and other health problems. *See* Bradford C. Mank, *A Scrivener's Error or Greater Protection of the Public: Does the EPA Have the Authority to Delist "Low-Risk" Sources of Carcinogens from Section 112's Maximum Achievable Control Technology Requirements?*, 24 VA. ENVTL. L.J. 75, 83 (2005).

144. REACH, *supra* note 118.

145. *Id.* art. 5, at 62; *id.* art. 6, at 62.

146. *Id.* art. 10, at 70–71.

147. *Id.* art. 14, at 77. The safety assessment must include assessments of human-health, physicochemical, and environmental hazards, as well as an assessment of the substance's persistence and bioaccumulative properties. *Id.* art. 14(3), at 78.

148. *Id.* art. 22, at 91–92.

149. *Id.* art. 20(2), at 87.

150. *Id.* art. 44, at 127; *id.* tit. VII, at 138; *id.* tit. VIII, at 163.

151. *Id.* art. 55, at 138.

152. *Id.* art. 40, at 121; *id.* art. 44, at 127.

For substances requiring authorization, the burden is on the manufacturer or importer to show that the risks of the substance are "adequately controlled," the socioeconomic benefits of its continued use outweigh the remaining risks, and there are no suitable alternatives.[153] If the risks are deemed unacceptable, any or all uses may be subjected to regulatory restrictions up to and including an outright ban.[154]

This regime will apply to both new and existing chemicals,[155] but it will be phased in, with pre-registration by 2010 for high-volume chemicals (produced or imported in quantities over 1,000 metric tons per year) as well as certain highly toxic substances,[156] and eventually reaching all substances produced or imported in quantities over one ton per year by 2018.[157]

The principal effect of REACH is to shift the burden of producing data and information on chemical toxicity and safe use from the regulatory agency to the manufacturers and importers of chemical substances, who are presumably better situated to conduct such evaluations. However, a public agency retains central oversight, data-management, supervisory, and regulatory roles, essentially managing a triage system in which industry-supplied data are evaluated for quality control and for substantive content. When a "suspicious" substance is singled out for further inquiry, the burden shifts back to the manufacturer or importer to supply additional data and information on its risks and safe uses, and to justify its continued use in light of the risks, the measures that may be taken to minimize or mitigate those risks, and a risk–benefit analysis.[158] If the regulatory agency is satisfied, it may authorize the continued use of the substance; if not, it may restrict any or all uses.[159]

Under this quasi-licensing scheme, chemical manufacturers and importers operate under a very different set of incentives than under the conventional U.S.-style approach. Not only are they under a legal mandate to produce the required information, but they no longer have an incentive toward willful blindness or strategic nonproduction or nondisclosure of relevant information. This is because failure to produce or disclose such information, or a regulatory determination that the submitted information is inadequate, could lead to suspension or termination of the right to produce or sell the substance in question. Moreover, chemical manufacturers and importers have a positive incentive to identify and disclose the safest

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153. *Id.* art. 60, at 148.

154. *Id.* tit. VIII, at 163.

155. *See id.* art. 6, at 62 (requiring registration from *any* manufacturer of a substance, without regard to whether the substance itself is new).

156. *Id.* art. 28, at 94–95.

157. *Id.* art. 23(3), at 95.

158. *See id.* art. 60(4), at 150 (listing factors to be considered in deciding whether to authorize use of a listed substance); *id.* art. 64(5), at 160 (outlining the procedure for an applicant to comment on the agency's draft opinion).

159. *Id.* tit. VIII, at 163.

methods of handling and using their products in order to avoid or limit the scope of any possible regulatory restrictions. And, although the regulatory restrictions that finally emerge will look much like conventional regulatory rules, the process of getting there appears to be structured more like a constructive, collaborative dialogue between the regulatory agency and the regulated entity, with the latter invited to make its best case for the continued use of its product by identifying and promoting its safest uses and methods of use.

While it is too early to say how REACH will work in practice, there are at least two areas of possible concern. The first is the sheer volume of information the European Chemicals Agency will be required to process, possibly leading to regulatory backlogs, cursory review of the information submitted, or both. The second concern is the static, one-off nature of the review process. The assumption seems to be that once a substance is initially screened and all the extant information is considered (stage 1), regulators can conclusively determine whether that substance poses enough of a risk to merit further inquiry, and once that further review is completed (stage 2), they can definitively decide whether it still poses "unacceptable risks" and should be restricted. Although registrants are required to revise their registrations if new information becomes available, they are not under an affirmative obligation to conduct further investigations.[160] Thus, the approach does not create dynamic incentives for ongoing investigation to push the boundaries of our understanding concerning chemical properties and their interactions with human biochemistry and microbiology.

