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Technology Assessment 2.0: Revamping Our Approach to Emerging Technologies

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Technology Assessment 2.0

REVAMPING OUR APPROACH TO EMERGING TECHNOLOGIES*

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INTRODUCTION

We live in an era of rapid and potentially revolutionary technological changes. These changes will play a critical role in addressing many of the problems facing human society. Improvements in energy efficiency may reduce our dependence on fossil fuels. Redesigned manufacturing processes may require less energy and generate less waste. Geoengineering projects may mitigate some of the effects of climate change. And developments in synthetic biology and nanotechnology may increase food production, generate new pharmaceuticals, remediate environmental pollution, and transform countless aspects of our lives.

At the same time, however, new technologies also raise the specter of adverse health effects, environmental degradation and disaster, and even dehumanization, should those technologies go awry. As past experiences teach us, new technologies do not merely solve old problems. Often, technologies create problems of their own, many of which reveal themselves only with time. Addressing these problems becomes especially difficult when technological systems become entrenched.[1] New technologies pose

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1 *See* DAVID COLLINGRIDGE, THE SOCIAL CONTROL OF TECHNOLOGY 17-19 (1980) ("[B]y the time a technology is sufficiently well developed and diffused for its unwanted social consequences to become apparent, it is no longer easily controlled."); RICHARD SCLOVE, WOODROW WILSON INT'L CTR. FOR SCHOLARS, REINVENTING TECHNOLOGY ASSESSMENT: A 21ST CENTURY MODEL 2-3 (2010), *available at* http://wilsoncenter.org/topics/docs/ReinventingTechnologyAssessment1.pdf.

a particularly high potential for unexpected effects.[2] They also have the potential to change cultural norms and social relationships in unpredictable ways.[3] German sociologist Ulrich Beck succinctly characterized the connection between science and risk in his book *Risk Society*, where he noted, "Science is *one of the causes* [of risks]*, the medium of definition* [of risks] *and the source of solutions* to risks."[4]

Given the transformative yet destabilizing potential of new technologies, it is critical to maximize our understanding of them and their effects—intended and unintended—as they are developed, introduced, and disseminated. While it would be naïve to think that we can fully predict the course of a technology's development and its consequences, ongoing and methodical evaluation can help us to anticipate, avoid, manage, and mitigate adverse effects. Merely carrying out more effective technology assessment is not sufficient, however. Because of the wide-ranging effects of technologies on society and individual lives, the assessment of emerging technologies must be broadened beyond technical experts to involve the general public. This article identifies tools for carrying out more open, effective, and encompassing technology management.

Part I begins with a brief introduction to several technologies that will be among the most important and controversial in the coming decades: biotechnology (including synthetic biology), nanotechnology, and geoengineering. The pervasive potential of these technologies warrants their thorough consideration as well as increased public participation in decision-making processes about them. As Part II explains, tools such as technology assessment and environmental impact assessment were developed in an attempt to understand and predict the ramifications of new technologies and to increase public involvement. For various reasons, however, these efforts generally have not achieved effective assessment or meaningful public participation, leaving the forces of technological change seemingly uncontrolled. Part III explores how we might better manage technology and its consequences. One option simply involves

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[2] Noting the increasingly unpredictable consequences of new technologies, David Owen has examined the possible implications for the requirement of foreseeability in tort law. David G. Owen, *Bending Nature, Bending Law*, 62 FLA. L. REV. 569 (2010).

[3] *See* COLLINGRIDGE, *supra* note 1, at 11, 16.

[4] ULRICH BECK, RISK SOCIETY: TOWARDS A NEW MODERNITY 155 (Mark Ritter trans., Sage Publ'ns 1992).

broader and more effective implementation of existing management tools that we have never fully utilized, such as technology assessment. Some efforts along these lines have been initiated, but their ultimate impact remains uncertain. More radical options, such as conducting national technology referenda or requiring assurance bonds for technologies with uncertain effects, are needed to bring about participatory and effective management of emerging technologies.

I. THE CHALLENGE OF NEW TECHNOLOGIES

Broadly defined, technology includes the tools, techniques, and knowledge that humans use to mediate their environment. Technology and the environment are inherently related, and emerging technologies, which are often incompletely understood, pose a challenging conundrum to societies that seek to reap their benefits while avoiding serious adverse harms.

A. The Technologies of Tomorrow

This section briefly discusses some of the technologies that are expected to have broad and revolutionary impacts on human societies and the environment in the near future. The goal here is not to provide a comprehensive account of these fields, but rather to demonstrate that such technologies warrant careful consideration and public deliberation.

1. Biotechnology

The term biotechnology, as used in this article, refers both to conventional genetic engineering, in which existing genetic material from one organism is transferred to another, and to synthetic biology, in which researchers synthesize novel genetic material coding for desired traits. Genetic engineering is a well-established technology projected to expand into numerous new applications in the coming years, whereas synthetic biology is in a comparatively early stage of research and development.[5] The discussion below focuses on agricultural biotechnology, which has proven particularly controversial.[6]

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[5] *See* Jim Haseloff & Jim Ajioka, *Synthetic Biology: History, Challenges, and Prospects*, 6 J. ROYAL SOC'Y INTERFACE S389 (2009), *available at* http://rsif.royalsocietypublishing.org/content/early/2009/06/02/rsif.2009.0176.focus.full.pdf+html.

[6] Other applications of genetic engineering include the manufacture of synthetic insulin, human growth hormone, and other desired proteins for medical

a. Genetic Engineering

Genetic engineering, the manipulation of existing genetic material to produce desired traits in an organism, has gained widespread use in crop modification over the past two decades.[7] Genetic engineering offers two major advantages over traditional breeding techniques. Through the introduction of *transgenes*—genetic material isolated from one organism and transferred to another—genetic engineers can incorporate a wider range of desired traits into a crop, including traits originally found only in unrelated species.[8] In addition, desired traits can be incorporated into a crop far more quickly through genetic engineering than through traditional crossbreeding.[9] To date, genetic engineers have focused primarily on incorporating pesticidal traits or herbicide resistance into commodity crops.[10] Genetically modified varieties have become widely prevalent among major crops, accounting for 80% of corn, 92% of soybeans, 86% of cotton, and 93% of canola planted in the United States.[11] Furthermore, an estimated 75% of processed foods in U.S. grocery stores contain genetically modified organisms (GMOs) of some sort.[12] Now, genetic engineers are turning their attention not only to improving crop traits such as drought resistance and enhanced yields, but also to developing plants and animals that will produce pharmaceutical compounds and industrial chemicals.[13]

Notwithstanding the widespread presence of GMOs in agriculture and in the food supply, critics have continued to raise concerns about potential health and environmental hazards associated with these crops. Health concerns generally involve potential allergenicity and toxicity.[14] Genes code for

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treatment. *See* Alan McHughen, *Learning from Mistakes: Missteps in Public Acceptance Issues with GMOs*, *in* WHAT CAN NANOTECHNOLOGY LEARN FROM BIOTECHNOLOGY? 33, 39-40 (Kenneth David & Paul B. Thompson eds., 2008).

[7] *See* U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-09-60, GENETICALLY ENGINEERED CROPS 1-2 (2008) [hereinafter GAO REPORT].

[8] *See id.*

[9] *See id.*

[10] *See* Gregory Jaffe, *The Next Generation*, ENVTL. F., Mar./Apr. 2009, at 38.

[11] GAO REPORT, *supra* note 7, at 1.

[12] *Americans Clueless About Gene-Altered Foods*, MSNBC.COM (Mar. 23, 2005, 6:13 PM), http://www.msnbc.msn.com/id/7277844.

[13] *See* GAO REPORT, *supra* note 7, at 1; Gregory N. Mandel, *Gaps, Inexperience, Inconsistencies, and Overlaps: Crisis in the Regulation of Genetically Modified Plants and Animals*, 45 WM. & MARY L. REV. 2167, 2186-89 (2004).

[14] Mandel, *supra* note 13, at 2190-94.

proteins, which are potential food allergens, and thus the transfer of genes from one plant to another may transfer allergenic properties along with it.[15] Toxic effects might arise from pesticides produced by engineered crops,[16] or from inadvertent increases in naturally occurring toxins resulting from genetic manipulation.[17] Genetic modification of plants can even lead to the creation of biological components that have not previously existed in nature, possibly causing unexpected allergenic or toxic effects.[18] Environmental risks include the potential for gene transfer and ecosystem disruption.[19] Gene transfer refers to the movement of transgenes through cross-pollination or other means from an engineered crop to relatives of that crop, including other varieties of that crop or a crop's wild relatives.[20] The transfer of transgenes could disrupt ecosystems in various ways. On the one hand, wild relatives might demonstrate increased weediness and crowd out competing species; on the other hand, a rare wild species may become extinct as it interbreeds and hybridizes with engineered crops.[21] Other environmental hazards include the establishment of wild populations of transgenic plants, and mortality among nontarget, beneficial species that consume crops engineered to contain pesticides.[22] The development of genetically modified plants that can produce drugs and industrial chemicals may pose even more significant health and environmental risks, as inedible and potentially harmful

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15 Premarket Notice Concerning Bioengineered Foods, 66 Fed. Reg. 4706, 4728 (Jan. 18, 2001) (to be codified at 21 C.F.R. pts. 192, 592); *see also* Dean D. Metcalfe, *What Are the Issues in Addressing the Allergenic Potential of Genetically Modified Foods?*, 111 ENVTL. HEALTH PERSP. 1110, 1111 (2003) (noting that simply avoiding the transfer of genes known to code for allergens does not solve the problem because "the characteristics of a protein with known allergenicity that would distinguish this protein from a protein unlikely to be allergenic are not known").

16 *See* Joël Spiroux de Vendômois et al., *A Comparison of the Effects of Three GM Corn Varieties on Mammalian Health*, 5 INT'L J. BIOLOGICAL SCI. 706 (2009) (reporting signs of kidney and liver toxicity in rats that had been fed corn genetically modified to synthesize Bt toxins used as insecticides).

17 *See* NAT'L RESEARCH COUNCIL, GENETICALLY MODIFIED PEST-PROTECTED PLANTS 69-73 (2000).

18 Katharine A. Van Tassel, *Genetically Modified Plants Used for Food, Risk Assessment, and Uncertainty Principles: Does the Transition from Ignorance to Indeterminacy Trigger the Need for Post-Market Surveillance?*, 15 B.U. J. SCI. & TECH. L. 220, 230-37 (2009) (discussing recent discoveries indicating that genes function and interrelate in much more complex ways than previously understood).

19 Mandel, *supra* note 13, at 2194-98.

20 *See* NAT'L RESEARCH COUNCIL, *supra* note 17, at 67.

21 *See id.*

22 *See id.* at 70-71.

substances are introduced into food crops.[23] Genetically modified animals raise further concerns, including the potential for the transmission of new disease agents or for the escape of transgenic animals that could outcompete wild animal species and wreak havoc on ecosystems.[24]

GMOs have become commonplace in U.S. agriculture and on American supermarket shelves despite surprisingly low public awareness and support. Only about one-fourth of the American public favors the introduction of GMOs into the food supply, and most Americans believe—incorrectly—that they have not ingested foods containing GMOs.[25] Lax government oversight enabled the spread of GMOs notwithstanding public opposition and minimal consideration of health and environmental risks. GMOs are loosely governed under the Coordinated Framework for Regulation of Biotechnology ("Framework"),[26] established by the federal government in 1986 with the ostensible purpose of regulating health and environmental risks that might result from the development, commercialization, and consumption of GMOs.[27] A principal motivation behind the policy, however, was to "minimize the uncertainties and inefficiencies that [could] stifle innovation and impair the competitiveness" of the nascent biotechnology industry.[28] Indeed, although the Framework is described as a "comprehensive federal regulatory policy,"[29] it is better understood as a patchwork of existing laws pieced together to deflect calls for new legislation specifically addressing GMOs.

The Framework identifies three primary agencies with authority under preexisting laws to regulate risks that biotechnology products might pose: the Animal and Plant Health Inspection Service, which monitors for plant-pest risks; the Environmental Protection Agency (EPA), which regulates pesticidal substances; and the Food and Drug Administration (FDA), which regulates the safety and labeling of foods. Under

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[23] NAT'L RESEARCH COUNCIL, ENVIRONMENTAL EFFECTS OF TRANSGENIC PLANTS: THE SCOPE AND ADEQUACY OF REGULATION 15, 68 (2002).

[24] Mandel, *supra* note 13, at 2200-02.

[25] *See* NAT'L SCI. FOUND., 1 SCIENCE AND ENGINEERING INDICATORS 2008, at 7-36 (2008) (summarizing findings of surveys conducted by Pew Initiative on Food and Biotechnology).

[26] Coordinated Framework for Regulation of Biotechnology, 51 Fed. Reg. 23,302 (June 26, 1986) [hereinafter Framework].

[27] Proposal for a Coordinated Framework for Regulation of Biotechnology, 49 Fed. Reg. 50,856, 50,856-57 (Dec. 31, 1984).

[28] *Id.* at 50,857.

[29] Framework, 51 Fed. Reg. at 23,302.

the Framework, the agencies are directed to focus on the characteristics of the biotechnology product at issue—not the fact that a product was genetically engineered—and to regulate only those risks they deem unreasonable.[30] The Framework does not require, however, comprehensive analyses of the health and environmental effects of individual GMOs or systematic consideration of the overall desirability of GMOs for society. In addition, the ad hoc nature of the Framework leaves significant regulatory gaps with respect to potential health and environmental risks.[31]

The FDA's regulation of GMOs in food exemplifies the piecemeal and relatively narrow scope of oversight under the Framework. The FDA's authority with respect to GMOs derives from its more general authority over adulterated foods, including foods containing additives that are unsafe.[32] Accordingly, the FDA views its jurisdiction over GMOs as limited to genetically modified (GM) foods or food products.[33] GM plants used to produce industrial chemicals, for example, receive no FDA review, and the FDA does not concern itself with environmental risks associated with the growing of GM crops.[34]

Although food additives by and large must be approved by the FDA before use, a substance added to food is exempt if it is generally recognized as safe (GRAS).[35] A genetic modification may create a substance that is considered a food additive.

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[30] Exercise of Federal Oversight Within Scope of Statutory Authority: Planned Introductions of Biotechnology Products into the Environment, 57 Fed. Reg. 6753, 6756 (Feb. 27, 1992).

[31] For detailed discussions and critiques of GMO oversight, see Mary Jane Angelo, *Regulating Evolution for Sale: An Evolutionary Biology Model for Regulating the Unnatural Selection of Genetically Modified Organisms*, 42 WAKE FOREST L. REV. 93, 112-41 (2007), and Mandel, *supra* note 13, at 2221-42.

[32] 21 U.S.C. §§ 342(a)(2)(C), 348 (2006). The term *adulterated food* also includes "any poisonous or deleterious substance which may render it injurious to health," *id.* § 342(a)(1), and the FDA has affirmed its authority to regulate GM foods containing toxicants through this provision. Statement of Policy: Foods Derived from New Plant Varieties, 57 Fed. Reg. 22,984, 22,990 (May 29, 1992).

[33] Statement of Policy: Foods Derived from New Plant Varieties, 57 Fed. Reg. at 22,989-90.

[34] *See* Rebecca Bratspies, *Some Thoughts on the American Approach to Regulating Genetically Modified Organisms*, 16 KAN. J.L. & PUB. POL'Y 393, 408 n.70 (2007). The Animal and Plant Health Inspection Service is charged with assessing the environmental risks of growing GM crops, but its analyses, which focus on plant-pest risks, are seen as inadequate. Angelo, *supra* note 31, at 137.

[35] 21 U.S.C. § 348 (2006). Under the Federal Food, Drug, and Cosmetic Act, a food additive is defined as "any substance the intended use of which results . . . in its becoming a component or otherwise affecting the characteristics of any food . . . if such substance is not generally recognized . . . to be safe under the conditions of its intended use." *Id.* § 321(s).

Under the FDA's policy on GM foods, however, most GM foods require no premarket approval or special labeling.[36] The policy, which provides that GM foods are to be treated no differently for regulatory purposes than foods developed through traditional plant breeding, presumes that most substances added to foods via genetic modification are GRAS because they "will be the same as or substantially similar to substances commonly found in food . . . ."[37] As commentators have pointed out, the minimal oversight under the policy is further diluted by its self-policing nature: producers of new plant varieties make the GRAS determinations themselves.[38] In fact, producers are not even required to report their GRAS determinations to the FDA, although they may do so of their own volition.[39] The discretionary judgment involved in making and reporting GRAS determinations essentially makes the FDA's regulatory scheme a voluntary one and reflects the Framework's hands-off approach.

b. Synthetic Biology

The emerging field of synthetic biology builds on the techniques of conventional genetic engineering and hints at both a wider array of uses as well as more disturbing risks. Synthetic biology involves the synthesis of organic molecules not found in nature, with the aim of creating artificial living systems or of facilitating the assembly of living systems based on interchangeable genetic sequences.[40] Unlike conventional genetic engineering, which relies on genetic material from existing organisms, synthetic biology entails the design of novel genetic sequences and even entire genomes.[41] Synthetic biology

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[36] Statement of Policy: Foods Derived from New Plant Varieties, 57 Fed. Reg. at 22,985; *id.* at 22,991 (declining to require disclosure of presence of GMOs in food labeling).

[37] *Id.* at 22,985.

[38] *See* Angelo, *supra* note 31, at 133; Mandel, *supra* note 13, at 2219.

[39] 21 C.F.R. § 170.35 (2010) (setting out procedure for voluntarily obtaining FDA affirmation of GRAS status); Substances Generally Recognized as Safe, 62 Fed. Reg. 18,938, 18,941 (Apr. 17, 1997) (to be codified at 21 C.F.R. pts. 170, 184, 186, 570) ("[A] manufacturer may market a substance that the manufacturer determines is GRAS without informing the agency."); Statement of Policy: Foods Derived from New Plant Varieties, 57 Fed. Reg. at 22,989.

[40] *See* Steven A. Benner & A. Michael Sismour, *Synthetic Biology*, 6 NATURE REVS. 533, 533 (2005); *see also* Paras Chopra & Akhil Kamma, *Engineering Life Through Synthetic Biology*, 6 IN SILICO BIOLOGY 401, 403 (2006) ("[W]e define Synthetic Biology as a field involving synthesis of novel biological systems which are not generally found in nature."); Haseloff & Ajioka, *supra* note 5, at 1 ("Synthetic biology . . . seeks to employ engineering principles to reprogramme living systems.").

[41] *See* Philip Ball, *Starting from Scratch*, 431 NATURE 624, 625 (2004).

is at an early stage of development, with most research involving biological materials isolated from cells within laboratory settings.[42] Scientists, however, are in the process of establishing standards for assembling DNA-based biological circuits and a legal framework for sharing standardized parts.[43]

The ability to design new biological materials and chemicals through synthetic biology is expected to lead to the development of new drugs, drug delivery systems, biofuels, biosensors, and microbes that can digest wastes and environmental toxins.[44] But synthesized forms of life also could have unpredictable effects if they are released or escape into the environment, and synthetic biology could even be deployed for nefarious purposes by bioterrorists.[45] Such concerns are magnified by the possibility that synthetic biology experiments could become quite easy to conduct. The fear is that relatively untrained people may someday be able to use widely available materials to assemble their own custom-built life forms.[46]

In a recent survey, researchers found that the large majority of the general public is in favor of greater public disclosure and government regulation of synthetic biology research.[47] No regulations specific to synthetic biology, however, are yet in place.[48] Rather, synthetic biology processes and

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42 *See id.* at 626; W. Wayt Gibbs, *Synthetic Life*, SCI. AM., May 2004, at 75, 81.

