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TECHNOLOGY-BASED? COST FACTORING IN U.S. ENVIRONMENTAL STANDARDS

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Abstract

Environmental controls in the United States are often said to be "technology-based" because the polluter's duties are determined by the available technology for controlling that pollution rather than by the social costs and benefits of doing so. Indeed, this is much of what distinguishes U.S. environmental law post-1970 from that which preceded it. But technology-based standards have in fact weighed the costs of controlling pollution in unique, often obscure ways, yielding an analysis that defies standardization and basic notions of transparency. Often lumped under an umbrella heading called "feasibility" analysis and justified on the grounds that it avoids many of the known pitfalls of cost-benefit analysis, the factoring of cost into technology assessments hands our Environmental Protection Agency a uniquely hard problem of prediction: the inducement of innovation. This Article traces the evolution of the practice to the state of the art today, offers several clarifications upon reflection, and suggests that cost estimation in technology-based standard setting is actually more likely to be a useful decision input than the orthodox cost-benefit balancing procedures. Most importantly, it is more likely to accurately assess the possibilities of inducing innovation—accuracy that is increasingly vital to meeting environmental challenges like climate change.

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Introduction

Pollution control standards in the U.S. are prototypically some function of the solutions that are "available" or "achievable," not of how much pollution is optimal in balancing benefits and costs. This has long drawn economists' ire because optimizing benefits and costs just sounds rational.[1] Indeed, if the allure of the American approach has been its embodiment of a "best efforts" mandate to reduce pollution at manageable cost,[2] it can diverge considerably from the broadest accounts of economic efficiency.[3] The Clean Air Act (CAA) and Clean Water Act (CWA) together impose more than a dozen requirements that polluters control to the degree the U.S. Environmental Protection Agency (EPA) (or its delegate) finds achievable, and many other statutes add requirements as well.[4] Variation is the norm, but the core feature of such "technology-based" standards is that they constrain independent of environmental benefit or of marginal cost—at least to a degree.[5] This is what makes a pollution standard technology-based. Yet most of these mandates reach for solutions that are, in some sense, *cost-available* to the regulated parties—an indefinite qualification further complicating an already complex regulatory tool.[6] Indeed, the intersection of cost and technology in these settings has been uniquely problematic given the dynamic properties of a mature economy.[7] The question has long been whether or not such policies can *improve* the technologies of production and

1. "Cost-benefit" balancing has a deep history in government. *See* Theodore M. Porter, Trust in Numbers: The Pursuit of Objectivity in Science and Public Life 148-90 (1997). In its more informal versions cost-benefit balancing might even seem to epitomize practical reason. *See, e.g.*, White Stallion Energy Ctr., LLC v. EPA, 748 F.3d 1222, 1260-63 (D.C. Cir. 2014) (Kavanaugh, J., dissenting). But the recent turn toward formal, professionalized cost-benefit analysis in regulation has provoked a pointed and well-developed opposition. *See* Amy Sinden, *Formality and Informality in Cost-Benefit Analysis*, 2015 Utah L. Rev. 93 (2015); *infra* notes 33-52 and accompanying text.

2. *See, e.g.*, James E. Krier & Edmund Ursin, Pollution and Policy 26 (1977); Allen V. Kneese & Charles L. Schultze, Pollution, Prices, and Public Policy 51-57, 69-84 (1975).

3. *Cf.* David A. Weisbach, *Distributionally Weighted Cost-Benefit Analysis: Welfare Economics Meets Organizational Design*, 7 J. Legal Analysis 151, 154 (2015) ("Unweighted cost-benefit analysis is a command to maximize efficiency."); *see also* Note, *Technology-Based Emission and Effluent Standards and the Achievement of Ambient Environmental Objectives*, 91 Yale L.J. 792, 793 (1982) (critiquing CAA and CWA for their supposed inefficiencies).

4. *See infra* notes 54-149 and accompanying text.

5. *See infra* notes 51-53 and accompanying text.

6. *See infra* notes 178-207 and accompanying text.