REACH almost certainly will add to the stock of knowledge concerning chemical toxicity and safe use, and just as importantly it will provide broad access to that assembled data and information, facilitating self-help actions to identify and implement safe uses and to avoid risky uses of chemical products. While the central focus is on chemical *product* safety, many of the substances in the REACH database are also sometimes environmental or workplace *pollutants*. To that extent, REACH will operate in aid of informed decision making in the environmental and occupational health-and-safety arenas, both in Europe and elsewhere, including the United States. Indeed, many observers expect that toxicity information generated through REACH could also profoundly shift the regulatory landscape in the United States by, for example, prompting EPA to exercise its authority under TSCA to demand further testing of substances deemed harmful by the EU, or triggering regulatory restrictions under TSCA or a variety of other statutory authorities.[161]

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160. *Id.* art. 61, at 152.

161. *See, e.g.*, Daryl W. Ditz, *The States and the World: Twin Levers for Reform of U.S. Federal Law on Toxic Chemicals*, 8 SUSTAINABLE DEV. L. & POL'Y 27, 29 (2007) (arguing that the flow of information generated by REACH will be an important resource supporting reform of U.S. policy on toxic chemicals).

III. Establishing Environmental Baselines and Benchmarks: The TRI Model

Another recurring problem across the landscape of environmental law and policy is the lack of good baseline information on environmental conditions and stressors.[162] Part of the problem is monitoring costs: it is expensive to establish comprehensive monitoring programs, and the government has been reluctant to incur those costs in the absence of specific and identifiable threats to human health or the environment.[163] On the other hand (and as others have pointed out), we spend enormous sums on environmental monitoring already.[164] But the vast majority of those expenditures go toward narrow enforcement-oriented monitoring, gauging specific sources' compliance with typically narrowly drawn, medium- and pollutant-specific regulatory standards and permit requirements.[165] Because this information is generally not reported in standard units or aggregated across sources, it carries little information value beyond source-specific enforcement.[166]

An alternative approach is represented by EPA's Toxics Release Inventory (TRI), part of the Emergency Planning and Community Right-to-Know Act[167] (EPCRA). TRI requires any business with ten or more employees in specified standard industrial classification (SIC) codes to report annually, on standardized forms, all releases of some 650 toxic pollutants into any medium.[168] The data are collected in a central, publicly accessible

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162. *See* Alyson C. Flournoy, *Restoration RX: An Evaluation and Prescription*, 42 ARIZ. L. REV. 187, 195 (2000) (stating that plans for ecological restoration are hampered by lack of a baseline information about the ecosystems prior to contamination); *see, e.g.*, Chelsea H. Congdon, Terry F. Young & Brian E. Gray, *Economic Incentives and Nonpoint Source Pollution: A Case Study of California's Grasslands Region*, 14 HASTINGS W.-NW. J. ENVTL. L. & POL'Y 215, 225 (2008) (explaining that harm to the fish population in California's San Joaquin River has been difficult to detect because of a lack of baseline information).

163. *See* Robert J. Jackson & David Rosenberg, *A New Model of Administrative Enforcement*, 93 VA. L. REV. 1983, 2002 (2007) (noting that EPA, because of concerns about cost, requires only the monitoring of "major" sources of airborne pollution and only aims to test each such source every five years); *see also* GAO, OPTIONS, *supra* note 99, at 22 (noting that since 1986, EPA has used "enforceable consent agreements" with greater frequency because it is "less costly and time-consuming" than actually monitoring and is "a good mechanism for acquiring needed test data").

164. *See, e.g.*, Jackson & Rosenberg, *supra* note 163, at 2002–2003 (noting that monitoring airborne pollutants is expensive and that EPA spends "more than $130 million per year" doing so); *see also supra* note 163 and accompanying text.

165. Karkkainen, *supra* note 19, at 284–85 & nn.115–19; *see* John C. Dernbach, *The Unfocused Regulation of Toxic and Hazardous Pollutants*, 21 HARV. ENVTL. L. REV. 1, 61–66 (1997) (describing how duplicative yet under-informative reporting requirements emerge from a framework of piecemeal, medium-specific regulation, with reporting requirements narrowly tailored toward setting and enforcing regulatory standards under incompatible statute-specific criteria).