43 *See* Haseloff & Ajioka, *supra* note 5, at 1; Jon Mooallem, *Do-It-Yourself Genetic Engineering*, N.Y. TIMES, Feb. 14, 2010 (Magazine), at 40 (describing efforts to build an open-source genetic library containing more than 5000 BioBricks).

44 *See* Ball, *supra* note 41, at 625; Gibbs, *supra* note 42, at 75, 81; Steven Yearley, *The Ethical Landscape: Identifying the Right Way to Think About the Ethical and Societal Aspects of Synthetic Biology Research and Products*, 6 J. ROYAL SOC'Y INTERFACE S559 (2009), *available at* http://rsif.royalsocietypublishing.org/content/early/2009/05/12/rsif.2009.0055.focus.full.pdf+html.

45 *See* Yearley, *supra* note 44, at 3.

46 *See id.* at 2 (comparing potential for informal experiments in synthetic biology to breakthroughs in information technology initiated in garages and other informal settings); Gibbs, *supra* note 42, at 81 (noting ease of access to information and synthetic DNA); Mooallem, *supra* note 43, at 40 (noting some synthetic biologists' goal of enabling "the most sophisticated custom-built life forms [to] be assembled from a catalog of standardized parts").

47 *See* HART RESEARCH ASSOCS., NANOTECHNOLOGY, SYNTHETIC BIOLOGY, & PUBLIC OPINION 16 (2009), *available at* http://www.nanotechproject.org/process/assets/files/8286/nano_synbio.pdf (reporting that 90% of respondents believed that "more should be done to inform the public about this research" and that 66% of respondents agreed that the "federal government should regulate this research").

48 *See* MICHAEL RODEMEYER, WOODROW WILSON INT'L CTR. FOR SCHOLARS, NEW LIFE, OLD BOTTLES: REGULATING FIRST-GENERATION PRODUCTS OF SYNTHETIC BIOLOGY 7-8 (2009), *available at* http://www.synbioproject.org/process/assets/files/6319/nano_synbio2_electronic_final.pdf (noting that scientists have started to raise concerns about risks of synthetic biology research).

products are likely to be governed by the same haphazard scheme that applies to conventional genetic engineering.[49]

2. Nanotechnology

Nanotechnology, the science of manipulating matter at the nanometer scale,[50] is an emerging suite of technologies with an even broader, more mind-boggling array of potential applications than genetic engineering. Hailed by some as the foundation for the "next industrial revolution," nanotechnology offers the promise of precise manufacturing methods that are cleaner and more efficient than the relatively crude, top-down methods that dominate industrial processes today.[51] Nanomaterials are already being used in medical diagnosis and treatment, cosmetics, sunscreens, stain-resistant clothing, paints and coatings, electronics, tires, tennis rackets, and foods. In addition to these existing applications, researchers also expect to produce new materials that can be used as drug delivery devices and chemical catalysts or incorporated into self-cleaning surfaces and other products.[52] With widespread commercialization on the near horizon, regulators are just beginning to grapple with the question of how to respond to nanotechnology's potential health and environmental effects.

Developing an approach for safe management of nanotechnology without unduly impeding innovation presents a daunting challenge. The health and environmental risks of nanotechnology are highly uncertain. Materials produced via nanotechnology are of interest because they often behave very differently from the conventional materials from which they are

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[49] *See id.* at 29-45 (reviewing potential applicability of existing laws and guidelines to synthetic biology); *id.* at 9 (characterizing new legislation specific to synthetic biology as "an unlikely option").

[50] THE ROYAL SOC'Y & THE ROYAL ACAD. OF ENG'G, NANOSCIENCE AND NANOTECHNOLOGIES: OPPORTUNITIES AND UNCERTAINTIES 5 (2004) [hereinafter ROYAL SOC'Y REPORT], *available at* http://www.nanotec.org.uk/finalReport.htm.

[51] *See* Press Release, The White House Office of the Press Secretary, National Nanotechnology Initiative: Leading to the Next Industrial Revolution (Jan. 21, 2000), http://clinton4.nara.gov/WH/New/html/20000121_4.html; *see also* Barbara Karn, *Overview of Environmental Applications and Implications*, *in* NANOTECHNOLOGY AND THE ENVIRONMENT 2, 3 (Barbara Karn et al. eds., 2005). Top-down manufacturing involves the processing of a larger sample of raw material into a smaller item for use, whereas bottom-up methods build things on an atom-by-atom or molecule-by-molecule basis. *See* Glenn Harlan Reynolds, *Nanotechnology and Regulatory Policy: Three Futures*, 17 HARV. J. L. & TECH. 179, 181 (2003).

[52] Albert C. Lin, *Size Matters: Regulating Nanotechnology*, 31 HARV. ENVTL. L. REV. 349, 353-54 (2007).

derived. Their small size, chemical composition, surface structure, solubility, shape, and aggregative tendencies also may make them particularly detrimental when taken into the body.[53] Nonetheless, health and environmental effects of exposure to nanomaterials have not been extensively studied, and the expected proliferation of nanotechnology materials and applications complicates efforts to draw generalizations regarding any such effects.[54] Future advances in nanotechnology could incorporate self-replicating capacities—that is, processing and fabrication mechanisms that would enable nanomachines to reproduce themselves in a process akin to cell division—and may pose even greater and more unpredictable threats.[55]

According to one estimate, over one thousand nanotechnology consumer products have now been brought to market,[56] yet most Americans remain unfamiliar with nanotechnology.[57] Once people are given basic information about it, they tend to form positive impressions and to expect that its benefits will outweigh its risks.[58] Nonetheless, surveys also suggest serious public concerns about unknown effects and

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[53] *See, e.g.*, ROYAL SOC'Y REPORT, *supra* note 50, at 41-42; Andre Nel et al., *Toxic Potential of Materials at the Nanolevel*, 311 SCIENCE 622 (2006); Günter Oberdörster et al., *Nanotoxicology: An Emerging Discipline Evolving from Studies of Ultrafine Particles*, 113 ENVTL. HEALTH PERSP. 823, 824 (2005); Craig A. Poland et al., *Carbon Nanotubes Introduced into the Abdominal Cavity of Mice Show Asbestos-Like Pathogenicity in a Pilot Study*, 3 NATURE NANOTECHNOLOGY 423 (2008); Benedicte Trouiller et al., *Titanium Dioxide Nanoparticles Induce DNA Damage and Genetic Instability* In Vivo *in Mice*, 69 CANCER RESEARCH 8784 (2009) (finding systemic genetic damage in mice exposed to titanium dioxide nanoparticles—which are widely used in cosmetics, sunscreen, and paint).

[54] *See* ENVTL. PROT. AGENCY, EPA 620/K-09/011, NANOMATERIAL RESEARCH STRATEGY 11, 20-21 (2009), *available at* http://www.epa.gov/nanoscience (listed in "Resources" menu on right-hand side) (discussing issues to be researched); Lin, *supra* note 52, at 357-58.

[55] *See* Lin, *supra* note 52, at 355.

[56] *Analysis*, PROJECT ON EMERGING NANOTECHNOLOGIES, http://www.nanotechproject.org/inventories/consumer/analysis_draft (last visited Jan. 19, 2011) ("As of August 25, 2009, the nanotechnology consumer products inventory contains 1015 products or product lines.").

[57] NAT'L SCI. FOUND., *supra* note 25, at 7-38; DAN M. KAHAN ET AL., WOODROW WILSON INT'L CTR. FOR SCHOLARS, NANOTECHNOLOGY RISK PERCEPTIONS: THE INFLUENCE OF AFFECT AND VALUES 2 (2007), *available at* http://www.nanotechproject.org/process/assets/files/2710/164_nanotechriskperceptions_dankahan.pdf (reporting that 81% of survey respondents had heard "nothing at all" or "just a little" about nanotechnology prior to survey).

[58] *See* JANE MACOUBRIE, WOODROW WILSON INT'L CTR. FOR SCHOLARS, INFORMED PUBLIC PERCEPTIONS OF NANOTECHNOLOGY AND TRUST IN GOVERNMENT 8 (2005), *available at* http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Reports/Nanotechnologies/Nanotech_0905.pdf. Subsequent research suggests that reactions to nanotechnology depend in large part on a person's underlying values. *See* KAHAN ET AL., *supra* note 57, at 1-2, 5.

potential health risks.[59] Participants in various studies have expressed not only a desire for information about such risks, but also a desire to be involved in decision making regarding nanotechnology development.[60]

Despite public unease, nanotechnology remains largely unregulated. The EPA has the authority to regulate chemical substances under the Toxic Substances Control Act (TSCA). However, the agency has taken the position that the molecular identity of a substance, and not particle size, is critical to determining whether a nanoscale substance is a new material subject to the new chemical reporting requirements found in section 5 of TSCA.[61] Thus, even though a nanoscale substance "may differ in certain physical and/or chemical properties resulting from the difference in particle size, the EPA considers the two forms to be the same chemical substance because they have the same molecular identity."[62] The EPA does possess authority under section 6 of TSCA to regulate substances classified as "existing" rather than "new."[63] That provision, however, places such heavy evidentiary burdens on the EPA that it is unlikely to be applied to nanoscale substances.[64] The EPA has expressed its intent to develop rules under TSCA to gather information on nanomaterial production, use, and exposure and to develop health and safety data.[65] Yet regulators face daunting challenges in terms of the present lack of such data and the expanding universe of nanoscale substances found in research labs and the marketplace.[66]

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[59] *See* MACOUBRIE, *supra* note 58, at 10.

[60] *See id.* at 3-4, 14; PATRICK HAMLETT ET AL., NATIONAL CITIZENS' TECHNOLOGY FORUM: NANOTECHNOLOGIES AND HUMAN ENHANCEMENT 2 (2008), *available at* http://cns.asu.edu/cns-library/type/?action=getfile&file=88&section=lib.

[61] ENVTL. PROT. AGENCY, TSCA INVENTORY STATUS OF NANOSCALE SUBSTANCES—GENERAL APPROACH 2 (2008), *available at* http://www.epa.gov/oppt/nano/nmsp-inventorypaper2008.pdf. Certain classes of nanoscale substances, such as pesticides containing nanomaterials, may be subject to regulation under narrower statutes, including the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). *See* Lynn L. Bergeson, *FIFRA Scientific Advisory Panel Considers Nanosilver*, 39 ENVTL. L. REP. 11, 143-44 (2009); Lin, *supra* note 52, at 371-74.

[62] ENVTL. PROT. AGENCY, *supra* note 61, at 6.

[63] 15 U.S.C. § 2605 (2006).

[64] *See* J. CLARENCE DAVIES, WOODROW WILSON INT'L CTR. FOR SCHOLARS, OVERSIGHT OF NEXT GENERATION NANOTECHNOLOGY 21 (2009), *available at* http://207.58.186.238/process/assets/files/7316/pen-18.pdf; Lin, *supra* note 52, at 362-67 (discussing difficulties in applying TSCA).

[65] Sixty-Fourth Report of the TSCA Interagency Testing Committee to the Administrator of the EPA, 74 Fed. Reg. 38,878, 38,880 (Aug. 4, 2009).

[66] *See* Lin, *supra* note 52, at 357-61.

3. Geoengineering

Geoengineering refers to proposed planetary-scale techniques to limit or avoid the consequences of higher greenhouse gas (GHG) concentrations in the Earth's atmosphere.[67] These techniques include the release of aerosols into the stratosphere to block a substantial fraction of the sun's radiation and the mass fertilization of the oceans to increase the uptake of carbon by phytoplankton.[68] The term usually does not encompass techniques for reducing GHG emissions or capturing such emissions before they are released into the environment (such as carbon capture and sequestration), nor is it typically applied to tree-planting and other efforts to enhance terrestrial carbon sinks.[69] Unlike these more conventional approaches, geoengineering proposals are highly controversial because of the grave risks and uncertainties involved, as well as the grand scale of any contemplated operations to deliberately alter the Earth's climate system. Geoengineering efforts could have unexpected effects on precipitation patterns, atmospheric quality, and ecosystems, and such efforts would not necessarily address all the effects of increased GHG concentrations.[70]

Although reducing GHG emissions is widely recognized as the preferred means of responding to climate change, geoengineering has attracted growing attention as a possible emergency or complementary response, given the difficulties, complexities, and costs involved in reducing emissions directly.[71] At present, no full-scale geoengineering projects have been undertaken, and research efforts have primarily involved computer modeling rather than field testing.[72] Yet even experimentation with geoengineering techniques could create a

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[67] *See* Albert C. Lin, *Geoengineering Governance*, 8 ISSUES LEGAL SCHOLARSHIP 1, 2 (2009), *available at* http://www.bepress.com/ils/vol8/iss3/art2.

[68] *Id.* at 3-7.

[69] David W. Keith, *Geoengineering*, 409 NATURE 420, 420 (2001).

[70] Lin, *supra* note 67, at 4-6. The release of aerosols to block some of the sun's radiation, for instance, would do nothing to counter the increasing acidity of the oceans caused by higher levels of carbon dioxide in the atmosphere.

[71] *See, e.g.*, Alan Carlin, *Why a Different Approach Is Required If Global Climate Change Is to Be Controlled Efficiently or Even at All*, 32 WM. & MARY ENVTL. L. & POL'Y REV. 685, 706-07 (2008); P.J. Crutzen, *Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?*, 77 CLIMATIC CHANGE 211, 217 (2006) (expressing preference for emissions reductions, but suggesting that alternative responses be researched).

[72] *See* U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-10-903, CLIMATE CHANGE: A COORDINATED STRATEGY COULD FOCUS FEDERAL GEOENGINEERING RESEARCH AND INFORM GOVERNANCE EFFORTS 13-15 (2010).

moral hazard that would undermine emissions-reduction efforts and could foster the growth of interest groups that would have strong incentives to advocate for geoengineering projects.[73] Because such experiments may affect millions of people—if not every person on Earth—experimentation on even a modest scale would demand some form of informed consent.[74] No international treaty directly governs geoengineering at this time.[75] Ideally, if a full-blown geoengineering project were carried out, it would take place as a cooperative effort following a consensual decision-making process by the international community. The logistics and costs of some geoengineering techniques, however, are such that a single nation—or even a wealthy individual—could undertake a geoengineering project on its own.[76] Finding ways to manage the uncertainties raised by various geoengineering techniques while accounting for ethical concerns poses yet another daunting technology challenge for society.

B. Goals in Technology Management

1. Assessment

Because emerging technologies can drastically transform society and the environment, such technologies should be carefully assessed and subjected to public input. Technological change does not occur on its own. Technology management is possible because technologies are a product of human discovery, choice, and policy. This is not to suggest, however, that society can exert complete control over technologies and their effects. Even technologies that are subject to close scrutiny before and during implementation can give rise to unanticipated consequences. Once introduced, technologies enter into a dynamic relationship with societies that shapes and transforms societies themselves.[77] Accordingly, the formative and continuing influence of technologies on

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[73] David R. Morrow et al., *Toward Ethical Norms and Institutions for Climate Engineering Research*, 4 ENVTL. RES. LETTERS 45,106, § 3 (2009).

[74] *See id.* at 4-5 (discussing principle of respect for individual autonomy as basis for requirement to obtain consent for geoengineering experiments).

[75] *See* Daniel Bodansky, *May We Engineer the Climate?*, 33 CLIMATIC CHANGE 309, 311-16 (1996).

[76] *See* Lin, *supra* note 67, at 12.

[77] *See* COLLINGRIDGE, *supra* note 1, at 19 (discussing "the dilemma of control" of technology).

humans and the environment generates a need for robust mechanisms to predict, evaluate, and govern their development. This is especially so in light of the often irreversible and global nature of the hazards associated with modern technologies.[78]

The practice of technology assessment came into being in the 1970s with the ambition of analyzing the full range of consequences—social, environmental, and otherwise—that a technology may have.[79] Technology assessment was to involve objective analysis drawing on the natural and social sciences; subjective value judgments were to be left to democratically elected officials.[80] A fundamental premise underlying technology assessment was that through the application of comprehensive rationality, society could effectively manage—if not solve—many of its problems.[81] Although this faith in rational analysis and control was overly optimistic, the underlying motivation—to develop and manage technologies in a more deliberate manner—remains critical. In recent years, refinements to technology assessment have sought ways to incorporate public values into the assessment process and to encourage greater self-reflection within the scientific community.[82]

Risk assessment is a central component of technology assessment.[83] Risk assessment seeks to produce quantitative estimates of the probability and magnitude of potential harms from an activity or occurrence—such as the adoption of a new technology—based on available data.[84] The risk assessment process generates a risk characterization, which ideally includes a range of estimates to quantify identified hazards, as well as a discussion of the degree of confidence with which estimates are made, uncertainties in the analysis, and underlying assumptions.[85]

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[78] *Cf.* BECK, *supra* note 4, at 21-23 (describing distinct characteristics of modern risks).

[79] *See* Laurence H. Tribe, *Technology Assessment and the Fourth Discontinuity: The Limits of Instrumental Rationality*, 46 S. CAL. L. REV. 617, 621-22 (1973); *see also* RON WESTRUM, TECHNOLOGIES & SOCIETY: THE SHAPING OF PEOPLE AND THINGS 325 (1991) (defining technology assessment as "an attempt to predict what the effects of a technology will be if it is implemented").

[80] *See* Norman J. Vig & Herbert Paschen, *Technology Assessment in Comparative Perspective*, *in* PARLIAMENTS AND TECHNOLOGY: THE DEVELOPMENT OF TECHNOLOGY ASSESSMENT IN EUROPE 3, 8 (Norman J. Vig & Herbert Paschen eds., 2000).

[81] *See* Tribe, *supra* note 79, at 622.

[82] *See infra* Part III.

[83] *See* Frank Fischer, *Are Scientists Irrational? Risk Assessment in Practical Reason*, *in* SCIENCE AND CITIZENS: GLOBALIZATION & THE CHALLENGE OF ENGAGEMENT 54, 54 (Melissa Leach et al. eds., 2005).

[84] *See* HOLLY DOREMUS ET AL., ENVIRONMENTAL POLICY LAW 395 (5th ed. 2008).

[85] *See id.* at 398.

Technology assessment can involve other predictive techniques in addition to risk assessment, such as mathematical modeling, technological forecasting, and scenario building.[86]

These technical analyses, of course, cannot provide all the data necessary to make perfectly informed decisions. Even the relatively well-developed practice of risk assessment has significant limitations. Although risk assessment can identify some hazards as well as options for coping with them,[87] risk quantification often involves rough probability estimates whose confidence intervals may vary by a degree of magnitude or more.[88] There are some hazards, moreover, that simply cannot be quantified because of insufficient data or the inability to perform useful experiments.[89] And beyond that, there are other hazards—"unknown unknowns"—that cannot be identified because of limitations in understanding, stochastic processes, and the inherent unpredictability of interactions between society and technology.[90] Decisions regarding technology must take these uncertainties into account, even if they cannot be well articulated.

These points lead to a more fundamental criticism of risk assessment. The quantitative analyses fostered by risk assessments tend to crowd out from debate qualitative factors and other pertinent considerations that are less amenable to scientific characterization.[91] In other words, the "technical rationality" of risk assessment, which focuses on scientific measurement, can differ quite dramatically from the "cultural

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[86] *See* WESTRUM, *supra* note 79, at 328-29.

[87] *See* E. J. Woodhouse, *Toward More Usable Technology Policy Analyses*, *in* SCIENCE, TECHNOLOGY, AND POLITICS: POLICY ANALYSIS IN CONGRESS 13, 16 (Gary C. Bryner ed., 1992).

[88] NAT'L RESEARCH COUNCIL, SCIENCE AND JUDGMENT IN RISK ASSESSMENT 165-66 (1994) (criticizing overreliance on "artificially precise single estimates of risk").