7. *See* David M. Driesen, The Economic Dynamics of Environmental Law 93-135 (2003); *see infra* notes 209-214 and accompanying text.

consumption.[8] Despite sustained and eclectic efforts, it has evaded rigorous answer.[9]

Orthodox economics has long emphasized the importance of technological change to productivity gains.[10] But the constant search for innovations maximizing profits—or minimizing costs—confounds straight-line thinking. The conventional methods have routinely over-estimated regulation costs[11]—so much so that deeper questions surrounding their concept of *cost*[12] are at least implicated.[13] Indeed, several critiques[14] have sustained widespread skepticism of those methods' overall justification.[15] Costs may necessarily be something to avoid, but which costs are worth avoiding has

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8. *See, e.g.*, Robert M. Solow, *Technical Change and the Aggregate Production Function*, 39 REV. ECON. & STATS. 312 (1957); JOSEPH A. SCHUMPETER, THE THEORY OF ECONOMIC DEVELOPMENT (1934).

9. *See* Wesley M. Cohen, *Fifty Years of Empirical Studies of Innovative Activity and Performance*, *in* 1 HANDBOOK ON THE ECONOMICS OF INNOVATION 129, 134-35 (Bronwyn H. Hall & Nathan Rosenberg eds., 2010); Wesley M. Cohen & Richard C. Levin, *Empirical Studies of Innovation and Market Structure*, *in* 2 HANDBOOK OF INDUSTRIAL ORGANIZATION 1059, 1062-66 (Richard Schmalensee & R.D. Willig eds., 1989); NATHAN ROSENBERG, INSIDE THE BLACK BOX: TECHNOLOGY AND ECONOMICS (1982).

10. *See, e.g.*, J. Fred Weston, *The Profit Concept and Theory: A Restatement*, 62 J. POL ECON. 152, 155 (1954) (calling innovations and exogenous changes two principal determinants of uncertainty and uncertainty the principal source of profits).

11. In one noted *ex post* assessment of regulatory cost estimates, Harrington and colleagues found that costs were much more likely to be over- than under-estimated because most of the analyses studied "ignore[d] the possibility of technological innovation. . . . Technical change is, after all, notoriously difficult to forecast; all that can be said with confidence, based on historical experience, is that the cost of compliance will likely decline, but no one can say at what rate." Winston Harrington et al., *On the Accuracy of Regulatory Cost Estimates*, 19 J. POL'Y ANALYSIS & MGMT. 297, 309 (2000). Cost over-estimations in regulatory impact analyses (RIAs) were first revealed by retrospective studies some two decades ago. *See, e.g.*, Thomas O. McGarity & Ruth Ruttenberg, *Counting the Cost of Health, Safety, and Environmental Regulation*, 80 TEX. L. REV. 1997, 1998-99 (1998) (finding vast overestimation of costs in influential studies attributable to dubious assumptions about cost avoidance); Lisa Heinzerling, *Regulatory Costs of Mythic Proportions*, 107 YALE L.J. 1981, 1998 (1998) (same).

12. For a critical, full spectrum account of economics' orthodoxy and its deepening methodological troubles, *see* TONY LAWSON, ECONOMICS AND REALITY (1997); TONY LAWSON, REORIENTING ECONOMICS (2003); *see also* MARK BLAUG, ECONOMIC THEORY IN RETROSPECT 1-8 (5th ed. 1997). "[T]he striking fact about the history of economics is how often economists have violated both their own and later methodological prescriptions." *Id.* at 690. On the specific problem of a theory of cost, *see* Robert Cooter, *The Cost of Coase*, 11 J. LEGAL STUDS. 1 (1982).

13. *See infra* notes 215-231 and accompanying text.

14. *See, e.g.*, R.G. Lipsey & Kelvin Lancaster, *The General Theory of Second Best*, 24 REV. ECON. STUDS. 11 (1956) (showing a convergence of critiques of welfare economics optimization and concluding that departing from any of its conditions in response can entail suspending all of them to improve anyone's welfare).

15. *See* Sinden, *supra* note 1, at 104-08 (noting there are many issues in assigning values, such as monetizing nonmarket goods and the declining value of money).

grown unremittingly contested in economics.[16] In the view of many, innovation is a principal source of the uncertainty.[17] Prevailing orthodoxy casts technological change as an autonomous function of time—immune to policy change. Yet costs in business are the enemy of profits. If they can be avoided by technical progress, that will be the firm's pursuit.[18] Thus, for as long as technology-based standards have been condemned for their inefficiencies, it has been conceded that they *might* ultimately achieve superior cost minimization simply by inducing innovation.[19] And as cost-benefit analysis has shouldered more duties in our administrative state, innovation's role in cost factoring has become its foil.[20]