166. Karkkainen, *supra* note 19, at 261.

167. 42 U.S.C. §§ 11001–11050 (2000). The Toxics Release Inventory was established by EPCRA § 313, 42 U.S.C. § 11023.

168. *See* 42 U.S.C. § 11023(a)–(d) (specifying basic reporting requirements, including who must report, what must be reported, and what chemicals are initially covered, subject to revision by the EPA Administrator). By regulation EPA has nearly doubled the initial list of 320 chemicals. *See* 40 C.F.R. § 372.65 (2007) (listing the chemicals covered by the provision).

and searchable EPA database.[169] Because the data are reported on standard forms using standard definitions, standard nomenclature, standard units of measurement, unique facility identifiers, and precise GIS-mappable geographical coordinates, the data can be aggregated or disaggregated geographically by firm or by industry, and longitudinally over time to produce a rich, multidimensional picture of the status of and trends in industrially sourced toxic pollution.[170] TRI thus takes full advantage of the information-storage, processing, and manipulation capacities of the Digital Age to create powerful new information tools at a very low cost.

Although not directly linked to any further regulatory requirements, TRI data have multiple uses.[171] The first TRI reports reportedly came as a shock to environmental regulators and corporate officers alike.[172] Many stated that before TRI they simply had no idea just how much toxic pollution was being released into the environment—until then, no one had ever bothered to ask.[173] Information generated through TRI has been used by regulatory agencies to help set regulatory and enforcement priorities;[174] by industry groups and individual firms to guide and monitor voluntary facility-specific, firm-wide, and industry-wide pollution-reduction programs;[175] and by local governments and nongovernmental organizations to inform themselves about the extent and severity of toxic pollution in their local communities and to take appropriate response measures.[176] Because TRI data provide a transparent yardstick of one important dimension of facility- and firm-level environmental performance, TRI releases have also been used by corporate management, shareholder groups, and academic researchers as a proxy for firm-, facility-, and industry-level environmental performance generally.[177]

Unleashing a host of regulatory, social, and market pressures, TRI prompted many firms to undertake ambitious programs of voluntary pollution reduction.[178] As a result, the overall volume of reported TRI

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169. *See* 42 U.S.C. § 11023(j) (directing the Administrator to "establish and maintain in a computer data base a national toxic chemical inventory" based on TRI data and to "make these data accessible by computer telecommunication and other means to any person"). To access TRI data, see EPA, Toxic Release Inventory (TRI) Program, http://www.epa.gov/tri (last updated May 16, 2008).

170. Karkkainen, *supra* note 19, at 261 ("Because TRI data are reported in standard units, they can be aggregated to produce profiles and performance comparisons at the level of the facility, firm, industrial sector, community, metropolitan region, state, watershed or other critical ecosystem, and the nation as a whole."); *see* EPA, Toxic Release Inventory (TRI) Program, http://www.epa.gov/tri (last updated May 16, 2008).

171. *See generally* Karkkainen, *supra* note 19 (discussing the effectiveness of the TRI regime and particularly its success in generating information).

172. *Id.* at 297.

173. *Id.*

174. *Id.* at 309–12.

175. *Id.* at 297–308.

176. *Id.* at 312–23.

177. *Id.* at 261–62.

178. *Id.* at 265.

emissions has fallen by roughly half since the program was inaugurated,[179] despite substantial economic growth over that period.

TRI is not without its faults. Perhaps most critically, TRI data are so crude as to be potentially misleading. TRI-reported releases are not indexed to the toxicity of the substance released; all releases are reported straightforwardly in pounds, even though one TRI substance may be pound-for-pound a thousandfold more toxic than another.[180] In addition, environmental and public-health risks are a function not only of a substance's toxicity but also of the number of persons or other organisms exposed, the levels of exposure, whether there are safe exposure thresholds, and the substance's rates of dispersal and persistence in the environment.[181] None of this information is reflected in the TRI data.[182] Third, because TRI reporting is limited to industrial sources, it may present a misleading picture of overall patterns of toxic pollution. In some areas, for example, automobile-generated hazardous air pollutants may equal or exceed those from industrial emissions, but only the pollutants from the industrial sources appear on TRI.[183] Finally, TRI provides a comprehensive national data set, but only on a single dimension of environmental performance.[184] Yet because the TRI data are so easy to acquire and use, they are often used as a proxy for overall environmental performance, again possibly creating a misleading picture as to who are the better environmental performers.[185]