[89] *Id.* at 165 (discussing sources of uncertainty); Albert C. Lin, *The Unifying Role of Harm in Environmental Law*, 2006 WIS. L. REV. 897, 968-69.

[90] Elizabeth Fisher et al., *Understanding Environmental Models in Their Legal and Regulatory Context*, 22 J. ENVTL. L. 251, 271-72 (2010) ("[I]rreducible ignorance about a complex system will always be an inherent feature of modeling."); Helena Valve & Jussi Kauppila, *Enacting Closure in the Environmental Control of Genetically Modified Organisms*, 20 J. ENVTL. L. 339, 353 (2008).

[91] *See* BECK, *supra* note 4, at 71 (criticizing assumption of scientific rationality "that so long as risks are not recognized scientifically, *they do not exist*—at least not legally, medically, technologically, or socially, and they are thus not prevented, treated or compensated for"); SHEILA JASANOFF, DESIGNS ON NATURE: SCIENCE AND DEMOCRACY IN EUROPE AND THE UNITED STATES 265 (2005) ("In the United States, a preferred method for displaying objectivity in public decisions has been to clothe the reasons for allocative choices as far as possible in the language of numbers.").

rationality" often reflected in the attitudes of nonscientists.[92] Cultural rationality considers not only quantifiable effects in the decision-making process, but also contextual factors such as personal experience and social values.[93] While thorough technical analysis is important to sound technology management, finding ways to incorporate social values and other concerns is critical as well.

2. Public Participation

In its conventional form, technology assessment assumed a linear model of technology development in which basic research is followed by applied research and then production. Technology assessment focused on objective analysis of virtually finished technologies and did little to involve the public or to account for the values that society holds. Technology assessors, in other words, were in charge of providing technical knowledge, leaving the judgments and decisions based on that knowledge to others.[94]

Public participation in technology management is essential as a matter of democratic governance and as a means of informing substantive choices with public values.[95] Because technology shapes both society as a whole and the lives of each individual, the public must have a meaningful role in technology management, including technology assessment, as a matter of basic autonomy.[96] Under the traditional liberal view

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[92] *See* MARY DOUGLAS & AARON WILDAVSKY, RISK AND CULTURE: AN ESSAY ON THE SELECTION OF TECHNOLOGICAL AND ENVIRONMENTAL DANGERS 7-9 (1982); Fischer, *supra* note 83, at 55; Alonzo Plough & Sheldon Krimsky, *The Emergence of Risk Communication Studies: Social and Political Context*, 12 SCI., TECH., & HUMAN VALUES, Summer/Fall 1987, at 4, 8-9.

[93] Fischer, *supra* note 83, at 55; Plough & Krimsky, *supra* note 92, at 8-9.

[94] *See* MARK B. BROWN, SCIENCE IN DEMOCRACY: EXPERTISE, INSTITUTIONS, AND REPRESENTATION 86 (2009) (discussing approaches "in which experts determine the means of politics and citizens choose the ends" or that make "a parallel distinction between technical knowledge and political judgment"); *see also* Tribe, *supra* note 79, at 657-59 (discussing potential for "our technological choices [to] define what we become").

[95] *See* Andy Stirling, *Opening Up or Closing Down? Analysis, Participation and Power in the Social Appraisal of Technology*, *in* SCIENCE AND CITIZENS: GLOBALIZATION & THE CHALLENGE OF ENGAGEMENT, *supra* note 83, at 218, 220 (discussing rationales for public participation in science and technology matters).

[96] Kristin S. Shrader-Frechette, *Evaluating the Expertise of Experts*, 6 RISK: HEALTH, SAFETY & ENV'T 115, 117 (1995) (arguing for right of public participation in risk assessments because they have consequences for public welfare). As Andy Stirling has pointed out, the narrow involvement and "opaque technical procedures associated with expert analysis . . . conflict with Habermasian principles of 'ideal speech' [and] with Rawlsian notions of 'public reason.'" Stirling, *supra* note 95, at 221. *See generally* JÜRGEN HABERMAS, THE THEORY OF COMMUNICATIVE ACTION VOL. 1: REASON AND THE

of democratic processes, citizens hold natural rights, including a right of liberty and a right against excessive government control.[97] Public participation in technology development, assessment, and management is rooted in the protection and expression of these rights and derives support from general normative principles of social justice, democratic emancipation, and equality.[98] The contemporary democratic notions of public reason and ideal speech reflect the principle that policy makers should engage as broad an array of societal interests as possible.[99] Such engagement seeks to ensure that policy decisions affecting society as a whole—including those decisions regarding new technologies—are not reduced to the agenda of dominant political and economic institutions or a small group of elites. Greater public participation in such decisions reflects a commitment to the empowerment of citizens, no matter how ideologically or economically marginalized they might be.[100]

Integrating public participation into decisions about technology is also critical because public values anchor relevant societal preferences about technology in terms of tolerance for risk and uncertainty, desire for change, and willingness to

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RATIONALIZATION OF SOCIETY 25 (Thomas McCarthy trans., 1984); John Rawls, *The Idea of Public Reason Revisited*, 64 U. CHI. L. REV. 765 (1997).

[97] *See* JOHN LOCKE, TWO TREATISES OF GOVERNMENT 374-81 (Peter Laslett ed., Cambridge Univ. Press 1968) (1689) (discussing how assertion of negative rights brings with it protection from government intervention and an opportunity for individuals to assert private interests, which aggregate to inform the political will and impact administrative institutions).

[98] *See* JÜRGEN HABERMAS, THE POSTNATIONAL CONSTELLATION: POLITICAL ESSAYS 62-69, 76, 110-18 (Max Pensky ed. & trans., MIT Press 2001) (1998) (contrasting liberal and conservative notions of democratic politics and the effects of globalization, and providing normative justifications for public participation in decision making).

[99] *See* JÜRGEN HABERMAS, THE THEORY OF COMMUNICATIVE ACTION 86, 98-101, 363-73 (Thomas McCarthy trans., Polity 1987) (1984) (discussing an "ideal speech situation" in which every competent actor has a right to participate in societal discourse and is permitted to introduce any assertion into that discourse without hindrance or coercion); JOHN RAWLS, POLITICAL LIBERALISM 7, 9, 214-20 (1996) (propounding "public reason" as an ideal mode of deliberation for issues of public concern in a pluralist society, and contending that an "overlapping consensus" can be reached through recognition of a core set of substantive moral principles common to a "reasonable" fragment of society). *See generally* JÜRGEN HABERMAS, LEGITIMATION CRISIS 17-24, 95-111 (Thomas McCarthy trans., Beacon Press 1975) (advocating a universal pragmatism requiring preacknowledgment among participants that the existence of an ideal speech situation is possible, and that participants engaged in competent discourse can reach a consensus that is representative of the general will of the public).

[100] *See* JOHN RAWLS, A THEORY OF JUSTICE 106-14 (1971) (arguing that "fair and equal opportunity" requires that positions of influence be distributed based on merit and that all persons have reasonable opportunity to acquire the skills upon which merits are assessed).

make tradeoffs. In theory, decisions by elected officials in a representative democracy can reflect public values and concerns. Indeed, the assumption that political representatives possess a particular competence to make decisions that are in the public interest and consistent with public values is foundational to the liberal theory of representative government.[101] With respect to technology matters, however, representation of the public is often inadequate. Factors that systematically bias the lawmaking process against focusing on the potential risks of new technologies include the pressures on politicians to respond to current headlines and regular election cycles rather than on issues with distant time horizons, such as the health or environmental consequences of emerging technologies;[102] the specialized body of knowledge necessary to understand science and technology issues—a knowledge that few legislators possess;[103] and the substantial uncertainty surrounding health and environmental risks, which generally leads to inaction rather than the adoption of precautionary measures.[104] In addition, public choice theory predicts that legislatures will cater to the interests of an organized and vocal minority at the expense of a majority whose interests are more diffuse.[105] This dynamic is especially pronounced with emerging technologies, which tend to have vigorous corporate or institutional advocates but little opposition from a public largely unaware of a technology or its potential risks.[106] These

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[101] *See* BROWN, *supra* note 94, at 78-85; THE FEDERALIST No. 63, at 320 (James Madison) (Ian Shapiro ed., 2009) (noting "how salutary will be the interference of some temperate and respectable body of citizens, in order to check" the potential for misguided and rash decisions by the general public).

[102] *See* Gary C. Bryner, *Science, Technology, and Policy Analysis in Congress: An Introduction*, *in* SCIENCE, TECHNOLOGY, AND POLITICS, *supra* note 87, at 3, 6; L. Christopher Plein & David J. Webber, *The Role of Technology Assessment in Congressional Consideration of Biotechnology*, *in* SCIENCE, TECHNOLOGY, AND POLITICS, *supra* note 87, at 123, 147.

[103] *See* M. Granger Morgan & Jon M. Peha, *Analysis, Governance, and the Need for Better Institutional Arrangements*, *in* SCIENCE AND TECHNOLOGY ADVICE FOR CONGRESS 3, 11 (M. Granger Morgan & Jon M. Peha eds., 2003); Michael Rodemeyer, *Back to the Future: Revisiting OTA Ten Years Later*, *in* MICHAEL RODEMEYER ET AL., WOODROW WILSON INT'L CTR. FOR SCHOLARS, THE FUTURE OF TECHNOLOGY ASSESSMENT 3 (2005), *available at* http://www.wilsoncenter.org/news/docs/techassessment.pdf.

[104] *See* Lin, *supra* note 89, at 898-99.

[105] Cynthia R. Farina & Jeffrey J. Rachlinski, *Foreword: Post-Public Choice?*, 87 CORNELL L. REV. 267, 268 (2002).

[106] *See* ALLAN SCHNAIBERG, THE ENVIRONMENT: FROM SURPLUS TO SCARCITY 131 (1980) (contending that "[i]n the absence of a public sector debate over 'science policy,' piecemeal decisions made in the U.S. continuously supported an exponential increase in energy-intensive production" and in production of synthetic and novel

obstacles to the expression of public values through ordinary channels of representation are an important justification for more direct public participation in technology matters.

When the government does attend to the hazards of emerging technologies, the empirical techniques of risk assessment and risk-benefit analysis often dominate its policies to the detriment of public preferences.[107] Technically, *risk management*—the values-driven, policy-making process of deciding how to respond to risk data—can be distinguished from *risk assessment*—the expert-driven process of identifying, analyzing, and quantifying risks.[108] Notwithstanding this distinction, risk managers often defer to the quantitative data of risk assessment (or the lack of such data) in deciding how to respond to the hazards posed by new technologies.[109] Because empirical techniques fail to account for all of the factors relevant to social decision making, however, an approach centered on quantifiable risks elides difficult, values-based choices under a veneer of objectivity. Indeed, the act of engaging in the discourse of risk through the risk management process reinforces the sometimes dubious assumption that risk can be understood, measured, and managed effectively.[110]

Moreover, although risk assessment is often characterized as a purely scientific, values-free undertaking, the values of those performing a risk assessment necessarily influence the assumptions made, inferences drawn, and calculations performed in an assessment.[111] Questions regarding how to deal with the uncertainty inherent in risk assessment are questions of policy,

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chemicals). The widespread adoption of GMOs despite public opposition or ignorance illustrates this tendency. *See supra* Part I.A.1.a.

[107] *See* Fischer, *supra* note 83, at 54; Brian Wynne, *Risk and Environment as Legitimatory Discourses of Technology: Reflexivity Inside Out?*, 50 CURRENT SOCIOLOGY 459, 460 (2002) ("Risk has become the form of public discourse through which public meaning is given to technology and innovation . . . .").

[108] *See* DOREMUS ET AL., *supra* note 84, at 395-99.

[109] *See* Melissa Leach & Ian Scoones, *Science and Citizenship in Global Context*, *in* SCIENCE AND CITIZENS, *supra* note 83 at 15, 22 ("Liberal understandings of citizenship . . . hold faith in the modern state's expertise [and] defer decisions to elected elites, who historically have been highly reliant on accredited scientific and technocratic expertise.").

[110] *See* Wynne, *supra* note 107, at 468-69; *see also* Baruch Fischhoff, *Public Values in Risk Research*, 545 ANNALS AM. ACAD. POL. & SOC. SCI. 75, 77 (1996) (describing origins of risk research in industry efforts to manage internal affairs and suggesting that risk analysis continues to "address[] the problems and speak[] the language of industry").

[111] Shrader-Frechette, *supra* note 96, at 116; *see also* BECK, *supra* note 4, at 29 ("[O]ne must assume an *ethical point of view* in order to discuss risks meaningfully at all."); Paul Slovic, *The Risk Game*, 86 J. HAZARDOUS MATERIALS 17, 19-22 (2001).

not of science.[112] Emerging technologies tend to involve highly uncertain consequences.[113] When decisions must be made in the face of uncertainty, reliance on beliefs, values, and experiences is rational and appropriate.[114] Incorporating greater public participation and discourse into technology assessment, including risk assessment, is essential for this reason. Lay citizens may have limited knowledge on technical matters,[115] but nonetheless, they can dialogue effectively with experts and play an important role in bringing public values into the technology assessment process.[116] Ultimately, rational debate involving citizens, experts, and other interested parties can lead to an expansion of relevant considerations or to the development of consensus regarding the common good.[117]

In sum, technology assessment, once characterized as the exclusive province of experts, can and should be opened up to public participation. Part III.B considers ways of doing so in greater detail. This broader and more open assessment process should occur *during* rather than *after* technology development, bringing public concerns into research decisions and technology design.[118] Ongoing public participation can make the decision

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[112] Shrader-Frechette, *supra* note 96, at 117; *see also* Stirling, *supra* note 95, at 224 (noting that "probability theory underlies the entire activity of risk assessment, yet its applicability is seriously constrained by recognition of intractable states of uncertainty, indeterminacy and ignorance").

[113] COLLINGRIDGE, *supra* note 1, at 16-18 (discussing the broad and unexpected consequences of the popularization of the automobile).

[114] LARS KLÜVER ET AL., EUROPEAN PARTICIPATORY TECHNOLOGY ASSESSMENT 173 (2000), *available at* http://www.tekno.dk/pdf/projekter/europta_Report.pdf (observing that "the inequalities and uncertainties attached to scientific-technological developments . . . call[] for more inclusive social policy analysis and decision-making"); Fischer, *supra* note 83, at 59 ("As the move to basic cultural orientations is in significant part a response to the fact that science cannot supply the needed answers, it is thus anything but irrational."); Shrader-Frechette, *supra* note 96, at 117 (discussing reasons supporting the public's right to participate in risk assessments).

[115] Laypersons nevertheless can contribute greater breadth and depth of knowledge to objective assessments. *See* Stirling, *supra* note 95, at 222.

[116] BROWN, *supra* note 94, at 233-34 (contending that laypersons possess a range of experiences and knowledge, as well as an ability to become knowledgeable through deliberation); Daniel Lee Kleinman, *Beyond the Science Wars: Contemplating the Democratization of Science*, 17 POLITICS & LIFE SCI. 133, 139 (1998) (discussing examples of informed participation by laypersons in scientific and technical dialogues).

[117] *See* HABERMAS, *supra* note 96, at 25; Leach & Scoones, *supra* note 109, at 24. Care must be taken in the design of participatory processes, however, to guard against the potential for simply reinforcing existing power relations. *See* Leach & Scoones, *supra* note 109, at 25; Stirling, *supra* note 95, at 225-26 (discussing framing effects on technical analyses and participatory deliberation).

[118] *See* Frank Fischer, *Technological Deliberation in a Democratic Society: The Case for Participatory Inquiry*, 26 SCI. & PUB. POL'Y 294, 297 (1999).

process more democratic, improve the quality of analysis, and facilitate public acceptance of resulting decisions.[119]

II. OUR EXPERIENCE WITH TECHNOLOGY ASSESSMENT AND PUBLIC INVOLVEMENT

Efforts in the United States to evaluate and manage technology's consequences fall into three basic categories: formal technology assessment, which was practiced previously by the Office of Technology Assessment (OTA) and is practiced occasionally by other government agencies; environmental impact assessment, which focuses on the potential health and environmental effects of policy choices and serves as a form of technology assessment when applied to technology policy decisions; and nonregulatory assessment, which is carried out by technology developers themselves or by other nongovernmental entities. This Part surveys these efforts and finds that they fall short in advancing the assessment and public participatory functions that technology assessment should achieve.

A. *Formal Technology Assessment*

1. The Office of Technology Assessment

The very concept of technology assessment arose as "critical voices within science began calling for preassessment before committing society to innovations such as supersonic transport and nuclear weapons."[120] In the United States, Congress created the OTA in 1972 to provide objective analyses to inform policy decisions on technology matters. While the OTA earned the respect of many for the quality of its work on issues ranging from the feasibility of the Star Wars missile defense system to the cleanup of nuclear-weapons laboratories,[121] it ultimately played no more than a modest role in influencing how the United States handles new technologies.

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[119] NAT'L RESEARCH COUNCIL, UNDERSTANDING RISK: INFORMING DECISIONS IN A DEMOCRATIC SOCIETY 23-24 (Paul C. Stern & Harvey V. Fineberg eds., 1996); Slovic, *supra* note 111, at 23.

[120] CLINTON S. ANDREWS, HUMBLE ANALYSIS: THE PRACTICE OF JOINT FACT-FINDING 48 (2002).

[121] *See* Robert M. Margolis & David H. Guston, *The Origins, Accomplishments, and Demise of the Office of Technology Assessment*, *in* SCIENCE AND TECHNOLOGY ADVICE FOR CONGRESS, *supra* note 103, at 53, 66; Paul Recer, *Office of Technology Assessment Killed*, ST. PAUL PIONEER PRESS (Minn.), Sept. 27, 1995, at 2C.

The OTA's official mission was "to provide early indications of the probable beneficial and adverse impacts of the applications of technology and to develop other coordinate information which may assist the Congress."[122] In creating the OTA, Congress was motivated by several factors, including its need for an independent source of technical information and objective analyses, a rise in government spending on scientific research and development, and growing social unease regarding the negative effects of science and technology.[123] The statute establishing the OTA declared, "As technology continues to change and expand rapidly, its applications are . . . increasingly extensive, pervasive, and critical in their impact, beneficial and adverse, on the natural and social environment."[124]

Although the OTA originally was to perform long-term analyses regarding entire technological fields, technology assessment at the OTA was fairly constricted in practice. Congress's requests for information tended to emphasize specific subjects and to require rapid responses, and short-term, narrow policy analyses eventually came to dominate the OTA's workload.[125] In an effort to maintain credibility and avoid alienating members of Congress who might disagree with its conclusions,[126] the agency generally avoided making recommendations and instead confined itself to surveys of the technical components of the issues.[127] More significantly, technology assessment came to be understood not as a process, but as a product—the reports generated by the OTA.[128] These developments are not surprising given the OTA's subordinate role and limited mandate. The OTA had no regulatory power and, in practice, limited advisory power. Nevertheless, the OTA never fulfilled its potential to study technological applications

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[122] 2 U.S.C. § 472(c) (2006).

[123] *See* Margolis & Guston, *supra* note 121, at 53, 54-57.

[124] 2 U.S.C. § 471(a) (2006).

[125] *See* Margolis & Guston, *supra* note 121, at 59; Vig & Paschen, *supra* note 80, at 9.

[126] *See* Nancy Carson, *Process, Prescience, and Pragmatism: The Office of Technology Assessment*, *in* ORGANIZATIONS FOR POLICY ANALYSIS: HELPING GOVERNMENT THINK 236, 243 (Carol H. Weiss ed., 1992).