Notwithstanding these criticisms, TRI has been an invaluable aid to governmental policymakers, corporate officers and directors, academic researchers, environmental NGOs, community organizations, and ordinary citizens. It has improved our understanding of the nature and extent of toxic pollution, and contributed, however indirectly, to pressures and incentives generally tending in the direction of improved environmental performance.[186] Most criticisms directed at TRI go to the question of what additional information would be needed to provide a clearer and more complete picture.[187] The problem, then, is not so much with the information TRI

179. According to the most recent publicly available data, releases of TRI pollutants have fallen by more than half since 1988. *See* EPA, TRI TOTAL DISPOSAL OR OTHER RELEASES BY INDUSTRY 2006, at A-5 (2008), *available at* http://www.epa.gov/tri/tridata/tri06/pdr/SectionA.pdf.

180. Karkkainen, *supra* note 19, at 331–35.

181. *See* SCI. ADVISORY BD., EPA, EPA-SAB-EEC-97-0122, REVIEW OF THE SECTOR FACILITY INDEXING PROJECT (SFIP), at A-4 (1997) (stating that the health risks of toxic pollutants are a function of volume released, relative toxicity, and exposure factors like population proximity, exposure pathways, persistence of the pollutant, and the activity patterns and susceptibility of affected populations).

182. Karkkainen, *supra* note 19, at 332–33.

183. *Id.* at 334.

184. *See id.* at 331 (noting that TRI does not measure other crucial indicia of environmental performance such as conventional pollutants, solid waste, or despoliation of wildlife habitat).

185. *Id.* at 331.

186. *Id.* at 261–62.

187. *Id.* at 331–35.

provides as with what it does *not* provide, much of which could be added at a relatively modest cost.

TRI has clearly induced private parties to produce, on a regular and recurring basis, one important class of information relevant to environmental problem-solving that otherwise would have been unavailable or difficult to obtain. It has placed the burden of producing that information on the parties best positioned to produce it—the industrial sources themselves—and unlike NEPA, it has done so at a relatively modest cost. By enabling closer scrutiny of corporate environmental performance by regulators, environmental groups, community organizations, shareholders, and corporate managers, it appears to have played a salutary (albeit so far unquantified) role in creating or strengthening incentives for private parties to act in more environmentally benign ways, while allowing them the flexibility to experiment in finding the most cost-effective means to do so and avoiding the straitjacketing effects of more coercive forms of regulation. Finally, unlike NEPA, TRI has provided for the centralized collection and efficient dissemination of data on facility- and firm-level environmental performance; indeed, centralized data collection and ease of distribution is TRI's signature feature.

Widely hailed as a policy success,[188] TRI might have been expected to spawn a host of imitators—as indeed it has. Numerous nations have now adopted their own pollutant release and transfer registries (PRTRs), as they are known in the international environmental-policy jargon.[189] Yet here in the United States, state and local governments have been slow to embrace environmental baseline reporting and monitoring systems based on the TRI model. Recently, however, the governors of thirty-one states announced their intention to follow California's lead by establishing a multistate Climate Registry.[190] It requires industries to report and disclose their greenhouse-gas emissions, and uses standard definitions and units of measurement—an important first step toward bringing greenhouse-gas emissions under control.[191]

188. *See* Archon Fung & Dara O'Rourke, *Reinventing Environmental Regulation from the Grassroots Up: Explaining and Expanding the Success of the Toxics Release Inventory*, 25 ENVTL. MGMT. 115, 116 (2000) (describing TRI as "an accidental success story").

189. Karkkainen, *supra* note 19, at 347–50 (discussing PRTRs based on TRI in several foreign countries).

190. Timothy Gardner, *31 U.S. States Form Registry to Cut Carbon Emissions*, REUTERS.COM, May 8, 2007, http://www.reuters.com/article/environmentNews/idUSN0823361220070508.

191. The Climate Registry, http://www.theclimateregistry.org/index.html. *See generally* Michael P. Vandenbergh & Anne C. Steinemann, *The Carbon-Neutral Individual*, 82 N.Y.U. L. REV. 1673, 1729–30 (2007) (urging the creation of a unified database on greenhouse-gas emissions from individuals and households, modeled on TRI and dubbed by the authors the Individual Carbon Release Inventory (ICRI)).

IV. Ecological Complexity and the Unfulfilled Promise of Adaptive Ecosystem Management

A final area rife with information deficits is the field broadly known as ecosystem management. The 1970s-era approach to environmental protection was to attack environmental stressors in piecemeal fashion, one at a time, often with nationally uniform regulatory approaches.[192] Similarly, natural-resources management was parceled out among a variety of mission-specific agencies and resource-specific management regimes, such as commercial and sport fisheries, wildlife, recreation areas, water-resource development, and so on.[193]

That fragmentary approach, however, is broadly inconsistent with the basic tenets of ecology, which tend to view ecological systems as ecological wholes.[194] Ecologists argued this stressor- and resource-specific management approach was shortsighted, suboptimally effective, and at times even counterproductive, because multiple stressors and multiple resources in any given location interact with each other in complex ways.[195] They claimed that management actions taken with respect to any particular stressor or resource could have unforeseen secondary effects throughout the system, some potentially adverse to other environmental-protection or natural-resource-management goals.[196] This critique crystallized around the concept of "ecosystem management," which came into vogue in natural-resources management and policy circles in the early 1990s.[197] On a parallel track, a

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192. *See, e.g.*, Stewart, *supra* note 47, at 29–30 (discussing the shortcomings of fragmentary and piecemeal regulation).

193. *See* Jon Cannon, *Choices and Institutions in Watershed Management*, 25 WM. & MARY ENVTL. L. & POL'Y REV. 379, 387–89 (2000) (describing horizontal and vertical fragmentation of management responsibilities and interagency competition as barriers to effective management at watershed scales).

194. E. Donald Elliott, *Toward Ecological Law and Policy*, *in* THINKING ECOLOGICALLY: THE NEXT GENERATION OF ENVIRONMENTAL POLICY 170, 170 (Marian R. Chertow & Daniel C. Esty eds., 1997) (observing that "[m]ost of today's environmental law violates the basic principles of ecology," because "[m]ost current-generation law regulates separate pollutants with little consideration of ecosystems as a whole").

195. *E.g.*, Karkkainen, *Adaptive Ecosystem Management*, *supra* note 65, at 947 ("For example, oyster populations may be profoundly affected by water quality and the availability of suitable habitat; yet these variables typically fall outside the jurisdiction of the state fisheries agency, which instead attempts to manage oyster abundance solely by regulating the size of the harvest.").

196. *See, e.g.*, Jonathan M. Cosco, *NEPA for the Gander: NEPA's Application to Critical Habitat Designations and Other "Benevolent" Federal Action*, 8 DUKE ENVTL. L. & POL'Y F. 345, 381–82 (1998) (noting that "actions intended to benefit the environment may have undesirable secondary effects" and giving the example of permitting naturally occurring wildfires to burn in a habitat to benefit the red-cockaded woodpecker, possibly to the detriment of other natural resources or species).

197. *See generally* Norman L. Christensen et al., *The Report of the Ecological Society of America on the Scientific Basis for Ecosystem Management*, 6 ECOLOGICAL APPLICATIONS 665 (1996) (discussing the importance of ecosystem management in achieving new legislative goals of sustainability); R. Edward Grumbine, *What Is Ecosystem Management?*, 8 CONSERVATION

group of top EPA political appointees and career officials argued for a dramatic reorientation of environmental and natural-resources policy, away from the status quo piecemeal and fragmentary approach, and toward what they called "place-based" integrated management of these ecological complexes.[198]

In each case the central idea was that, rather than managing stressors and resources piecemeal and from an abstract national perspective, we should endeavor to manage entire suites of stressors and resources that jointly comprise the ecosystem. In principle, then, a new convergence of environmental protection and natural-resource management, and a reorientation of both in the direction of a new, ecologically informed, and distinctly locally oriented paradigm, appeared to be at hand.

But a funny thing happened on the way to ecosystem management—we never quite figured out a way to get there. Moreover, and worse perhaps, we were never quite sure where "there" was. To be sure, there were attempts to integrate heretofore disparate management arrangements through interagency, intergovernment, and public–private collaboration.[199] Some persist to this day.[200] But many fizzled, and those that survived have yet to demonstrate much real, tangible progress toward better environmental outcomes or more effective resource management.[201]

BIOLOGY 27 (1994) (tracing the historical development of the concept of ecosystem management and providing a framework for its implementation).