[127] ANDREWS, *supra* note 120, at 181 ("OTA consciously chose to minimize normative content in its work. Instead, OTA strove to make its work useful to decision makers representing diverse perspectives, and who often did not share the same values."); Carson, *supra* note 126, at 249; Daniel Sarewitz, *This Won't Hurt a Bit: Assessing and Governing Rapidly Advancing Technologies in a Democracy*, *in* RODEMEYER ET AL., *supra* note 103; SCLOVE, *supra* note 1, at 10-11.

[128] *See* Margolis & Guston, *supra* note 121, at 61-62, 71-72; Vig & Paschen, *supra* note 80, at 9-10.

and consequences in a broader and more systematic way, or to transform how Congress and society relate to technology.[129]

Ultimately, the OTA was unable to maintain the difficult balancing act of providing objective information to Congress while securing political support for its continued existence. Shortly after the Republican takeover of Congress in 1994, Congress eliminated the agency as part of the new majority's promise to enact its "Contract with America."[130] Among the primary reasons given for eliminating the agency was its slow pace relative to Congress's timetables.[131] Because the OTA's assessments could take one to two years to complete, they often failed to meet the more pressing political needs of Congress's members.[132] Also contributing to the OTA's elimination were accusations of bias—whether justified or not—often from parties whose interests were undermined by the OTA's reports.[133]

America's experiment with formal technology assessment through an agency dedicated to the task came to an end with the demise of the OTA. The need for technology assessment and deliberate management of technology, however, has not diminished. To the contrary, that need is ever greater in an era of rapidly developing technologies with widespread and long-lasting impacts.

2. Institutional Alternatives to the OTA

In the OTA's absence, a number of governmental institutions do have some capacity to carry out technology assessment. Such assessments, however, have been performed on a narrow and ad hoc basis, if at all, and their scope and impact have been limited by traditional and legal constraints.[134]

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[129] Vig & Paschen, *supra* note 80, at 9 ("[OTA's] reports gradually shifted from technology-driven topics to more problem-focused studies that were less distinctive from traditional policy analyses than originally envisaged.").

[130] *See* Margolis & Guston, *supra* note 121, at 70-71. Congress eliminated all funding for OTA, but did not formally abolish the agency. Legislative Branch Appropriations Act, 1996, Pub. L. No. 104-53, 109 Stat. 468 (1995). Subsequent efforts to revive the agency with renewed funding have not succeeded. *See* Bruce L.R. Smith & Jeffrey K. Stine, *Technical Advice for Congress: Past Trends and Present Obstacles*, *in* SCIENCE AND TECHNOLOGY ADVICE FOR CONGRESS, *supra* note 103, at 23, 40.

[131] *See* Margolis & Guston, *supra* note 121, at 71.

[132] *See id.*

[133] Jon M. Peha, *Science and Technology Advice for Congress: Past, Present, and Future*, 24 RENEWABLE RESOURCES J. 19, 20-21 (2006).

[134] *Id.* at 22 (noting that existing "organizations already have their own missions and their own cultures, which are not perfectly compatible with the technology assessment process").

The Government Accountability Office (GAO), for example, has conducted a few technology assessment pilot projects at Congress's direction.[135] For the most part, these analyses have focused on narrow topics related to counterterrorism, such as the use of biometric technologies for border security and the use of cybersecurity measures to protect infrastructure.[136] The credibility of the GAO's work, moreover, is open to question, given the agency's traditional expertise in performing audits, the past use of its reports for partisan political objectives, and its limited experience with predictive assessments.[137] Another institution, the Office of Science and Technology Policy (OSTP), advises the president on science and technology issues. The OSTP has the authority to initiate studies, including technology assessments, to resolve critical and emerging problems.[138] With its fairly limited resources, however, the OSTP has focused primarily on serving as a channel of communication between the president and the scientific community and on coordinating science and technology policy across the federal government.[139] Lastly, the National Research Council (NRC) issues reports on science and technology topics in response to congressional and agency requests.[140] These

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[135] GENEVIEVE J. KNEZO, CONG. RESEARCH SERV., RS21586, TECHNOLOGY ASSESSMENT IN CONGRESS: HISTORY AND LEGISLATIVE OPTIONS 4-6 (2005), *available at* http://www.fas.org/sgp/crs/misc/RS21586.pdf.

[136] *See id.; e.g.*, GEN. ACCOUNTING OFFICE, GAO-04-321, TECHNOLOGY ASSESSMENT: CYBERSECURITY FOR CRITICAL INFRASTRUCTURE PROTECTION (2004), *available at* http://www.gao.gov/new.items/d04321.pdf; GEN. ACCOUNTING OFFICE, GAO-03-174, TECHNOLOGY ASSESSMENT: USING BIOMETRICS FOR BORDER SECURITY (2002), *available at* http://www.gao.gov/new.items/d03174.pdf.

[137] *See* Christopher T. Hill, *An Expanded Analytical Capability in the Congressional Research Service, the General Accounting Office, or the Congressional Budget Office*, *in* SCIENCE AND TECHNOLOGY ADVICE FOR CONGRESS, *supra* note 103, at 106, 115-16; *Hearing on 2011 Appropriations Before the Subcomm. on Legislative Branch Appropriations of the H. Comm. on Appropriations*, 111th Cong. 4 (2010) (written testimony of Francesca T. Grifo, Senior Scientist with the Union of Concerned Scientists), *available at* http://www.ucsusa.org/scientific_integrity/solutions/big_picture_solutions/restoring-the-ota.html.

[138] 42 U.S.C. § 6614(a)(5) (2006). The OSTP's statutory mission is to serve "as a source of scientific and technological analysis and judgment for the President with respect to major policies, plans, and programs of the Federal Government." *Id.* § 6614(a).

[139] DEBORAH D. STINE, CONG. RESEARCH SERV., RL 34736, THE PRESIDENT'S OFFICE OF SCIENCE AND TECHNOLOGY POLICY (OSTP): ISSUES FOR CONGRESS 5-7, 24-25 (2009), *available at* http://ncseonline.org/NLE/CRSreports/09Mar/RL34736.pdf. The OSTP receives external advice from the President's Council of Advisors on Science and Technology (PCAST), whose members are selected from industry, education, research, and other nongovernmental institutions. PCAST conducts workshops and convenes technical advisory groups that could carry out technology assessment functions. *Id.* at 9, 24-25.

[140] *See* John Ahearne & Peter Blair, *Expanded Use of the National Academies*, *in* SCIENCE AND TECHNOLOGY ADVICE FOR CONGRESS, *supra* note 103, at 118, 118-19,

authoritative reports are prepared by committees of leading experts through an extensive, peer-reviewed study process.[141] While well respected, these reports require significant time and resources to produce,[142] and they are designed to generate expert recommendations in response to specific questions rather than to raise issues independently, address broader policy questions, or foster public debate.[143]

B. NEPA as Technology Assessment

Technology assessment can also take place in the context of environmental impact assessment. In particular, the National Environmental Policy Act (NEPA) requires federal agencies to assess the environmental impacts of their actions.[144] To the extent that such actions involve the development or implementation of technology, NEPA analysis could serve as a form of technology assessment with respect to health and environmental effects. The federal government's extensive involvement or potential involvement in sponsoring research and development,[145] establishing technology policies, and regulating technology's adverse impacts underscores NEPA's prospective reach. Nevertheless, narrow interpretations of NEPA by agencies and courts have minimized the statute's value in technology assessment.

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123. The NRC is the operating arm of the National Academies, which include the National Academy of Sciences, a private, nonprofit organization established by congressional charter. *Id.* at 118.

[141] *Id.* at 120; DEBORAH D. STINE, CONG. RESEARCH SERV., RL 34454, SCIENCE AND TECHNOLOGY POLICYMAKING: A PRIMER 29 (2009), *available at* http://www.fas.org/sgp/crs/misc/RL34454.pdf.

[142] Ahearne & Blair, *supra* note 140, at 121; Rodemeyer, *supra* note 103, at 3-4 (noting that the peer-review process ensures quality and balance, but takes time).

[143] SCLOVE, *supra* note 1, at 19; Rodemeyer, *supra* note 103, at 4 ("[T]he Academies have only a limited independent capacity to raise questions that no political sponsor has an incentive to want answered."). In addition, the National Academy of Sciences, and thus the NRC, is a private institution that can reject Congressional requests. *Hearing on 2011 Amendments*, *supra* note 137, at 4.

[144] 42 U.S.C. § 4332(2)(C) (2006).

[145] The 2009 federal budget, for instance, provided $1.5 billion to support nanotechnology research and development through thirteen federal agencies. EXEC. OFFICE OF THE PRESIDENT, NATIONAL NANOTECHNOLOGY INITIATIVE, FY 2009 BUDGET AND HIGHLIGHTS (2008), *available at* http://www.nano.gov/NNI_FY09_budget_summary.pdf.

1. The Basics of NEPA

Sometimes described as a "Magna Carta" for the environment,[146] NEPA was enacted with the purpose of integrating environmental values into national policies and planning processes. The central requirement of NEPA is the environmental impact statement (EIS), a document that must be prepared for "major [f]ederal actions significantly affecting the quality of the human environment."[147] In the EIS, the government must describe the environmental impacts of the proposed action, including unavoidable adverse effects; alternatives to the proposed action; and any irreversible and irretrievable commitments of resources that the proposed action would involve.[148] As the Supreme Court has recognized, the purpose of the EIS requirement is to

> ensure[] that the agency, in reaching its decision, will have available, and will carefully consider, detailed information concerning significant environmental impacts; it also guarantees that the relevant information will be made available to the larger audience that may also play a role in both the decisionmaking process and the implementation of that decision.[149]

But NEPA was not meant merely to impose a requirement on agencies to document environmental impacts. Rather, NEPA was intended to achieve a wholesale reorientation of the government's actions and values, sensitizing agencies to environmental values.[150] Through programmatic EISs, for example, agencies could evaluate the environmental impacts of entire programs—not just individual

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146 DANIEL R. MANDELKER, NEPA LAW AND LITIGATION § 1:1 (2d ed. 1992); *see also* 40 C.F.R. § 1500.1(a) (2010) (characterizing NEPA as "our basic national charter for protection of the environment").

147 42 U.S.C. § 4332(2)(C).

148 *Id.*

149 Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 349 (1989). For federal actions deemed to have less than significant impacts on the environment, agencies still must make a more limited inquiry known as an environmental assessment (EA), which identifies the environmental consequences of a proposed action and documents the agency's determination that those consequences do not reach the statutory threshold of significance. 40 C.F.R. §§ 1501.4, 1508.9 (2010).

150 MATTHEW J. LINDSTROM & ZACHARY A. SMITH, THE NATIONAL ENVIRONMENTAL POLICY ACT: JUDICIAL MISCONSTRUCTION, LEGISLATIVE INDIFFERENCE & EXECUTIVE NEGLECT 8 (2001). Senator Henry Jackson, NEPA's main sponsor, touted NEPA as "the most important and far-reaching environmental and conservation measure ever enacted by the Congress." 115 CONG. REC. 40,416 (1969).

projects—and reorient the programs in light of those impacts.[151] But whether NEPA created any enforceable substantive obligations, including any that might apply to new technologies, was not obvious on the face of the statute.[152]

2. Implementing and Interpreting NEPA

The implementation of NEPA by federal agencies and its interpretation by the courts have not fulfilled the promise embodied in the statute's broad language and legislative history. NEPA's primary mandate, the requirement that federal agencies prepare an EIS, has turned out to be less powerful than some of its crafters might have envisioned. First, that mandate applies only to "major federal actions";[153] it does not apply to private actions or to most legislation enacted by Congress.[154] Moreover, the Supreme Court has construed the EIS requirement to impose only a procedural duty, rather than to mandate substantive results.[155] This does not necessarily make the EIS requirement a toothless one; federal agencies, having analyzed the environmental ramifications of their decisions, may make decisions that are more environmentally sound than they would be otherwise. Nonetheless, agencies sometimes view the EIS as little more than a paper-pushing hurdle to be overcome before the agency can proceed with a predetermined course of action.[156]

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[151] 40 C.F.R. § 1502.20 (2010) (encouraging practice of tiering analysis of site-specific actions to broader EISs).

[152] *See, e.g.*, Denis Binder, *NEPA, NIMBYs and New Technology*, 25 LAND & WATER L. REV. 11 (1990) (arguing that "those seeking to obstruct the application of new technology and processes [through NEPA] will have to find a new legal tool to rely on" because agencies need only make requisite disclosures). At the time of NEPA's enactment, many legislators viewed the statute as an uncontroversial way to burnish their environmental credentials, and the legislation received relatively little attention from lobbyists and interest groups. *See* RICHARD A. LIROFF, A NATIONAL POLICY FOR THE ENVIRONMENT: NEPA AND ITS AFTERMATH 10-11 (1976).

[153] 42 U.S.C. § 4332(2)(C).

[154] Although the EIS requirement applies to agency "proposals for legislation," *id.*, the Council on Environmental Quality (CEQ) regulations define legislation narrowly to include only legislative proposals "developed by or with the significant cooperation and support of a Federal agency" and to exclude requests for appropriations, 40 C.F.R. § 1508.17 (2010).

[155] Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 353 (1989) (noting that NEPA relies "on procedural mechanisms—as opposed to substantive, result-based standards"); Vt. Yankee Nuclear Power Corp. v. Natural Res. Def. Council, Inc., 435 U.S. 519, 558 (1978) ("NEPA does set forth significant substantive goals for the Nation, but its mandate to the agencies is essentially procedural.").

[156] COUNCIL ON ENVTL. QUALITY, THE NATIONAL ENVIRONMENTAL POLICY ACT: A STUDY OF ITS EFFECTIVENESS AFTER TWENTY-FIVE YEARS iii (1997) ("Some [agencies]

Supreme Court decisions have played a critical role in constraining the statute's reach and effectiveness. First, in *Aberdeen & Rockfish R.R. v. Students Challenging Regulatory Agency Procedures* (*SCRAP*), the Court rejected the argument that an EIS must be integrated into an agency's decision-making process from the outset.[157] Rather, only when an agency "makes a recommendation or report on a proposal for federal action" must an EIS be prepared.[158] Then, in *Kleppe v. Sierra Club*, the Court held that the mere contemplation of a project and preparation of a study do not trigger the obligation to prepare a programmatic EIS absent a proposal for federal action.[159] Together, *SCRAP* and *Kleppe* allowed agencies to defer analyzing environmental impacts until after the overall policy-making process is well underway.[160] Although these decisions did not specifically involve new technologies, the negative implications for attempting to situate an effective technology assessment function within NEPA analyses are clear.

The Court made its most direct pronouncements regarding the analyses of new technologies in *Vermont Yankee Nuclear Power Corp. v. Natural Resource Defense Council, Inc.*[161] In this challenge to licenses granted to specific nuclear facilities, the Court rejected the notion that NEPA provides a forum for the wholesale consideration of the desirability of new technologies:

> Nuclear energy may some day be a cheap, safe source of power or it may not. But Congress has made a choice to at least try nuclear energy, establishing a reasonable review process in which courts are

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act as if the [EIS] . . . is an end in itself, rather than a tool to enhance and improve decision-making."); Bradley C. Karkkainen, *Toward a Smarter NEPA: Monitoring and Managing Government's Environmental Performance*, 102 COLUM. L. REV. 903, 922-23 (2002) (contending that NEPA documentation is often "overstuff[ed] . . . with information from every available source, regardless of its quality," but that little evidence suggests that the information discussed in such documentation actually influences agency decisionmaking).

157 Aberdeen & Rockfish R.R. v. Students Challenging Regulatory Agency Procedures (SCRAP), 422 U.S. 289, 320-22 (1975).

158 *Id.* at 320.

159 Kleppe v. Sierra Club, 427 U.S. 390, 406 (1976).

160 As various critics have pointed out, the preparation of environmental documentation in practice often remains separated from much of the decision-making process. Daniel A. Farber, *Adaptation Planning and Climate Impact Assessments: Learning from NEPA's Flaws*, 39 ENVTL. L. REP. 10,605, 10,609 (2009) ("[T]he EIS process has been isolated from agencies' primary decision processes."); Oliver A. Houck, *How'd We Get Divorced?: The Curious Case of NEPA and Planning*, 39 ENVTL. L. REP. 10,645, 10,648-49 (2009).

161 Vt. Yankee Nuclear Power Corp. v. Natural Res. Def. Council, Inc., 435 U.S. 519 (1978).

> to play only a limited role. The fundamental policy questions appropriately resolved in Congress and in the state legislatures are *not* subject to reexamination in the federal courts . . . . NEPA does set forth significant substantive goals for the Nation, but its mandate to the agencies is essentially procedural.[162]

In *Vermont Yankee*, the Court correctly recognized that NEPA's obligations do not apply to legislative decisions, and that democratic institutions—Congress and state legislatures—should resolve fundamental policy questions. Nonetheless, the Court failed to appreciate NEPA's potential to inform those decisions and to guide agencies in the exercise of policy-making authority delegated to them. Rather, the Court continued to steer agencies towards a narrow, technocratic approach to NEPA analysis that has prevailed ever since. The Court's opinions have not ended the preparation of programmatic EISs—the sort of overarching analyses that could serve as a useful instrument of technology assessment—but many agencies try to defer programmatic assessments as long as possible if not all together.[163] Ultimately, NEPA has not lived up to its potential to serve as a tool for analyzing the environmental risks and uncertainties of major policy developments, including the development of new technologies. In the words of Oliver Houck: "NEPA is missing the point. It is producing lots of little statements on highway segments, timber sales, and other foregone conclusions; it isn't even present, much less effective, when the major decisions . . . are made."[164]

C. Nonregulatory Mechanisms

Technology assessments can be carried out not only by government agencies, but also by those directly engaged in technology development. Researchers, for example, may look to personal morals and professional ethics to guide, shape, and constrain their research pursuits. The predominant model of technology development, however, is for scientists and engineers to conceive of technology instrumentally; that is, as value free and neutral, not based on morals.[165] This model does

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[162] *Id.* at 557-58.

[163] Jon C. Cooper, *Broad Programmatic, Policy and Planning Assessments Under the National Environmental Policy Act and Similar Devices: A Quiet Revolution in an Approach to Environmental Considerations*, 11 PACE ENVTL. L. REV. 89, 117-18 (1993).

[164] Houck, *supra* note 160, at 10,648.

[165] *See* Erik Fisher & Clark A. Miller, *Collaborative Practices for Contextualizing the Engineering Laboratory*, *in* ENGINEERING IN CONTEXT 369, 376 (S.H. Christensen et

not encourage researchers to consider their work in a broader context or in an ethically critical way.[166] Furthermore, researchers—including those in academic institutions—face strong economic incentives to tailor their efforts in favor of technologies with marketing potential.[167]

Firms may have a stronger incentive to carry out health and safety assessments with respect to the technologies they develop and market, given their greater potential for legal liability or reputational damage. Indeed, corporations can and often do go beyond what the law explicitly requires.[168] With respect to new technologies, corporations might, for example, assess potential social and environmental consequences with an unusual degree of care, reach out to the public to try to identify and address externalities, or choose not to develop hazardous applications despite their potential for profit.[169] Such actions need not be altruistic; they can translate into lower costs, reduced risk exposure, the avoidance of onerous regulation, and an ability to command higher product premiums.[170] In addition, companies may lose their social

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al. eds., 2009); Byron Newberry, *Are Engineers Instrumentalists?*, 29 TECH. SOC'Y 107, 109, 112-13 (2007); *see also* J. Britt Holbrook, *Assessing the Science-Society Relation: The Case of the US National Science Foundation's Second Merit Review Criterion*, 27 TECH. SOC'Y 437, 438 (2005) (describing institutionalization of Vannevar Bush's views regarding the degree of autonomy necessary for basic scientific research).