198. *See* Ecosystem Protection Workgroup, EPA, Toward a Place-Driven Approach: The Edgewater Consensus on an EPA Strategy for Ecosystem Protection (Mar. 15, 1994), *in* JOHN COPELAND NAGLE & J.B. RUHL, THE LAW OF BIODIVERSITY AND ECOSYSTEM MANAGEMENT 384, 385 (2d ed. 2006) (concluding that "even if we had perfect compliance with all our authorities, we could not assure the reversal of disturbing environmental trends" and that because EPA is caught up in "program-driven" standard-setting and permitting, "the Agency has not paid enough attention to the overall environmental health of specific ecosystems"). The "Edgewater Consensus" was the product of "EPA's top managers." James Salzman et al., *Protecting Ecosystem Services: Science, Economics, and Law*, 20 STAN. ENVTL. L.J. 309, 310 n.4 (2001).

199. *See* Bradley C. Karkkainen, *Collaborative Ecosystem Governance: Scale, Complexity, and Dynamism*, 21 VA. ENVTL. L.J. 189, 217–18 (2002) (noting the emergence of regional coordinating mechanisms for collaborative ecosystem management in "the Chesapeake Bay, NCCP, and South Florida cases, among others").

200. Notable ongoing efforts include the Florida Everglades Restoration Project, South Florida Ecosystem Restoration Task Force, http://www.sfrestore.org (last updated May 7, 2008); the Chesapeake Bay Program, Bay Restoration, Chesapeake Bay Program, http://www.chesapeakebay.net/bayrestoration.aspx?menuitem=13989; and to some extent the joint U.S.–Canadian effort to manage the Great Lakes, *see* Bradley C. Karkkainen, *Managing Transboundary Aquatic Ecosystems: Lessons from the Great Lakes*, 19 PAC. MCGEORGE GLOBAL BUS. & DEV. L.J. 209, 214–15 (2006) (describing joint U.S.–Canadian efforts to manage pollution in the Great Lakes, including the Great Lakes Water Quality Agreement (GLWQA)). At the international level, a promising effort is the regional Baltic Sea program, BALLERINA: Environment in the Baltic Sea Region, http://www.baltic-region.net/index.htm (last updated May 29, 2007).

201. *See* Karkkainen, *Adaptive Ecosystem Management*, *supra* note 65, at 994 ("[S]ome regional ecosystem management efforts, such as the Chesapeake Bay Program, have persisted over many years and appear to involve genuine efforts to achieve environmental objectives, but critics suggest that these are the exception, not the norm." (citing Jon Cannon, *Choices and Institutions in Watershed Management*, 25 WM. & MARY ENVTL. L. & POL'Y REV. 379, 407–16 (2000))).

In part, the problem is institutional. Once established, bureaucracies do not surrender power lightly. Old interagency and intergovernmental rivalries, clashing institutional cultures, incompatible statutory authorities and directives, careerist timidity to break with the status quo, and the sheer weight of bureaucratic inertia (a formidable force in its own right) conspire against genuine cooperation and policy integration.[202]

In part, the problem is also legal and political. The statutes authorizing environmental protection and natural-resource management were constructed around the familiar piecemeal approach,[203] and the amount of discretionary "wiggle room" left to agency officials is often (and by design) quite small.[204] Moreover, even if agency officials are willing to lighten up on rigid enforcement of the extant statutes and their implementing regulations, the device of the environmental citizen suit hangs like Damocles' sword over their heads.[205] For their part, and for understandable reasons, some environmental NGOs and other advocates of environmental protection do not trust the agencies to do the right thing. They therefore fiercely resist efforts to weaken mandatory, top-down rules or to widen the zone of discretion to allow for the local tailoring that ecosystem management seems to require.[206] Nor do they trust that decisions made at local and regional levels, insulated from the vigilant gaze of the national environmental watchdogs, will hew to the same lofty environmental protection goals that informed the national statutes of the environmental decade of the 1970s.[207] Instead, they fear that localization and regionalization is an open invitation to parochial economic and political interests to capture the policy-making apparatus and steer policy and management decisions toward even higher levels of resource exploitation and lower levels of environmental protection.[208] Meanwhile, resource-

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202. Robert B. Keiter, *Beyond the Boundary Line: Constructing a Law of Ecosystem Management*, 65 U. COLO. L. REV. 293, 320–21 (1994).

203. *See* Stewart, *supra* note 47, at 30 ("[Regulatory] problems are the product of the environmental statutes that EPA administers, which are largely unrelated to each other and lack any unified vision of environmental problems or of EPA's mission, resulting in regulatory fragmentation, gaps, overlaps, and inconsistencies.").

204. *See* Keiter, *supra* note 202, at 303–04 (stating that land-management agencies have discretionary authority to act only within their defined statutory missions).

205. *See* Barton H. Thompson, Jr., *The Continuing Innovation of Citizen Enforcement*, 2000 U. ILL. L. REV. 185, 198 ("Citizen prosecutors have . . . forced public officials to do a more effective job of enforcement, lest they be embarrassed by private enforcers.").

206. *See* Oliver A. Houck, *On the Law of Biodiversity and Ecosystem Management*, 81 MINN. L. REV. 869, 880–83 (1997) (chronicling the dilution of environmental law by "commodity users" in cases where agencies were vested with "good intentions and . . . discretionary language").

207. *See* David R. Hodas, *Enforcement of Environmental Law in a Triangular Federal System: Can Three Not Be a Crowd When Enforcement Authority is Shared by the United States, the States, and Their Citizens?*, 54 MD. L. REV. 1552, 1622 (1995) (noting that, in order to maintain lax enforcement, "[m]any states routinely preempt citizen suits by entering into mild enforcement consent orders . . . [with] a violator who had not been previously subject to state enforcement attention").

208. *See id.* at 1615–17 (describing a "race to the bottom" among states in environmental law enforcement so that each may avoid creating a poor environment for business); Karkkainen,

strapped state and local agencies are not eager to assume too much of the heavy lifting, which for the most part they are underequipped to handle. In many places the only business and industry groups that have shown much interest in local and regional ecosystem management are the very resource industries that the environmental NGOs most distrust and fear, which only reinforces their suspicions.[209] At the end of the day, then, the constituency for locally and regionally based integrated ecosystem management often consists of a small circle of agency managers, scientists, and a smattering of other academics—hardly a politically potent coalition.

But an equally important factor is information, or rather, its scarcity. Given the complex interdependencies among the various resources, biogeochemical processes, and stressors that comprise ecosystems, it is easy enough to say that we should attempt to manage all these factors in an integrated way. Having said that, however, it is another thing entirely to say what, precisely, we should do.[210] The raw, unvarnished truth is that in all but the simplest systems, we do not now have, and likely never will have, a comprehensive, synoptic understanding of the system, its components, and its dynamic processes and functions such that would allow us to predict accurately and with precision how the system will respond to any particular management intervention. This is not to say we are completely in the dark; we do know some things, and we know more about some systems than others. But even for those we have studied most thoroughly, like the Chesapeake Bay, which we have been studying and attempting to manage as an ecosystem for roughly thirty-five years now, there are huge gaps in our understanding due to incomplete science, inadequate data, limited monitoring and analytical capacity, incomplete integration of the knowledge that is available, and limitations inherent in our models that necessarily represent radical oversimplifications of processes that are in fact far more complex in the real world.[211]

For at least thirty years now, at least one wing of ecological science has advocated what seems to be a promising response to all this complexity and

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Adaptive Ecosystem Management, *supra* note 65, at 961 (examining the argument that industrial interests are better able to control policy makers at the local level, where they have fewer free riders, while environmental interests must maximize their power by concentrating it on a few problems, national in scope).

209. *See* Hodas, *supra* note 207, at 1619 (noting that underfunded state enforcement programs cannot increase their enforcement activities and may decrease activities as a result of a race to the bottom to appease industrial interests); Barton H. Thompson, Jr., *Conservative Environmental Thought: The Bush Administration and Environmental Policy*, 32 ECOLOGY L.Q. 307, 345–46 (2005) (remarking on the Bush Administration's devolution of environmental enforcement to states "in areas where stakeholders have complained about federal regulation," but withholding it "in areas where states . . . have tried to impose stricter regulations than the federal government").

210. *See* Keiter, *supra* note 202, at 301–02 (discussing these complexities).