[166] *See* Fisher & Miller, *supra* note 165, at 376.

[167] *See* JASANOFF, *supra* note 91, at 235-36 (describing the effect of industrial funding of university research and of the Bayh-Dole Act, which allowed recipients of federal grants to patent discoveries funded by federal money).

[168] The concept of corporate social responsibility (CSR), broadly defined, refers to socially beneficial decisions and actions by firms that go beyond the legal minimum. Paul R. Portney, *Corporate Social Responsibility: An Economic and Public Policy Perspective*, *in* ENVIRONMENTAL PROTECTION AND THE SOCIAL RESPONSIBILITY OF FIRMS 107, 108 (Bruce L. Hay et al. eds., 2005). A narrower definition of CSR focuses on profit-sacrificing behavior by businesses acting under moral or social obligations. *Summary of Discussion on Corporate Social Responsibility and Economics*, *in* ENVIRONMENTAL PROTECTION AND THE SOCIAL RESPONSIBILITY OF FIRMS, *supra*, at 145, 146. Whether such activity—which is arguably contrary to the very purpose of private corporations and to the interest of shareholders—exists at a meaningful level is a matter of debate. *Id.* at 146 (noting that a number of discussion participants "were quick to point out that profit-sacrificing behavior is exceedingly difficult to observe").

[169] Daniel C. Esty, *On Portney's Complaint: Reconceptualizing Corporate Social Responsibility*, *in* ENVIRONMENTAL PROTECTION AND THE SOCIAL RESPONSIBILITY OF FIRMS, *supra* note 168, at 137, 141-42 (suggesting ways in which CSR could be reconceptualized).

[170] Forest L. Reinhardt, *Environmental Protection and the Social Responsibility of Firms: Perspectives from the Business Literature*, *in* ENVIRONMENTAL PROTECTION AND THE SOCIAL RESPONSIBILITY OF FIRMS, *supra* note 168, at 151, 159-68. In addition, banks and insurance companies often have an interest in overseeing the risk exposure of their clients. *See* DANIEL C. ESTY & ANDREW S. WINSTON, GREEN TO GOLD: HOW SMART COMPANIES USE ENVIRONMENTAL STRATEGY TO INNOVATE, CREATE

license to operate should they fail to live up to social expectations about environmental behavior.[171] Whatever their motivation may be, however, it is unlikely that firms' efforts along these lines will lead to adequate technology assessment. Firms are profit-seeking entities whose ultimate obligations are to their shareholders.[172] Often, the analyses that firms undertake are internal assessments that focus on marketing potential and do little to inform policymakers or to involve the public in fundamental decisions about technology.[173]

III. REVITALIZING TECHNOLOGY ASSESSMENT

As a society, we are not doing enough to assess the health and environmental effects of emerging technologies or to involve the public and incorporate its values into decisions about technology. This Part considers options for addressing these inadequacies: reconstituting the OTA or reinvigorating NEPA practice would be relatively simple ways to increase our understanding of new technologies, but achieving substantive change and meaningful participation will require more radical reforms.

A. Resurrecting Old Tools

1. Reconstituting the OTA

Reestablishing the Office of Technology Assessment would be a modest first step towards building societal capacity to make

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VALUE, AND BUILD COMPETITIVE ADVANTAGE 11, 94-95 (2006). The re-insurance company Swiss Re, for instance, has been active in drawing attention to potential risks of nanoparticles. *See* Arie Rip, *Nanoscience and Nanotechnologies: Bridging Gaps Through Constructive Technology Assessment*, *in* HANDBOOK OF TRANSDISCIPLINARY RESEARCH 145, 152 (G. Hirsch Hadorn et al. eds., 2008). If the uncertainties associated with the adverse consequences of a technology are too great, however, insurers may exert little constraint on the behavior of firms.

171 *See* ESTY & WINSTON, *supra* note 170, at 12.

172 Portney, *supra* note 168, at 126 (contending that almost all examples of CSR are profit-motivated); *see also Summary of Discussion*, *supra* note 168, at 146 (recounting the view that avoiding tort liability and influencing future regulation explain beyond-compliance behavior).

173 David J. Vogel, *Opportunities for and Limitations of Corporate Environmentalism*, *in* ENVIRONMENTAL PROTECTION AND THE SOCIAL RESPONSIBILITY OF FIRMS, *supra* note 168, at 197, 199 (contending that as an empirical matter, self-regulation is inadequate to address adverse effects and arguing that government regulation is responsible for almost all improvements in environmental quality).

informed and accountable decisions about new technologies.[174] Such a move would address Congress's ongoing need for informed and objective advice on scientific and technical matters.[175] Indeed, since the OTA's elimination, several proposals have been made either to create a new technology assessment office or to authorize funding to reestablish the OTA.[176] None of these proposals has gained much traction, however.[177] Few current members of Congress have had any experience with the OTA,[178] and a truly independent technology assessment office might raise broad, long-range concerns that are not politically expedient to address.[179] In addition, while the reestablishment of the OTA could contribute to better informed policymaking, an OTA patterned after its predecessor would not generate new information on the hazards of emerging technologies, nor bring about broad and meaningful public engagement. Revitalized technology assessment should involve not only an OTA-like institution, but also other measures that can bring about dynamic and participatory technology management, as Part III.B will explain.

2. Recapturing NEPA's Lost Potential

Another modest step towards improving societal decision making on technology would involve more robust implementation of NEPA. As discussed above, current implementation of NEPA entails little wholesale consideration of technological developments and their ramifications for society and the environment.[180] Overall, NEPA practice is a pale shadow of the possibilities embodied in the statute.[181] The implementation of NEPA can better reflect the technological concerns that motivated its enactment. Changes in

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[174] *See* Daryl E. Chubin, *Filling the Policy Vacuum Created by OTA's Demise*, ISSUES SCI. & TECH., Winter 2000-2001, at 31; Gerald L. Epstein & Ashton B. Carter, *A Dedicated Organization in Congress*, *in* SCIENCE AND TECHNOLOGY ADVICE FOR CONGRESS, *supra* note 103, at 157.

[175] *See* Rodemeyer, *supra* note 103, at 3.

[176] KNEZO, *supra* note 135, at 2-4.

[177] *See id.* at 4; SCLOVE, *supra* note 1, at 18.

[178] Rodemeyer, *supra* note 103, at 4.

[179] *Id.* at 4-5.

[180] *See supra* Part II.B.2.

[181] This view is shared by numerous critics. *See, e.g.*, Farber, *supra* note 160, at 10,605 (identifying "shortcomings of current environmental assessment procedures"); Bradley C. Karkkainen, *Whither NEPA?*, 12 N.Y.U. ENVTL. L.J. 333 (2004) (discussing potential NEPA reforms); Daniel R. Mandelker, *Thoughts on NEPA at 40*, 39 ENVTL. L. REP. 10,640 (2009) (arguing for greater application of NEPA analyses to agency programs and not just individual projects).

implementation would provide only a partial response to emerging technologies, however, since NEPA's scope is confined to those developments that involve federal agency action.

a. NEPA's Concern with Technology

NEPA requires agencies to adopt a long-term orientation that considers environmental consequences for present as well as future generations.[182] Thus, EISs must discuss "the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity," as well as "any irreversible and irretrievable commitments of resources."[183] Moreover, the statute explicitly recognizes "the profound influences of . . . new and expanding technological advances" on the environment and declares a purpose of "promot[ing] efforts which will prevent or eliminate damage to the environment and biosphere."[184] The statute's objective of transforming the relationship between human activity, productivity, and long-term effects on the environment necessarily requires new ways of analyzing and managing modern technologies.

NEPA's legislative history singles out the dangers posed by technology even more explicitly. In floor debates and committee hearings, various congressmen expressed their individual concerns about the damage done by technology to the environment.[185] Quoting an editorial that appeared in the *New York Times*, the House committee responsible for considering NEPA legislation singled out technology as the greatest threat to the environment:

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[182] JAMES MCELFISH & ELISSA PARKER, REDISCOVERING THE NATIONAL ENVIRONMENTAL POLICY ACT: BACK TO THE FUTURE 12-15 (1995).

[183] 42 U.S.C. § 4332(2)(C) (2006).

[184] *Id.* §§ 4321, 4331(a).

[185] On the House side, see, for example, 115 CONG. REC. 26,569, 26,577 (1969) (statement of Rep. Farbstein) ("For too long, we have stressed technological progress, assuming that our environment could take care of itself."); *id.* at 26,583 (statement of Rep. Donohue) ("Every school child and adult in this country is well aware that the advance of modern technology, however great its material benefits, has been unrestrained in its accompanying afflictions upon us through byproducts that increasingly poison our air and pollute our waters."); *id.* (statement of Rep. Cohelan) ("We are fast becoming a victim of our own technology and progress."). On the Senate side, see, for example, 115 CONG. REG. 40,415, 40,417 (1969) (statement of Sen. Jackson) ("While the National Environmental Policy Act of 1969 is not a panacea, it is a starting point. A great deal more, however, remains to be done . . . if mankind and human dignity are not to be ground down in the years ahead by the expansive and impersonal technology modern science has created.").

> By land, sea, and air, the enemies of man's survival relentlessly press their attack. The most dangerous of all these enemies is man's own undirected technology. The radioactive poisons from nuclear tests, the runoff into rivers of nitrogen fertilizers, the smog from automobiles, the pesticides in the food chains, and the destruction of topsoil by strip mining are examples of the failure to foresee and control the untoward consequences of modern technology.[186]

The counterpart committee in the Senate likewise recognized the dangers posed by "[a] growing technological power which is far outstripping man's capacity to understand and ability to control its impact on the environment."[187] Indeed, an influential report prepared for that committee singled out technology as the root cause of the perceived environmental crisis:

> Technology . . . has greatly increased environmental stress in general. The net result has been enormously increased demands upon the environment in addition to the increase in population. . . . Unfortunately, our productive technology has been accompanied by side effects which we did not forsee [sic]. . . . It is now becoming apparent that we cannot continue to enjoy the benefits of our productive economy unless we bring its harmful side effects under control.[188]

That report called for a "pay-as-you-go" approach to the development and use of technology, under which the cost of environmental harms would be internalized, with "provision . . . made for the protection, restoration, replacement, or rehabilitation of elements in the environment before, or at the time, these resources are used."[189]

b. *The EIS as Technology Assessment*

The effects of emerging technologies were undoubtedly an important motivation behind NEPA's enactment, and the EIS was to be a central tool for identifying and better managing these effects.[190] Indeed, early judicial interpretations

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[186] H.R. REP. NO. 91-378, at 3 (1969).

[187] S. REP. NO. 91-296, at 6 (1969); *see also id.* at 8 (identifying population growth and "advancing technological developments which have enlarged man's capacity to effectuate environmental change" as primary causes for environmental concern).

[188] 115 CONG. REC. 29,069 (1969) (reprinting *A National Policy for the Environment: A Report on the Need for a National Policy for the Environment, Special Report to the S. Comm. on Interior and Insular Affairs*, 90th Cong. (1968)).

[189] *Id.* at 29,070.

[190] *See* LYNTON KEITH CALDWELL, THE NATIONAL ENVIRONMENTAL POLICY ACT: AN AGENDA FOR THE FUTURE xvi (1998) ("[T]he procedural requirements of NEPA are intended to force attention to the policies declared in the Statement of Purpose . . . and in Title I (Section 101) of the Act.").

of NEPA recognized the potential for EISs to enable a proactive and comprehensive approach to new technologies. The opinion of the United States Court of Appeals for the District of Columbia Circuit in *Scientists' Institute for Public Information, Inc. v. Atomic Energy Commission* (*SIPI*),[191] issued three years after NEPA's enactment, exemplifies this approach. In *SIPI*, the plaintiffs alleged that the Atomic Energy Commission (AEC) was required to prepare an EIS for its breeder reactor program, which was in the research and development stage. The AEC conceded that an EIS would be required before the construction of individual breeder reactors and facilities, but argued that no NEPA analysis was required for the research and development program as a whole.

Recognizing "NEPA's objective of controlling the impact of technology on the environment," the court rejected the AEC's arguments.[192] The court explained that environmental analysis of the research and development program was necessary because the program would facilitate subsequent use of breeder reactor technology by private parties that in turn would affect the environment.[193] In the words of the court: "[T]he decisions our society makes today as to the direction of research and development will determine what technologies are available 10, 20, or 30 years hence . . . ."[194] As the court further noted, consideration of a technology's environmental impacts would be far more meaningful at the research and development stage than at the point when specific facilities are being constructed.[195] Once a specific project is in mind, substantial resources have already been committed in developing the technology, and vested interests in that technology—perhaps including the regulatory agency itself—will undermine the objectivity of the decision-making process.[196] Only a programmatic EIS at the research and development stage, in the court's view, would fulfill NEPA's purpose of informing Congress, the executive branch, and the public of the

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[191] Scientists' Inst. for Pub. Info., Inc. v. Atomic Energy Comm'n (SIPI), 481 F.2d 1079 (D.C. Cir. 1973).

[192] *Id.* at 1089.

[193] *Id.* at 1088-89.

[194] *Id.* at 1090.

[195] *Id.* at 1089-90.

[196] *Id.* at 1089-90 & n.43.

environmental effects of new technologies in such a way as to ensure informed decision making.[197]

The D.C. Circuit's interpretation of the EIS obligation in *SIPI* is consistent with NEPA's text as well as its implementing regulations, and it hews closely to Congress's purpose in enacting NEPA. As noted earlier, an EIS must be prepared for "major [f]ederal actions significantly affecting the quality of the human environment."[198] NEPA does not define major federal actions, but federal decisions and policies regarding new technologies often do have a significant effect on environmental quality. Moreover, NEPA's regulations provide that major federal action, "include[s] new and continuing activities, including projects and programs entirely or partly financed, assisted, conducted, regulated, or approved by federal agencies."[199] The regulations also indicate that agencies may conduct their evaluations "[b]y stage of technological development including federal or federally assisted research, development or demonstration programs for new technologies which, if applied, could significantly affect the quality of the human environment."[200]

In light of these regulations and the *SIPI* analysis, federal research funding decisions should be treated as major federal actions subject to NEPA. The nature of the environmental analysis and level of detail will depend on the stage of technological research and development. Where the funding is for basic research in a new field, discussion of possible environmental effects may necessarily be general and couched in uncertainty. Where research involves technology nearing commercialization or deployment, however, a more thorough and specific environmental analysis should be prepared.[201] The EIS,

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[197] *Id.* at 1089-90.

[198] 42 U.S.C. § 4332(2)(C) (2006).

[199] 40 C.F.R. § 1508.18(a) (2010). One category of major federal actions identified in the regulation includes "[a]doption of programs, such as a group of concerted actions to implement a specific policy or plan." *Id.* § 1508.18(b)(3).

[200] *Id.* § 1502.4.

[201] *Cf. SIPI*, 481 F.2d at 1094 (discussing factors to be considered by an agency in deciding when to draft an EIS for a technology development program, including likelihood that technology will prove commercially feasible, and availability of meaningful information on effects of technology and alternatives). Post-*SIPI* decisions have declined to mandate preparation of programmatic impact statements for unrelated research projects, but environmental analyses of individual projects continue to be required. *See, e.g.*, Found. on Econ. Trends v. Lyng, 817 F.2d 882, 884-85 (D.C. Cir. 1987) (no programmatic EIS required for "diverse and discrete" animal productivity research projects); Found. on Econ. Trends v. Heckler, 756 F.2d 143 (D.C.

in sum, is a well-suited vehicle for agencies to study and consider an emerging technology's potential consequences—environmental or otherwise—during developmental stages and before a technology has become entrenched.

c. *Other NEPA Tools for Technology Assessment*

NEPA also contains other mechanisms that could be used to better manage new technologies. Section 101 of the statute expresses Congress's concern about the environmental impacts of new technologies and suggests the dawning of a more thoughtful approach to the relationship between technology and the environment:

> The Congress, recognizing the profound impact of man's activity on the interrelations of all components of the natural environment, particularly the profound influences of . . . *new and expanding technological advances* . . . , declares that it is the continuing policy of the Federal Government . . . to use all practicable means and measures . . . to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans.[202]

Section 101 is a policy statement that the Supreme Court has held to be judicially unenforceable.[203] Nonetheless, the provision represents a broad, government-wide commitment to address the potential dangers of new technologies[204] and thereby to foster "conditions under which man and nature can exist in productive harmony." Section 101, in other words, provides federal agencies with direction and authority to make discretionary choices—

Cir. 1985) (vacating lower court injunction of GMO deliberate release experiments in absence of programmatic EIS).

[202] 42 U.S.C. § 4331(a) (2006) (emphasis added).

[203] Strycker's Bay Neighborhood Council, Inc. v. Karlen, 444 U.S. 223, 227-28 (1980) (stressing that NEPA does establish substantive goals, but imposes only procedural duties). *Compare* Holly Doremus, *Constitutive Law and Environmental Policy*, 22 STAN. ENVTL. L.J. 295, 355 (2003) ("Section 101 of NEPA declares a national policy for the environment in a provision with no direct regulatory force."), *and* Michael C. Blumm, *The National Environmental Policy Act at Twenty*, 20 ENVTL. L. 447, 450 (1990) (noting Supreme Court decisions "ignoring the high-minded aspirations contained in section 101 and apparently considering NEPA to require just the paperwork and public disclosure specified in section 102"), *with* Nicholas C. Yost, *NEPA's Promise—Partially Fulfilled*, 20 ENVTL. L. 533, 548 (1990) ("[S]ection 102(1) . . . explicitly requires all agencies to follow the policies of section 101. That is a substantive requirement, and it is appropriately judicially enforceable.").

[204] CALDWELL, *supra* note 190, at xvi ("NEPA, as policy, is a 'template' against which decisions affecting the environment can be compared for consistency with its declared principles.").

whether in determining technology priorities, funding research and development, or investigating potential technology hazards—in ways that reduce environmental damage, mitigate harmful effects, and maximize public input.[205]

NEPA also established an institutional mechanism to study and address the environmental ramifications of new technologies: the Council on Environmental Quality (CEQ). The CEQ's functions were to include the gathering of information concerning conditions and trends in environmental quality—including the environmental impacts of new technologies.[206] Congressional debate on the provisions to establish the CEQ repeatedly emphasized the authority of the CEQ to conduct research and provide policy advice regarding the long-overlooked environmental consequences of new technologies.[207] And shortly after NEPA's enactment, President Nixon issued an executive order directing the CEQ to "[f]oster investigations, studies, surveys, research, and analyses relating to (i) ecological systems and environmental quality, (ii) the impact of new and changing technologies thereon, and (iii) means of preventing or reducing adverse effects from such technologies."[208] Just as the Council of Economic Advisers provides economic advice to the president, the CEQ would oversee the execution of NEPA's declared policy of protecting

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[205] *See* Philip Michael Ferester, *Revitalizing the National Environmental Policy Act: Substantive Law Adaptations from NEPA's Progeny*, 16 HARV. ENVTL. L. REV. 207, 211-17 (1992) (discussing potential substantive mandates under NEPA).

[206] 42 U.S.C. § 4344 (2006); *see also National Environmental Policy: Hearing on S. 1075, S. 237, and S. 1752 Before the S. Comm. on Interior and Insular Affairs*, 91st Cong. (1969) (statement of Sen. Jackson upon introducing NEPA legislation), *available at* 1970 NEPA Leg. Hist. 30 (LEXIS) ("The Council would . . . help the President evaluate the trends of new technologies and developments as they affect our total surroundings, and to develop broad policies, including those related to anticipatory research, to prevent future man-induced environmental changes which could have serious social and economic consequences.").

[207] *See, e.g.*, 115 CONG. REC. 26,569, 26,575 (1969) (statement of Rep. Schadeberg) ("If such a council existed at the time of the invention of the automobile, perhaps we would have been able to realize the threat that would be presented to our atmosphere by the internal combustion of hydrocarbons before it was too late."); *id.* at 26,583-84 (statement of Rep. Cohelan) ("The proposed five-man Council would provide a broad and independent overview of . . . environmental problems that have been created by advancing technology."); *id.* at 26,585 (statement of Rep. Boland) ("[T]here is a growing body of evidence that society is paying a high price in environmental pollution for the advantages that flow from the rapid spread of technology. . . . [CEQ will] provide a vitally needed source for reviewing the total environmental situation—an 'early warning' system that warns us of the effect on the environment of a particular program.").

[208] Exec. Order No. 11,514 § 3(k), 35 Fed. Reg. 4247, 4248 (Mar. 7, 1970).

the environment and provide advice as to what actions should be taken to further that policy.[209]

The role of the CEQ, however, has turned out to be far more circumscribed than originally envisioned. The CEQ has issued regulations and guidance documents that have played a significant role in the implementation of the EIS requirement.[210] But the CEQ's broader mission of anticipating environmental problems and providing policy advice has been largely neglected.[211] The CEQ has been poorly funded and since 1980 has operated through a single member rather than through a full council of three.[212] The CEQ nonetheless retains its statutory authority to analyze environmental trends, to study the environmental impacts of new technologies, and to play a greater role in policymaking. With robust support from Congress and the president—support that it has not received to date—the CEQ could exercise that authority to play a key role in technology assessment.[213] In particular, the CEQ's most valuable function could be to take the lead in identifying emerging technologies and potential hazards that might be associated with them, thereby laying the groundwork for more detailed assessment, policy initiatives, or legislative action.[214]

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[209] *See* CALDWELL, *supra* note 190, at 38-42; *see also* 42 U.S.C. § 4344 (2006) (describing CEQ's duties and functions).

[210] *See* 40 C.F.R. §§ 1500.1-1508.28 (2010); Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 Fed. Reg. 18,026 (1981). Recently, the CEQ has turned its attention to how agencies should incorporate climate change analyses into environmental review documents. Memorandum from Nancy H. Sutley, Chair of the Council on Envtl. Quality, on Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions (Feb. 18, 2010), *available at* http://ceq.hss.doe.gov/nepa/regs/Consideration_of_Effects_of_GHG_Draft_NEPA_Guidance_FINAL_02182010.pdf; *see also* Bradley C. Karkkainen, *Framing Rules: Breaking the Information Bottleneck*, 17 N.Y.U. ENVTL. L.J. 75, 79-81 (2008); Madeline June Kass, *A NEPA Climate Paradox: Taking Greenhouse Gases into Account in Threshold Significance Determinations*, 42 IND. L. REV. 47, 48-49, 52-55 (2009); Amy L. Stein, *Climate Change Under NEPA: Avoiding Cursory Consideration of Greenhouse Gases*, 81 U. COLO. L. REV. 473, 475-76 (2010).

[211] *See* CALDWELL, *supra* note 190, at 39-42; *see also* Scott C. Whitney, *The Role of the President's Council on Environmental Quality in the 1990's and Beyond*, 6 J. ENVTL. L. & LITIG. 81, 104 (1991) (recommending that CEQ devote its energy to serving as an expert advisory body).

[212] CALDWELL, *supra* note 190, at 39-42; LINDSTROM & SMITH, *supra* note 150, at 130-31; Michael E. Kraft & Norman J. Vig, *Environmental Policy from the 1970s to the 1990s: Continuity and Change*, *in* ENVIRONMENTAL POLICY IN THE 1990S 3, 19 (Norman J. Vig & Michael E. Kraft eds., 2d ed. 1994). Indeed, several proposals have been made for the CEQ's elimination. LINDSTROM & SMITH, *supra* note 150, at 130-31.

[213] *See* CALDWELL, *supra* note 190, at 156-57.

[214] *Cf.* Jonathan Zasloff, *Choose the Best Answer: Organizing Climate Change Negotiation in the Obama Administration*, 103 NW. U. L. REV. COLLOQUY 330, 335-36 (2009) ("Presidents have used the CEQ as a vehicle for administering their pet projects.").

B. *Technology Assessment 2.0*

A reconstituted OTA and revitalized NEPA process would improve our understanding of emerging technologies and our policies towards them. But genuine transformation of our relationship with such technologies requires redesigned technology assessment and additional mechanisms to incorporate careful analysis and public participation.

In conventional technology assessment (conventional TA), the OTA considered the potential impacts of a relatively finished technology and submitted the results in reports to Congress. This form of technology assessment was quite limited: its purposes were relatively circumscribed, its intended audience was narrow, and its impacts were uncertain. Rather than attempting to involve the public or to comprehensively project the consequences of new technological developments, the OTA took on the more manageable task of summarizing the existing state of knowledge on narrowly focused issues.[215] And as noted above, the term technology assessment was commonly understood to refer to the OTA's written reports, rather than the entire assessment process.[216]

An important factor in the relative ineffectiveness of conventional TA is the longstanding separation of the promotion of technology from its control and regulation.[217] Conventional TA, in other words, had little effect on the technology development process itself and exercised whatever modest influence it had by contributing towards regulation as an "after-the-fact gatekeeper."[218] Furthermore, conventional TA tended to treat technology decisions as single-shot decisions rather than as ongoing processes.[219] The process of analyzing a technology, however, is an integral aspect of technology management.[220] Depending on who participates in TA and how TA is carried out, these processes themselves can have a critical influence on the shapes and uses of a technology. The separation of technical analysis—conducted by the OTA—from

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[215] Sarewitz, *supra* note 127, at 3; *see also supra* Part II.A.1 (discussing the fairly constricted practice of technology assessment at the OTA).

[216] *See supra* text accompanying note 128.

[217] *See* Arie Rip et al., *Constructive Technology Assessment: A New Paradigm for Managing Technology in Society*, *in* MANAGING TECHNOLOGY IN SOCIETY: THE APPROACH OF CONSTRUCTIVE TECHNOLOGY ASSESSMENT 1, 2 (Arie Rip et al. eds., 1995).

[218] *Id.*

[219] *See id.* at 7-8.

[220] *See* WESTRUM, *supra* note 79, at 325.

the decision-making process in Congress meant that there was little assurance that the OTA's analysis would make a difference.[221] And because the conventional TA process was limited largely to experts, it was relatively distant from democratic control and unresponsive to public values.

In an effort to address the deficiencies of conventional TA, various countries have experimented with modified forms of TA, including participatory technology assessment (PTA) and constructive technology assessment (CTA). These more recent forms of TA represent important advances, but would benefit from further reforms to improve the analysis of emerging technologies and better incorporate public values.

1. Participatory Technology Assessment

Like conventional TA, PTA considers technology options that have already been developed. Unlike conventional TA, however, PTA actively seeks to incorporate outside viewpoints and public values into the assessment process by involving a wider range of actors.[222] Participants in PTA include lay members of the public, as well as stakeholders and experts.[223] In widening the scope of participation, PTA may perform functions such as educating the public, stimulating public debate, setting the political agenda, breaking a political stalemate, and informing decisionmakers of public opinions and values.[224] PTA does not, however, replace or eliminate the expert assessment function of conventional TA. Rather, PTA complements this function by providing more information on the social acceptability of a technology and by bolstering the credibility of expert assessments.[225] PTA's strength, in other words, lies in its ability to introduce public values into decisions concerning technology.

PTA taps into both participatory and representative conceptions of democracy. Citizens who take part in PTA engage directly and extensively with critical issues, and their views and

221 *See* Sarewitz, *supra* note 127, at 4 ("[C]onventional TA embodies a sort of hyper-rational approach to decision making whose greatest error lies not in its unrealistic expectation of accurate predictions, but in its linear view of how decisions should be made.").

222 *See* KLÜVER ET AL., *supra* note 114, at 9, 23-24; SCLOVE, *supra* note 1, at 24-25.

223 *See* KLÜVER ET AL., *supra* note 114, at 9.

224 *See id.* at 130, 137-39.

225 *See id.* at 170.

conclusions may be presented to decisionmakers.[226] Participants are not accountable to constituents nor do they formally represent particular interests, but they are expected to reflect varying viewpoints.[227] PTA differs from the more familiar participatory format of town hall meetings in this representational aspect, as well as in the depth of citizen involvement.[228] Unlike polls or focus groups, which are comparatively superficial means of gauging public opinion, PTA strives to elicit citizens' views in a policy-making context after citizens have had an opportunity to learn about and reflect upon an issue.[229] And because panel membership is drawn from a pool of randomly selected individuals, PTA is less subject to political capture or grandstanding than are advisory commissions.[230]

PTA techniques for assessing new technologies include consensus conferences, citizens' juries, and planning cells. All of these techniques organize lay persons into panels that consult over several days and consider the input of experts and others.[231] In a consensus conference, for example, a multiday public meeting is convened to foster a dialogue between a panel of fifteen to twenty-five citizens and a group of experts.[232] Citizens invited to serve on the panel are drawn from a random sample of the population and then selected through an

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[226] *See* Ida-Elisabeth Andersen & Birgit Jæger, *Scenario Workshops and Consensus Conferences: Towards More Democratic Decision-Making*, 26 SCI. & PUB. POL'Y 331, 334 (1999).

[227] *See id.*

[228] *Cf.* ANNA COOTE & JO LENAGHAN, CITIZENS' JURIES: THEORY INTO PRACTICE 7 (1997) (noting potential for public meetings to be dominated by self-selected, seasoned activists or narrow interests who simply rehearse fixed positions).

[229] Ned Crosby, *Citizens' Juries: One Solution for Difficult Environmental Questions*, *in* FAIRNESS AND COMPETENCE IN CITIZEN PARTICIPATION: EVALUATING MODELS FOR ENVIRONMENTAL DISCOURSE 157, 173 (Ortwin Renn et al. eds., 1995); Georg Hörning, *Citizens' Panels as a Form of Deliberative Technology Assessment*, 26 SCI. & PUB. POL'Y 351, 358 (1999); *see also* Daniel J. Fiorino, *Citizen Participation and Environmental Risk: A Survey of Institutional Mechanisms*, 15 SCI., TECH. & HUMAN VALUES 226, 234 (1990) (noting that surveys "isolate problems and issues from their social and community context"); COOTE & LENAGHAN, *supra* note 228, at 6 (describing polls as "superficial and non-interactive, designed to elicit the uninformed views of the public"); Fischhoff, *supra* note 110, at 79 ("Polls might obtain snapshots of current beliefs; however, those beliefs should have little value for policymakers who are contemplating long-term policies or anticipating the outcome of an intensive public debate."). For a critical view of citizens' juries, see Audrey Armour, *The Citizens' Jury Model of Public Participation: A Critical Evaluation*, *in* FAIRNESS AND COMPETENCE IN CITIZEN PARTICIPATION, *supra*, at 175, 181.

[230] SCLOVE, *supra* note 1, at 34.

[231] *See* Hörning, *supra* note 229, at 351.

[232] Andersen & Jæger, *supra* note 226, at 331; Hörning, *supra* note 229, at 352.

application process.[233] Applicants submit a statement explaining their interest in participation, and these statements are used to identify persons sufficiently dedicated to participate.[234] Assisted throughout the process by a facilitator trained in communication skills and cooperative techniques, the panel conducts two preparatory meetings prior to the consensus conference.[235] At these meetings, panel members learn basic information about the technology at issue and formulate questions to be addressed at the conference.[236] At the conference itself, experts (selected in part by the citizen panel) present their answers to the panel's questions; citizens may then cross-examine the experts.[237] In some instances, interest group representatives and members of the audience may participate in the discussion as well.[238] After the discussion period, the citizen panel prepares a consensus-based report presenting its conclusions and recommendations.[239] The report has no binding effect, but is available to the public, experts, and politicians for their consideration.[240]

Other PTA techniques may differ in the details of implementation, but the underlying purposes are the same: to involve the public and incorporate public input more effectively into decisions regarding technology.[241] Citizens' juries, for example, generate lay findings and recommendations on focused policy questions in a process akin to a jury trial, often in a local or regional context.[242] Planning cells also involve randomly selected citizens in a trial-like process, but participants have more freedom than citizens' juries to design policy options and to consider a range of concerns.[243]

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[233] Andersen & Jæger, *supra* note 226, at 335-36; FRANK FISCHER, CITIZENS, EXPERTS, AND THE ENVIRONMENT 235 (2000) (suggesting that use of sociodemographic criteria to select participants results in panels that are "generally a reasonable cross section of ordinary citizens with no special interest or knowledge").

[234] *See* FISCHER, *supra* note 233, at 235.

[235] *See id.* at 235-36.

[236] Andersen & Jæger, *supra* note 226, at 331.

[237] *See id.*

[238] *Id.*; FISCHER, *supra* note 233, at 236-37.

[239] Andersen & Jæger, *supra* note 226, at 331-32.

[240] *Id.* at 335-36.

[241] *See generally* Hörning, *supra* note 229, at 352 (identifying differences among PTA methods).

[242] *See* Crosby, *supra* note 229, at 157-58; Simon Joss, *Participation in Parliamentary Technology Assessment: From Theory to Practice*, *in* PARLIAMENTS AND TECHNOLOGY, *supra* note 80, at 325, 341.

[243] *See* Peter C. Dienel & Ortwin Renn, *Planning Cells: A Gate to "Fractal" Mediation*, *in* FAIRNESS AND COMPETENCE IN CITIZEN PARTICIPATION, *supra* note 229,

2. Constructive Technology Assessment

Unlike PTA and conventional TA, constructive technology assessment (CTA) seeks to influence technology design itself. Typically, innovation occurs within private laboratories outside of public scrutiny,[244] and regulation is contemplated after a technology appears in commercial applications.[245] In contrast to this typical approach, CTA seeks to promote interaction among stakeholders—technology developers, regulators, workers, end users, and the potentially affected public—during the technology development process.[246] By facilitating incorporation of interested parties' values into the design process, such interaction can lead to more widely accepted outcomes with fewer adverse effects.[247] CTA may involve public participation, but such participation serves as a means of shaping technology and identifying risks rather than as an end in and of itself.[248]

Advocates have identified three key features of CTA: anticipation, reflexivity, and social learning.[249] Anticipation of potential technological interactions and adverse side effects occurs through the involvement of a broad range of stakeholders early in the design process and through "early

at 117, 121-24; Ortwin Renn et al., *The Pursuit of Fair and Competent Citizen Participation*, *in* FAIRNESS AND COMPETENCE IN CITIZEN PARTICIPATION, *supra* note 229, at 339, 344.

[244] SCLOVE, *supra* note 1, at 4; WESTRUM, *supra* note 79, at 107-27 (discussing process of invention).

[245] *See* COLLINGRIDGE, *supra* note 1, at 16-19 (explaining that control of a technology is hampered at early stages by lack of knowledge about adverse consequences and at later stages by diffusion and entrenchment of the technology); *see also* Rip et al., *supra* note 217, at 2 (noting "two-track approach that separates promotional activities from control and regulation").

[246] Johan Schot, *Towards New Forms of Participatory Technology Development*, 13 TECH. ANALYSIS & STRATEGIC MGMT. 39, 40-41 (2001). The terms "interactive TA" and "real-time TA" refer to similar approaches. *See* David H. Guston & Daniel Sarewitz, *Real-Time Technology Assessment*, 24 TECH. SOC'Y 93, 97-98 (2002) (comparing real-time technology assessment with CTA); Rip, *supra* note 170, at 148. Although governmental or semi-governmental bodies are the more likely practitioners of CTA, businesses, nonprofit organizations, and other actors can perform and facilitate CTA as well. *See* Johan Schot & Arie Rip, *The Past and Future of Constructive Technology Assessment*, 54 TECH. FORECASTING & SOC. CHANGE 251, 256 (1996).

[247] Schot, *supra* note 246, at 40-42; Arne Remmen, *Pollution Prevention, Cleaner Technologies and Industry*, *in* MANAGING TECHNOLOGY IN SOCIETY, *supra* note 217, at 199, 201 (stating that "constructive approach aims at integrating social and environmental criteria right from the beginning").

[248] *See* Rip, *supra* note 170, at 147.

[249] Schot, *supra* note 246, at 40.

and controlled experimentation."[250] Because not all concerns can be identified at the outset, however, the technology development process should be flexible and iterative, allowing for periodic reexamination of interactions and effects.[251] Reflexivity refers to an appreciation of the various social effects that different technology design options may have.[252] Rather than focusing narrowly on technical goals, technology developers should take into account social, environmental, and other consequences as they design and evaluate new technologies. Finally, social learning refers to a mutual process in which relevant actors learn from each other in the course of technology development and use.[253] Through social learning, companies learn about consumer preferences and regulatory requirements and can design products accordingly, and in addition, existing preferences and requirements might be shaped in favor of more sustainable technologies.[254] Variants of CTA may incorporate public opinion polling, content analysis, and other tools to complement the basic CTA process.[255]

Denmark and the Netherlands have been at the forefront of the development of PTA and CTA.[256] In Denmark, where the consensus conference was developed, the technique has addressed topics such as the use of knowledge about the human genome, irradiation of food, and genetically engineered animals.[257] These conferences produced recommendations that were later incorporated into legislation and policy.[258] In the Netherlands, CTA techniques were applied to the creation and design of novel, environmentally-friendly alternatives to meat.

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[250] *Id.* at 43; Guston & Sarewitz, *supra* note 246, at 97-98.

[251] Remmen, *supra* note 247, at 201; Schot, *supra* note 246, at 43-44.

[252] Erik Fisher et al., *Midstream Modulation of Technology: Governance from Within*, 26 BULLETIN OF SCI., TECH. & SOC'Y 485, 492 (2006); Schot, *supra* note 246, at 44. The concept is rooted in Ulrich Beck's contention in *Risk Society* that a more reflexive, self-critical approach must replace the traditional technocratic understanding of science. *See* BECK, *supra* note 4, at 155-56.

[253] Schot, *supra* note 246, at 44.

[254] *See id.* at 44-45.

[255] *See* Guston & Sarewitz, *supra* note 246, at 98; *see also* Sarewitz, *supra* note 127, at 4-5 (describing principles of real-time TA).

[256] *See* Thomas Petermann, *Technology Assessment Units in the European Parliamentary Systems*, *in* PARLIAMENTS AND TECHNOLOGY, *supra* note 80, at 37, 49-50 (discussing the discursive and participatory function of TA in Denmark and the Netherlands).

[257] Lars Klüver, *The Danish Board of Technology*, *in* PARLIAMENTS AND TECHNOLOGY, *supra* note 80, at 173, 190-91.

[258] *See id.* For a practical evaluation of PTA efforts in Denmark, see Joss, *supra* note 242, at 342-53.

Meetings between various stakeholders generated agreement on minimum standards for such products, and led technology developers to devote more attention to issues of taste and texture.[259] More recently, the United States has begun to experiment with a variant of CTA, real-time technology assessment, in managing nanotechnology. This development is considered below in more detail.[260]

3. Concerns

Commentators have raised a number of concerns applicable to PTA and CTA. Notwithstanding such concerns, these more recent forms of technology assessment offer valuable options for society to manage new technologies more effectively and democratically.