211. *See* Karkkainen, *Adaptive Ecosystem Management*, *supra* note 65, at 947–48 (remarking that the difficulty in managing ecosystems stems from factors such as incomplete scientific understanding of complex systems); *supra* Part I.

uncertainty—an approach dubbed "adaptive management."[212] The core ideas are to candidly acknowledge the limitations of present knowledge and proceed the way science might, by (1) treating present ecological models, understandings, and the management interventions predicated upon them as provisional; (2) designing interventions as testable hypotheses where possible; (3) carefully and systematically monitoring and evaluating the results; and (4) adjusting our models, understandings, and management interventions in accord with what we have learned through experience.[213] Applying this approach iteratively promises both to increase our stock of knowledge about the system and how it responds, and to create a more dynamic and supple decision-making process that is capable of responding to new information, advancing science, and changing real-world conditions.[214]

Like ecosystem management, the concept of adaptive management has been seized upon eagerly by policy wonks in the federal resource-management agencies, although the way that concept has been applied in practice has often fallen far short of the lofty, science-driven ideal described by its most ardent advocates.[215] Like ecosystem management, adaptive management has also been met with suspicion by many in the environmental community who see it as a step toward greater agency discretion, less accountability, and less certainty that basic environmental-protection standards will be attained.[216]

The idea, in this author's view, remains an appealing one. But the onus is clearly on the proponents of adaptive management to demonstrate that it can succeed in producing not only better-informed decisions, but also, and ultimately, superior substantive results. A number of ambitious, large-scale experiments in adaptive ecosystem management are presently underway. Of these, one of the most ambitious, sophisticated, and well resourced is the multistate effort to restore the Chesapeake Bay—an effort that predates, and does not employ, the term "adaptive management." Another is the joint

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212. The idea can be traced to the seminal work of the ecologist C.S. "Buzz" Holling, who developed the idea of "adaptive environmental assessment and management" in the context of environmental impact assessment. *See* ADAPTIVE ENVIRONMENTAL ASSESSMENT AND MANAGEMENT 133–39 (C.S. Holling ed., 1978) (giving an "underview" of adaptive assessment). For further discussion of the evolution of the idea and its multiple variants, see Karkkainen, *Adaptive Ecosystems Management*, *supra* note 65, at 948–56.

213. *See* Karkkainen, *Adaptive Ecosystem Management*, *supra* note 65, at 948 ("The favored solution [for managing complex ecosystems] . . . is some form of adaptive management, a 'learning-by-doing' approach that views policies and management interventions as explicitly experimental and provisional, and looks to revise both our understanding of ecosystems and subsequent policies as we learn from an iterative series of policy experiments.").

214. *Id.* at 948.

215. *See id.* at 953–58 (detailing how the U.S. Fish & Wildlife Service, the U.S. Forest Service, and the Army Corps of Engineers have all purported to adopt adaptive management techniques).

216. *See id.* at 964 ("On the other hand, if the critics are right that in the absence of tough mandatory rules we risk agency capture, lack of accountability, and inadequate motivation on the part of private parties, then we open the possibility of backsliding with respect to environmental protection goals.").

federal–state effort to restore the Florida Everglades by altering the hydrological regime so as to mimic the natural flows that existed prior to the massive anthropogenic interventions that radically altered South Florida's hydrology and ecology in the latter half of the twentieth century.[217] As impressive as these efforts are for their scientific and technical achievements and institutional sophistication, they have yet to deliver clearly convincing victories on the ground in the form of substantial advances in environmental protection and ecological restoration.[218] Until they achieve those breakthroughs, adaptive management may remain an attractive idea whose time has not yet—and may never—come.

V. Conclusion

This Article has endeavored to isolate and examine four distinct types of information failure that characterize our environmental law and policy. Each of these—information asymmetries, medical and scientific uncertainty with respect to health effects, lack of adequate baseline information on environmental conditions, and incomplete understandings of the dynamic processes and functions of complex ecosystems—has led to a distinct set of regulatory pathologies. Yet in response to each of these categories of information failure, promising alternative approaches have begun to emerge. As yet, these alternative approaches are crude and underdeveloped. But they do suggest, at least in a glimmering light, a series of paths forward. Much work remains to be done, however, to flesh out this preliminary typology of the information failures that characterize environmental law and policy, and to refine the family of remedial approaches that has been outlined here.

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217. *See id.* at 955 (discussing the Army Corps of Engineers' attempted use of adaptive management as a "touchstone" in its "Comprehensive Everglades Restoration Plan").

218. *See id.* at 956 ("Although 'adaptive management' as practiced by federal agencies to date must be rated as something of a disappointment, the concept is not likely to go away anytime soon.").