One obvious issue involves the interest and competence of laypersons. The average citizen is likely to have limited understanding of the technical matters that undergird modern technologies.[261] Laypersons may defer to experts or rely on simplifying heuristics when assessing new technologies.[262] Citizen participation could cripple technology development if unwarranted and irrational fears come to dominate the assessment process.[263] Furthermore, low levels of voter turnout and other measures of civic engagement in general suggest that laypersons may not take much interest in technology assessment.[264]

If given the opportunity to participate in a meaningful way, however, citizens have proven willing and competent to engage in matters of public debate. Layperson interest is suggested not only by anecdotal evidence, such as high levels of participation in policy blogs, but also by studies finding an

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[259] *See* Schot, *supra* note 246, at 47-48.

[260] *See infra* Part III.B.4.

[261] *See* Fiorino, *supra* note 229, at 227 ("Given the sheer complexity of the issues, the 'transscientific' nature of the factual premises, and the rapid changes in the definition of problems and their solutions, the lay public lacks the time, information, and inclination to take part in technically based problem solving.").

[262] *See* Matthew C. Nisbet & Dietram A. Scheufele, *What's Next for Science Communication? Promising Directions and Lingering Distractions*, 96 AM. J. BOTANY 1767, 1768 (2009) (remarking that the wider public tends to "rely on cognitive shortcuts and heuristic decision making to help them reach opinions about policy-related matters" involving science and technology).

[263] *See* Leonhard Hennen, *Impacts of Participatory TA on Its Societal Environment*, *in* KLÜVER ET AL., *supra* note 114, at 154.

[264] *See generally* THOMAS E. PATTERSON, THE VANISHING VOTER: PUBLIC INVOLVEMENT IN AN AGE OF UNCERTAINTY (2002).

eagerness to participate and resentment at exclusion.[265] In evaluating citizen competence, it is critical to keep in mind that lay participation is primarily meant to provide a read on public values, particularly with respect to public understandings of risk, and not to replace technical expertise.[266] Of course, laypersons sometimes do identify technical issues, problems, and contextual factors that experts have overlooked.[267] But the main question is whether laypersons can become sufficiently informed on the technical issues such that they can apply their personal experiences, belief systems, and values to new technological situations of risk and uncertainty.[268] PTA enables informed participation by providing citizens with the time and access to expertise required to learn about the issues.[269] Citizens participating in PTA exercises have served effectively as "values consultants" and have not been too intimidated to question experts, regulators, and stakeholders critically.[270] Similarly, examples of citizen activism in technical controversies demonstrate that laypersons can come to sufficiently informed views, particularly if they develop cooperative relationships with experts.[271] This is not to say that laypersons necessarily will agree with the experts or policymakers after engaging on technology matters. Ultimately, public opposition to the deployment of a new technology often reflects *not* an inability to comprehend

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[265] *See* FISCHER, *supra* note 233, at 35-36; *see also* Michael X. Delli Carpini et al., *Public Deliberation, Discursive Participation, and Citizen Engagement*, 7 ANN. REV. POL. SCI. 315, 315-16, 323-24, 336 (2004) (reviewing studies of public deliberation).

[266] *See* FISCHER, *supra* note 233, at 42 ("[S]cience is laden with social value judgments, judgments typically hidden within the steps and phases of the research process . . . ."); Nisbet & Scheufele, *supra* note 262, at 1768 (noting that values are far more important determinants of public opinion about controversial areas of science than knowledge); *see also supra* Part I.B.2.

[267] ALAN IRWIN, CITIZEN SCIENCE: A STUDY OF PEOPLE, EXPERTISE AND SUSTAINABLE DEVELOPMENT 172-73 (1995) (discussing citizens as a source of information and expertise); Fiorino, *supra* note 229, at 227; *see also* FISCHER, *supra* note 233, at 193-218 (discussing local knowledge that laypersons can contribute).

[268] *See* FISCHER, *supra* note 233, at 132-42 (describing concept of cultural rationality).

[269] *See* Dienel & Renn, *supra* note 243, at 125; *see also* FISCHER, *supra* note 233, at 32 (contending that citizens "are much more capable of grappling with complex problems than generally assumed").

[270] Nisbet & Scheufele, *supra* note 262, at 1770 (reporting that participants not only learn about the technical, social, ethical, and economic aspects of the scientific topic, but also become more confident and motivated to participate in science decisions); Renn et al., *supra* note 243, at 345.

[271] FISCHER, *supra* note 233, at 148-55 (discussing citizen activists' efforts to combat AIDS, identify cancer clusters, and engage in a nuclear power plant siting decision).

scientific matters, but rather a distrust of the scientific and government institutions that are invested in them.[272]

Another criticism of participatory approaches to TA concerns the legitimacy of citizen participation.[273] Lay participants do not constitute democratic representatives of the public will. In addition, because they need not answer to an electorate, participants may endorse unrealistic or politically infeasible policy options.[274] PTA, however, does not replace representative decision-making procedures. Rather, PTA serves in a consultative role in support of decisions made by elected representatives who are politically accountable.[275] PTA thus incorporates elements of direct participatory democracy, yet remains rooted in a representative democratic system.[276] The method of selecting lay participants nevertheless does matter to the credibility and utility of the process. While random selection of participants does not ensure that citizen deliberations will be representative, it can facilitate the expression of a wide range of views, promote participants' independence, and ameliorate interest group efforts to rig the process.[277]

To the extent that PTA and CTA techniques tend to emphasize the formation of consensus, they may mute the expression of alternative viewpoints or dampen values conflicts that are healthy for social risk management.[278] Conversely, achieving consensus may not be possible where value differences are great, as is often the case with new technologies.[279] Indeed, one review of PTA efforts suggests that PTA "increases the complexity of decision making by taking into account different values to assess impacts of technology, [and] by supplying all information and knowledge available

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[272] Brian Wynne, *Creating Public Alienation: Expert Cultures of Risk and Ethics on GMOs*, 10 SCI. AS CULTURE 445, 447, 475-76 (2001).

[273] Armour, *supra* note 229, at 180; Hans-Jörg Seiler, *Review of "Planning Cells:" Problems of Legitimation*, *in* FAIRNESS AND COMPETENCE IN CITIZEN PARTICIPATION, *supra* note 229, at 142-49.

[274] *See* Dienel & Renn, *supra* note 243, at 129.

[275] *See* KLÜVER ET AL., *supra* note 114, at 171; Dienel & Renn, *supra* note 243, at 129; Hörning, *supra* note 229, at 357.

[276] *See* Joss, *supra* note 242, at 335-36.

[277] KLÜVER ET AL., *supra* note 114, at 134; Hörning, *supra* note 229, at 357; Renn et al., *supra* note 243, at 353. Notwithstanding random selection, certain demographic groups, such as students and retirees, may be overrepresented on citizen panels, just as they tend to be overrepresented on ordinary juries. *See* Dienel & Renn, *supra* note 243, at 125.

[278] *See* Audley Genus, *Rethinking Constructive Technology Assessment as Democratic, Reflective Discourse*, 73 TECH. FORECASTING & SOC. CHANGE 13, 19 (2006).

[279] *See* Renn et al., *supra* note 243, at 353-54.

and conveying uncertainties or deficiencies of knowledge."[280] Moreover, the time constraints inherent in some participatory techniques may not allow adequate opportunity for the sort of deep normative deliberation that democratic idealists might desire.[281] These concerns underscore the limitations of PTA and CTA in reflecting the full range of public values and in providing concrete solutions.[282] Participatory approaches to TA nonetheless can identify public concerns and provide a useful roadmap for future research and analysis.[283]

The most serious objections to PTA and CTA involve the relatively limited effect that such assessments may have on actual decisions. Unless technology assessment efforts are integrated into the policy-making process, those efforts may prove to be little more than an academic exercise. Simply providing the results of assessments to decisionmakers may not overcome the domination of political decisions by vested interests.[284] Policymakers may be inclined to dismiss such results as neither representative nor the product of expert deliberation.[285] And public participation may be of limited value if experts control the framing of a problem and of policy options.[286] Rather than changing the relationship between society and new technologies, TA might merely defuse opposition by creating the appearance of an open, participatory process.[287] At the same time, powerful actors might escape accountability for their role in promoting risky technologies.[288]

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280 KLÜVER ET AL., *supra* note 114, at 155.

281 *See* FISCHER, *supra* note 233, at 238-39 ("Beyond merely uncovering normative assumptions and beliefs, deliberation can lead to changes in assumptions, as well as creations of new ones.").

282 *See* KLÜVER ET AL., *supra* note 114, at 155 (describing TA as a "contested field of interests, preferences and values").

283 *See* Arie Rip, *Assessing the Impact of Innovation: New Developments in Technology Assessment*, *in* OECD PROCEEDINGS: SOCIAL SCIENCES AND INNOVATION 197, 197 (2001).

284 *See* KLÜVER ET AL., *supra* note 114, at 154.

285 *See* Seiler, *supra* note 273, at 150.

286 Alan Irwin, *Constructing the Scientific Citizen: Science and Democracy in the Biosciences*, 10 PUB. UNDERSTANDING SCI. 1, 12-13 (2001) (discussing an example in which the institutional framing of public consultation constrained the role of the public).

287 Genus, *supra* note 278, at 21-23 (suggesting potential for TA to become a "participation trap"); *see also* Wynne, *supra* note 107, at 463 (suggesting that efforts to make science and technology more participatory "have perversely reinforced attention only on back-end scientific questions about consequences" and thus "exclude[d] more reflexive questions about the human purposes and visions which shape front-end innovation commitments").

288 *See* Genus, *supra* note 278, at 19.

Indeed, the effect of citizen deliberations on policymaking, while difficult to measure, generally appears modest.[289] Defenders of PTA attribute the limited policy impact of PTA to its consultative nature; PTA is intended to inform rather than to dictate policy decisions.[290] Critics, however, contend that PTA fails to bring about the multi-way communication between lay citizens, stakeholders, and decision makers that is needed.[291] Ensuring openness in the process and widespread dissemination of results,[292] while timing citizen deliberations so that their output can be incorporated into an ongoing decision-making process, can enhance PTA's effectiveness.[293] Likewise, incorporating the results of CTA into actual technological development has proven to be a daunting challenge.[294] Technology developers are often reluctant to open up their processes to outsider scrutiny, let alone outsider participation. Absent a regulatory mandate, the effect of CTA activities may be at best indirect, serving primarily as an external critique or source of pressure on technology developers.[295]

4. Incipient U.S. PTA/CTA Efforts . . . and Beyond

Attempts to use modified TA techniques in the United States during the 1980s and 1990s were limited in scope and generally did not consider emerging technologies.[296] More recently, however, the growing field of nanotechnology has become a testing ground for these methods.[297] The 21st Century

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[289] Hörning, *supra* note 229, at 356.

[290] KLÜVER ET AL., *supra* note 114, at 11.

[291] *See* Armour, *supra* note 229, at 181.

[292] Hörning, *supra* note 229, at 356. In the Netherlands, for example, PTA organizers have sought to increase the influence of lay panels by raising their profile and by facilitating communications between the panels and the general public via the Internet. Rinie van Est, *The Rathenau Institute's Approach to Participatory TA*, TA-DATABASE-NEWSL. (Institut für Technikfolgenabschätzung und Systemanalyse), Oct. 2000, at 13, 18, *available at* http://www.itas.fzk.de/deu/tadn/tadn003/vest00a.pdf.

[293] KLÜVER ET AL., *supra* note 114, at 146. The desired timing may depend on the function of PTA in a particular case: if the intent is to initiate debate or decide whether to fund basic research, PTA should occur early in the process; if the intent is to assess suitable applications of a controversial technology, PTA can be deferred, but nonetheless should take place before irreversible commitments are made. *Id.* at 145-47.

[294] Schot & Rip, *supra* note 246, at 255.

[295] *See id.* at 255-56; SCLOVE, *supra* note 1, at 6 (European industries have "come to support [PTA] as a low-stress, low-cost mechanism for gauging societal reactions to alternative research, development and innovation trajectories.").

[296] *See* Dienel & Renn, *supra* note 243, at 135-36 (describing use of planning cells in the 1980s).

[297] For a summary of U.S. PTA efforts, see SCLOVE, *supra* note 1, at 43-46.

Nanotechnology Research and Development Act ("Nanotechnology Act") established a national nanotechnology program whose mission includes "ensuring that ethical, legal, environmental, and other appropriate societal concerns, including the potential use of nanotechnology in enhancing human intelligence and in developing artificial intelligence which exceeds human capacity, are considered during the development of nanotechnology."[298] The Nanotechnology Act anticipates integration of public input in this process "through mechanisms such as citizens' panels, consensus conferences, and educational events."[299]

Per Congress's direction in the Nanotechnology Act, the National Science Foundation has funded the Centers for Nanotechnology in Society at Arizona State University (CNS-ASU) and the University of California, Santa Barbara to identify and address social, ethical, and environmental concerns.[300] CNS-ASU is developing a "real-time technology assessment" program incorporating CTA principles of reflexivity and anticipatory governance.[301] The program consists of four main components: (1) characterizing nanotechnology research; (2) monitoring opinion and values among researchers and the public regarding nanotechnology; (3) involving researchers and the public in deliberation and shared participation; and (4) assessing the program's effects on nanotechnology researchers and on nanotechnology in society.[302] Efforts to integrate modified TA techniques into nanotechnology development pursuant to the Act represent a promising departure from the past, and these efforts are still in

[298] 15 U.S.C. § 7501(b)(10) (2006).

[299] *Id.* § 7501(b)(10)(D).

[300] The discussion here focuses on CNS-ASU's more extensive efforts in the area of real-time technology assessment. For a description of research activities at CNS-UCSB, see *Research*, CNS-UCSB, http://www.cns.ucsb.edu/research (last visited Jan. 20, 2011); *see also* Nick Pidgeon et al., *Deliberating the Risks of Nanotechnologies for Energy and Health Applications in the United States and United Kingdom*, 4 NATURE NANOTECHNOLOGY 95 (2009) (discussing results of public workshops on energy and health nanotechnologies held at Santa Barbara and in the United Kingdom).

[301] *See* David H. Guston, *The Center for Nanotechnology in Society at Arizona State University and the Prospects for Anticipatory Governance*, *in* NANOSCALE: ISSUES AND PERSPECTIVES FOR THE NANO CENTURY 377, 380 (Nigel M. de S. Cameron & M. Ellen Mitchell eds., 2007); *see also* Daniel Barben et al., *Anticipatory Governance of Nanotechnology: Foresight, Engagement & Integration*, *in* THE HANDBOOK OF SCIENCE & TECHNOLOGY STUDIES (Edward J. Hackett et al. eds., 3d ed. 2008).

[302] *See* Guston, *supra* note 301, at 382-84; s*ee also Center for Nanotechnology in Society at Arizona State University*, CNS-ASU, http://cns.asu.edu/index.htm (last visited Jan. 20, 2011).

progress. But for the reasons discussed below, they fall short in generating the upfront assessment and widespread public participation needed.

For example, an important part of CNS-ASU's efforts to engage the public was the organization of a "National Citizens' Technology Forum" (NCTF) linking six groups of citizens from different parts of the United States.[303] The forum, held in 2008, did not deliberate on nanotechnology in general, but instead focused on the specific topic of human enhancement through nanotechnology, biotechnology, information technologies, and cognitive science.[304] Following face-to-face and electronic deliberative sessions, each group of citizens drafted a report that represented the consensus of the group.[305] The organizers of the forum concluded that citizens are supportive of research on these transformational technologies if coupled with trustworthy oversight, and that "average citizens want to be involved in the technological decisions that might end up shaping their lives."[306]

The results of the NCTF do suggest that citizens have the desire and ability to participate in decisions about technology development. In addition, the citizens' reports reflect a slice of public opinion reached after substantial deliberation. Nonetheless, the ultimate impact of the NCTF on actual nanotechnology development and policy appears minimal. Simply publishing citizens' reports hardly ensures any influence on the course of research or on nanotechnology regulation.[307] The reports have no clear constituency or audience, and efforts to diffuse them have been limited.[308]

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[303] HAMLETT ET AL., *supra* note 60. A similar citizens' jury met in the United Kingdom in 2005 to consider nanotechnology. That group made recommendations on the use of nanotechnology in health care and renewable energy, and called for labeling, safety testing, and greater public involvement in the direction of research. *See* James Wilsdon, *Paddling Upstream: New Currents in European Technology Assessment*, *in* RODEMEYER ET AL., *supra* note 103.

[304] HAMLETT ET AL., *supra* note 60, at 1; Brice Laurent, *Replicating Participatory Devices: The Consensus Conference Confronts Nanotechnology* 5 (Centre de Sociologie de l'Innovation Working Paper No. 018, 2009).

[305] HAMLETT ET AL., *supra* note 60, at 1.

[306] *Id.* at 2.

[307] *Cf.* Maria Powell & Daniel Lee Kleinman, *Building Citizen Capacities for Participation in Nanotechnology Decision-Making: The Democratic Virtues of the Consensus Conference Model*, 17 PUB. UNDERSTANDING SCI. 329, 341, 344 (2008) (reporting that several participants in 2005 Wisconsin nanotechnology consensus conference expressed view that neither scientists nor government would be responsive to their concerns and that the conference would not influence policy).

[308] *See* Laurent, *supra* note 304, at 12; *see also* Ira Bennett & Daniel Sarewitz, *Too Little, Too Late?: Research Policies on the Societal Implications of Nanotechnology*

Indeed, one commentator characterized the NCTF primarily "as a social scientific research instrument."[309] The main purpose of the NCTF, in other words, was to demonstrate the value of deliberation and to investigate ways of structuring consensus conferences to foster high-quality deliberation.[310] Apparently, the objective of influencing technology development or technology policy was of far less importance. Furthermore, although participants in the NCTF undoubtedly learned about and became engaged in the issues, the public at large was not brought into the process and generally remains uninformed about nanotechnology.[311]

There are a number of other shortcomings in technology assessment efforts under the Nanotechnology Act. First, the magnitude of those efforts is dwarfed by the magnitude of efforts to develop and implement nanotechnology. Only about 5% of federal nanotechnology funding—authorized for a total of approximately $3.7 billion from fiscal year 2005 to fiscal year 2008[312]—falls under the rubric of research on health and environmental effects. That general category includes a wide range of projects such as the use of nanotechnology to remediate environmental pollution; only about one-third of that five percent figure supports research aimed at addressing nanotechnology's hazards.[313] Given this funding imbalance and the diversity of nanomaterials to be studied, identifying health

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in the United States, 15 SCI. AS CULTURE 309, 319 (2006) (noting that the 21st Century Nanotechnology Research and Development Act does not specify "the processes by which research results are to enhance decision making").

[309] Laurent, *supra* note 304, at 11. One researcher involved in the NCTF observed that participants "knew that they were part of a research project" and consequently "tended to not even bother to fight for ideas or opinion[s]." *Id.* at 25 (emphasis and internal quotation marks omitted).

[310] *Id.* at 10-11.

[311] HART RESEARCH ASSOCS., NANOTECHNOLOGY, SYNTHETIC BIOLOGY & PUBLIC OPINION 1 (2009), *available at* http://www.nanotechproject.org/process/assets/files/8286/nano_synbio.pdf (reporting that "nearly 7 in 10 [Americans] (68%) have heard just a little or nothing about [nanotechnology]"); Guston, *supra* note 301, at 389 (noting that polls reflect modest public knowledge of and engagement in nanotechnology); *see also* Elizabeth A. Corley & Dietram A. Scheufele, *Outreach Gone Wrong?*, SCIENTIST, Jan. 2010, at 22 (finding "widening gaps in nanotech knowledge between the least educated and the most educated citizens"). Broadening public awareness of and engagement in nanotechnology is left to the Nanoscale Informal Science Education Network (NISE Net), which promotes nanotechnology education through science museums. *See* Guston, *supra* note 301, at 379, 389; NANOSCALE INFORMAL SCI. EDUC. NETWORK, http://www.nisenet.org (last visited Jan. 20, 2011).

[312] 15 U.S.C. § 7505 (2006).

[313] J. CLARENCE DAVIES, WOODROW WILSON INT'L CTR. FOR SCHOLARS, NANOTECHNOLOGY OVERSIGHT: AN AGENDA FOR THE NEW ADMINISTRATION 7 (2008), *available at* http://nanotechproject.org/process/assets/files/6709/pen13.pdf.

and environmental concerns and integrating them into the technology development process is a daunting challenge. Nanotechnology development essentially "got a 15 year head start"[314] on technology assessment efforts, with the number of nanotechnology-based consumer products currently on the market exceeding one thousand.[315] Although nanotechnology products are becoming increasingly common, quantitative and validated risk assessment data for nanotechnology remains generally unavailable, and will continue to be unavailable for some time.[316]

Moreover, as CNS-ASU Director David Guston has observed, overall nanotechnology research "has grown much larger and faster than the societal implications work that might engage it."[317] Whether the TA efforts sponsored by the Nanotechnology Act will affect the overall course of nanotechnology research and development is uncertain.[318] CNS-ASU's efforts to encourage nanotechnology researchers to be more reflexive about their research have influenced research focus and design in some individual instances, but such influence has been limited largely to graduate student researchers on the ASU campus.[319] Similarly, the role of the NCTF and other technology assessment activities within the broader context of nanotechnology research is somewhat unclear. As other commentators have explained, the Nanotechnology Act contains an inherent tension between the goal of promoting rapid nanotechnology development and

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314 Bennett & Sarewitz, *supra* note 308, at 322.

315 *Analysis*, PROJECT ON EMERGING NANOTECHNOLOGIES, http://www.nanotechproject.org/inventories/consumer/analysis_draft (last visited Jan. 19, 2011) ("As of August 25, 2009, the nanotechnology consumer products inventory contains 1015 products or product lines.").

316 *See* Elizabeth A. Corley et al., *Of Risks and Regulations: How Leading U.S. Nanoscientists Form Policy Stances About Nanotechnology*, 11 J. NANOPARTICLE RES. 1573, 1574 (2009).

317 Guston, *supra* note 301, at 389 (noting that "a $1 billion/per year NNI in the United States overwhelms the $3-million/year nanotechnology-in-society network"); *see also* Guston & Sarewitz, *supra* note 246, at 106 (noting that widespread nano-scale science and engineering activity "is already too large and diverse to be the subject of a single TA effort").

318 *Cf.* Monika Kurath & Priska Gisler, *Informing, Involving or Engaging? Science Communication, in the Ages of Atom-, Bio-, and Nanotechnology*, 18 PUB. UNDERSTANDING SCI. 559, 568 (2009) (contending that public outreach efforts in Europe with respect to nanotechnology have occurred after major investment decisions were already made and "tend to limit public engagement to matters of values and social and ethical aspects, rather than to expose expertise to scrutiny").

319 *See* Guston, *supra* note 301, at 384-85; Interview with Jameson Wetmore, Ass't Professor, Ariz. State Univ., in Pacific Grove, CA (Mar. 24, 2010). Efforts to export such activities to other universities have begun. Interview with Jameson Wetmore, *supra*.

implementation and the goal of integrating societal concerns into the research and development process.[320] The risk remains that technology assessment efforts with respect to nanotechnology may serve as little more than a political tool for obtaining public acceptance.[321]

Thus, notwithstanding some progress in addressing the concerns raised at the outset of this article,[322] questions persist regarding how to promote a broader and more thorough analysis of a technology's consequences, how to engage the general public in emerging technology issues, and how to interject public values more forcefully into the technology decision-making process.

A recent proposal for facilitating expert assessment and citizen participation involves the establishment of an "Expert & Citizen Assessment of Science & Technology Network" comprised of universities, science museums, policy institutions, and nonprofit organizations.[323] Such a network would not require legislative approval or appropriation and could act flexibly in selecting, framing, and analyzing topics for assessment.[324] It is vital, however, that the network's processes and analyses be well-executed, insightful, and nonpartisan in order to establish credibility with policymakers and the public.

One means of linking PTA more immediately to policymaking would be to involve elected officials and other policymakers directly in the technology assessment process. During the 1980s, several citizens' juries were convened in the United States on an experimental basis.[325] In an effort to

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[320] *E.g.*, Erik Fisher & Roop L. Mahajan, *Contradictory Intent? US Federal Legislation on Integrating Societal Concerns into Nanotechnology Research and Development*, 33 SCI. & PUB. POL'Y, Feb. 2006, at 5, 10-14 (comparing 15 U.S.C. § 7501(b)(1)-(9) (2006) with § 7501(b)(10)).

[321] *See* Mette Ebbesen, *The Role of The Humanities and Social Sciences in Nanotechnology Research and Development*, 2 NANOETHICS 1, 2-3 (2008); *see also* Fisher & Mahajan, *supra* note 320, at 13 ("Depending on how it is implemented, the Act could emerge as a shrewd piece of legislative rhetoric, reducing societal research and related activities to a sideshow in order to push rapid nanotechnology development past a potentially wary public, or as a tool for ushering in a prudent new paradigm in technology development . . . ."); Tee Rogers-Hayden & Nick Pidgeon, *Moving Engagement "Upstream"? Nanotechnologies and the Royal Society and Royal Academy of Engineering's Inquiry*, 16 PUB. UNDERSTANDING SCI. 345, 345 (2007) (discussing danger that public engagement on nanotechnology in the United Kingdom "may well, intentionally or unintentionally, serve only token purposes").

[322] *See* Part I.B.

[323] *See* SCLOVE, *supra* note 1, at 38-41.

[324] *Id.* at 38-39.

[325] According to one organizer, legislators viewed these efforts "as a bother at best and, at worst, as a real challenge to the way business is currently conducted."

overcome the political and cultural resistance to these forms of public participation, organizers convinced two congressional representatives to participate in portions of citizens' jury hearings.[326] Widespread legislator participation in PTA is unlikely, however, given the numerous demands on legislators' time and the limited payoff for legislators who do participate.

A more realistic approach would have politicians raise the profile of emerging technology issues for the purpose of stimulating public debate. A prominent example of this approach involves federal funding of research on stem cells derived from human embryos. In 2001, President George W. Bush issued a statement limiting such funding after personally deliberating on the issue in a very public way.[327] Of interest here is not the substance of that decision, which was criticized on a number of grounds[328] and later reversed by President Obama,[329] but rather the process leading up to it. Although that controversy involved primarily ethical concerns, the public discussions surrounding the issue demonstrate how public deliberation on technology matters can identify important societal values at stake.[330] President Bush's high-profile consideration of the issue appropriately expanded to the general public a debate that had been previously limited to a "small, professionally invested elite."[331] Government support for efforts to communicate emerging technology issues broadly through cable channels such as the Discovery Channel, local media outlets, and creative media would similarly foster public engagement.[332]

Nonbinding national technology referendums are another promising mechanism to increase public involvement and input. Potential subjects of such referendums could be identified by Congress, the president, or the CEQ. Ideally, such

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Crosby, *supra* note 229, at 159; *see also id.* at 167 (noting "cultural discrepancy" between citizens' jury process and "normal political procedure").

[326] *Id.*

[327] Press Release, White House Office of Commc'ns, Remarks by the President on Stem Cell Research (Aug. 9, 2001), 2001 WL 896981.

[328] *E.g.*, Russell Korobkin, *Embryonic Histrionics: A Critical Evaluation of the Bush Stem Cell Funding Policy and the Congressional Alternative*, 47 JURIMETRICS 1 (2006).

[329] Exec. Order No. 13,505, 74 Fed. Reg. 10,667 (Mar. 11, 2009).

[330] *See* Richard Lacayo, *How Bush Got There*, TIME, Aug. 20, 2001, at 17 (discussing President Bush's consultations on the subject and accompanying political debate).

[331] Paul Root Wolpe & Glenn McGee, *"Expert Bioethics" as Professional Discourse: The Case of Stem Cells*, *in* THE HUMAN EMBRYONIC STEM CELL DEBATE 185, 186 (Suzanne Holland et al. eds., 2001); *see also* Gretchen Vogel, *Rumors and Trial Balloons Precede Bush's Funding Decision*, 293 SCIENCE 186 (2001).

[332] Nisbet & Scheufele, *supra* note 262, at 1774-75.

referendums would take place on a periodic basis after citizens' juries or similar panels have already met to consider an emerging technology. An appointed panel of experts, social scientists, and citizens would develop a limited number of questions, each having several possible responses, to be set forth in the referendums.[333] The purpose of such referendums would be to supplement, rather than to replace representative decision making.[334] A technology referendum would bring the broader public into discussions about technology and would provide an opportunity for a societal-level debate.[335] Such debate could take into account the in-depth considerations and recommendations of citizens' juries, which would help to counter the effects of any superficial media campaigns that would likely arise.[336] Through technology referendums, the public would gain a direct voice in critical developments that shape their lives.[337]

Of course, referendums are an imperfect tool for gauging public sentiment or promoting public deliberation. Like voters in general, referendum voters tend to be older, wealthier, and more educated than the average person.[338] The

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[333] Presenting several options would generate more information about voter preferences while encouraging voters to think as public citizens. *See* BENJAMIN R. BARBER, STRONG DEMOCRACY: PARTICIPATORY POLITICS FOR A NEW AGE 286-88 (2003).

[334] *See* David Butler & Austin Ranney, *Theory*, *in* REFERENDUMS AROUND THE WORLD: THE GROWING USE OF DIRECT DEMOCRACY 11, 13-16 (David Butler & Austin Ranney eds., 1994) (discussing benefits from supplementing representative institutions with referendums); Maija Setälä, *On the Problems of Responsibility and Accountability in Referendums*, 45 EUR. J. POL. RES. 699, 701-02 (2006). The potential for a referendum to undermine representative institutions, *see* Butler & Ranney, *supra*, at 20, is reduced by making the referendums nonbinding. The use of a nonbinding procedure at the national level has the additional advantage of requiring only congressional authorization, rather than constitutional amendment.

[335] Bruno S. Frey, *Efficiency and Democratic Political Organisation; The Case for the Referendum*, 12 J. PUB. POL'Y 209, 219 (1992) (contending that the public discussion induced by referenda "shapes the citizens' preferences" by confronting them with issues they have not previously considered and by encouraging them to evaluate those issues according to their basic values).

[336] *See* BARBER, *supra* note 333, at 267-98 (recommending that participatory institutions include mechanisms for improving people's competence to make reasonable political judgments); Setälä, *supra* note 334, at 702-03 (discussing deliberative democratic rationale for the referendum and initiative).

[337] BARBER, *supra* note 333, at 284 ("In sum, the initiative and referendum can increase popular participation in and responsibility for government, provide a permanent instrument of civic education, and give popular talk the reality and discipline of power that it needs to be effective."); *see also* THOMAS E. CRONIN, DIRECT DEMOCRACY: THE POLITICS OF INITIATIVE, REFERENDUM, AND RECALL 78-79 (1989) (discussing surveys finding that citizens generally are in favor of having a direct vote with respect to important issues and policies).

[338] *See* Butler & Ranney, *supra* note 334, at 18; CRONIN, *supra* note 337, at 76-77.

results of a nonbinding referendum could be viewed as analogous to the results of a national public opinion poll.[339] And questions must be framed with care to ensure their comprehensibility and neutrality. But nonbinding referendums could bring needed attention to emerging technology issues and prove far more effective than polls in engaging and educating the public.[340] A nonbinding referendum would essentially open up the public hearing phase of legislation to the country, while leaving the lawmaking details and final exercise of policy judgments to Congress.[341] Moreover, as an empirical matter, representative bodies often do follow the results of nonbinding referendums, a fact that suggests their persuasive effect on elected officials is tangible.[342] Carrying out such referendums in conjunction with each presidential election would promote relatively high turnout and public interest and limit the potential for strategic timing of referendums.[343]

The most powerful tools for bringing about effective and open technology assessment would involve stronger incentives for technology developers to consider public concerns, including health and environmental risks. First, technology assessment and public involvement should be included as criteria for awarding research grants. The National Science Foundation (NSF), for example, considers both the "intellectual merit" and the "broader impacts" of proposed research in reviewing research grant proposals.[344] Under the "broader impacts

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[339] *See* CRONIN, *supra* note 337, at 179.

[340] *See* David Butler & Austin Ranney, *Theory*, *in* REFERENDUMS: A COMPARATIVE STUDY OF PRACTICE AND THEORY 23, 30 (David Butler & Austin Ranney eds., 1978) (explaining how referendums can bring policymaking and political decisions psychologically closer to the people); CRONIN, *supra* note 337, at 87-89 (noting need for ingenuity in efforts to interest and inform voters, while concluding that "[v]oters who do vote on ballot measures do so more responsibly and intelligently than we have any right to expect"); *see also* MAIJA SETÄLÄ, REFERENDUMS AND DEMOCRATIC GOVERNMENT: NORMATIVE THEORY AND THE ANALYSIS OF INSTITUTIONS 165 (1999) (suggesting that "referendums offer the increasing number of citizens outside party organisations and without strong party identification an opportunity to participate in decision-making without the mediation of the parties").

[341] *See* CRONIN, *supra* note 337, at 178.

[342] *See* Setälä, *supra* note 334, at 713-14.

[343] Where candidate choices and referendum propositions are on the same ballot, there is on average a fifteen percentage point drop-off in the proportion of voters casting ballots on the latter as compared with the former. *See* Butler & Ranney, *supra* note 334, at 16. However, propositions involving controversial or highly visible issues may attract higher levels of voting. CRONIN, *supra* note 337, at 67-69.

[344] Robert Frodeman & Jonathan Parker, *Intellectual Merit and Broader Impact: The National Science Foundation's Broader Impacts Criterion and the Question of Peer Review*, 23 SOC. EPISTEMOLOGY 337, 339 (2009). The federal government funds over one-quarter of research and development expenditures in the United States. Mark Boroush,

criterion" (BIC), the NSF considers whether a proposal would "promot[e] teaching, training and learning," "broaden the participation of underrepresented groups," "enhance the infrastructure for research and education," enhance scientific understanding, and provide benefits to society.[345] In theory, the BIC could be a means of evaluating a research proposal's incorporation of public participation and the social and environmental implications of such research. But application of the BIC has run into deep-rooted resistance among researchers and reviewers in the scientific community.[346] In practice, the BIC is often treated as a relatively unimportant criterion that can be fulfilled merely by hiring educational professionals to disseminate information to the general public.[347] Such a limited conception of the BIC not only fails to encourage scientists to involve the public in the process of technology research and development; it also fails to transform how the scientists think about their research and its broader societal implications.[348] Including social scientists on proposal review panels would be one way of facilitating an expanded understanding of the BIC and ensuring that it plays a role in government research funding decisions.[349] Another way to make the BIC more effective and to encourage reflexivity within the scientific community would be for NSF to amend its grant proposal

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New NSF Estimates Indicate that U.S. R&D Spending Continued to Grow in 2008, INFOBRIEF, Jan. 2010, *available at* http://www.nsf.gov/statistics/infbrief/nsf10312; *see also* Corley et al., *supra* note 316, at 1577 (discussing survey finding that nanotechnology researchers rely heavily on government grants).

345 NAT'L SCI. FOUND., OMB CONTROL NO. 3145-0058, PROPOSAL AND AWARD POLICIES AND PROCEDURES GUIDE pt. I, ch. II, at 8 (2009); NAT'L SCI. FOUND., MERIT REVIEW BROADER IMPACTS CRITERION: REPRESENTATIVE ACTIVITIES (2007), *available at* http://www.nsf.gov/pubs/gpg/broaderimpacts.pdf.

346 Holbrook, *supra* note 165, at 437-48 (describing difficulties encountered in applying BIC and suggesting that difficulties reflect basic philosophical differences regarding the relevance of broader social considerations to "pure" scientific research).

347 Frodeman & Parker, *supra* note 344, at 340-41 ("BIC is not simply an education and public outreach . . . criterion—but it generally gets (mis)interpreted in this way."); Robert Frodeman & J. Britt Holbrook, *Science's Social Effects*, ISSUES SCI. & TECH., Spring 2007, at 28, 28.

348 Frodeman & Holbrook, *supra* note 347, at 28 (observing that such an approach to BIC "emphasize[s] a triumphalist view" of science and technology and that it "does not reflect on the larger moral, political, and policy implications of the advance of scientific knowledge and technological capabilities").

349 *Id.* at 30; *see also* Frodeman & Parker, *supra* note 344, at 342 (advocating interaction between scientists and researchers on science, technology, and society at all stages of research).

guidance to explicitly state the importance of consulting with the public and considering a broader range of impacts.[350]

Finally, it is essential to put incentives in place to hold technology developers responsible for the adverse health and environmental effects of their products. An important step towards this goal would be to require greater disclosure to increase social awareness of emerging technologies and their uses. Labeling foods that contain GMOs or products that incorporate nanotechnology can enable more informed consumer choices, increase general public awareness of new technologies, and reduce barriers to holding manufacturers legally responsible for adverse consequences caused by their products.[351] Additional measures will likely be necessary, however, to create stronger incentives further upstream in the technology development process. One such measure could impose liability under tort law for "foreseeably unforeseeable" consequences of new technologies.[352] Or, as I have contended elsewhere with respect to products containing nanomaterials, environmental assurance bonding can be a suitable policy tool to address situations where health and environmental risks are substantially uncertain.[353] Requiring companies that introduce new technologies in such circumstances to post bonds helps to assure "the existence of funds to pay for damages that are subsequently discovered," without blocking new technologies from entering the market.[354] Bonding requirements also give companies an economic incentive to undertake research to demonstrate that their products are safe.[355] The prospect of reducing or releasing the bond would prompt companies to support technology assessment more actively—by conducting assessments themselves or by facilitating government or independent third-party assessments. Environmental assurance bonding ultimately offers, as Doug Kysar has argued, a "pragmatic combination of respect for the power of

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[350] *Cf.* Rip, *supra* note 170, at 150-55 (recommending interactions between different types of actors in order to increase reflexivity in development of nanotechnology).

[351] Lin, *supra* note 52, at 393-94.

[352] *See* Owen, *supra* note 2, at 609-10 (suggesting that such liability should be limited "to situations where industry has recklessly let loose untested new technology with frightening potential consequences").

[353] Lin, *supra* note 52, at 397-404.

[354] *Id.* at 398-99.

[355] *Id.*

markets and human technology, and caution before the complexities of nature."[356]

CONCLUSION

Transforming our approach to emerging technologies to integrate more thorough assessment and greater public participation into the ongoing process of technology management will not be easy. By their very nature, emerging technologies often defy prediction regarding their developmental paths, applications, and adverse consequences. Furthermore, the approach advocated here runs counter to cultural norms that celebrate innovation, scientific paradigms that emphasize freedom of inquiry and expert peer review, and political discourse that demands scientific certainty as a prerequisite for regulatory oversight. Yet to continue with our current approach would be narrow, shortsighted, and unrepresentative. At the very least, the government can take modest steps towards taking technology assessment seriously by reconstituting the OTA and revisiting NEPA's potential as a tool for meaningful planning and participation in technology matters. Transforming our relationships with emerging technologies, however, will require more radical mechanisms to incorporate citizen participation and to compel thoughtful and responsible technology development. Ultimately, citizens must take an active role in the management of emerging technologies by informing themselves on the issues, participating in assessment and management processes, and demanding that their representatives exercise effective oversight.

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[356] Douglas A. Kysar, *Ecologic: Nanotechnology, Environmental Assurance Bonding, and Symmetric Humility*, 28 UCLA J. ENVTL. L. & POL'Y 201, 208-09 (2010).