The unfocused approach we have taken to this nexus has left too much to chance. Technology-based standard setting is as far from a theory of inducing innovation today as it was four decades ago.[21] This article makes the case that technology-based standards, though still a bit of a muddle, can create clearer paths to consensus actions on long-lived, broad-scale environmental challenges like climate change. Were it finally to resolve some basic assumptions and methodological priors, *induced cost-avoidance* might be able to navigate the uncertainties mentioned above in ways far superior to orthodox cost-benefit analysis.[22] Especially in bigger picture cost factoring, *e.g.*, the social costs of carbon, this misapprehension of cost is becoming an urgent problem in the pursuit of environmental quality.[23] Equilibrium model-

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16. *See, e.g.*, Lee Anne Fennell, *The Problem of Resource Access*, 126 HARV. L. REV. 1471, 1483-87 (2013).

17. *See infra* note 42 and accompanying text.

18. Pursuing, of course, is not the same thing as attaining. *See infra* notes 210-14 and accompanying text.

19. *See, e.g.*, Note, *Technology-Based*, *supra* note 3, at 799 ("It is conceivable that a pollution abatement program that is not cost-effective in the short run could produce least-cost long-term results by forcing the development of superior abatement technology, and thereby minimizing the aggregate long-term costs of compliance with environmental regulations."); KNEESE & SCHULTZE, *supra* note 2, at 82 ("Over the long haul, perhaps the most important single criterion on which to judge environmental policies is the extent to which they spur new technology toward the efficient conservation of environmental quality.").

20. *See* Timothy F. Malloy, *Regulating by Incentives: Myths, Models, and Micromarkets*, 80 TEX. L. REV. 531, 547 (2002) ("Despite the attention given to innovation and regulation . . . there is surprisingly little empirical support for the proposition that either [pollution] trading or [conventional] regulation actually leads to continuous and systematic innovation.").

21. To be sure, design, performance and goal standards all allocate freedoms differently and can make real differences in markets for innovation. Because the technology-based standards examined herein overwhelmingly take the form of performance standards, however, we contrast that form with other, more immediately market-facing tools like taxes and allowances.

22. *See infra* notes 277-99 and accompanying text.

23. *See* NATIONAL ACADEMIES OF SCIENCES, ENGINEERING & MEDICINE, REPORT—VALUING CLIMATE DAMAGES: UPDATING ESTIMATION OF THE SOCIAL COST OF CARBON DIOXIDE 3-11 (2017).

ing of policy costs and benefits lacks even a modicum of accuracy if we cannot predict the direction or pace of technological innovations rearranging costs and benefits over whatever interval is in question.[24]

Part I argues that the economics of inducing innovation has failed to yield any general guidance regarding regulatory choice while Part II introduces what little legal doctrine governs our technology-based approach. Part III sets out the microeconomics of production and what we should be looking for in understanding cost-availability. Finally, Part IV uses two recent case studies to test some of the observations made in Parts II and III.

I. An Economics of Inducing Innovation?

The economist John Hicks first hypothesized "induced innovation," *i.e.*, that "a change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind—directed to economizing the use of a factor which has become relatively expensive."[25] Hicks spoke of labor costs. But scarcity—or, really, production constraints of any kind—can provide the inducement.[26] Orthodox economics views factors of production like labor and capital as fungible[27] and this has long complicated its very notion of *cost*.[28] Vital inputs like energy services sometimes fluctuate wildly in price to negligible overall effect.[29] Still, if innovation can be induced, the costs of regulation become a cryptic target. Since 2000, EPA's

24. Typically, probabilities are used to round out any model's parameters—decisions that not even economists can agree make much sense. *See* Itzhak Gilboa et al., *Probability and Uncertainty in Economic Modeling*, 22 J. Econ. Persp. 173 (2008); Martin L. Weitzman, *On Modeling and Interpreting the Economics of Catastrophic Climate Change*, 91 Rev. Econ. & Stats. 1, 2-6 (2009). The more parameterized any cost estimation, the more likely it is to make internally contradictory assumptions about human behavior, markets, information flows, and, ultimately, about innovation itself. *See infra* notes 226-28 and accompanying text.

25. John R. Hicks, The Theory of Wages 124-25 (1932).

26. *See, e.g.*, Julian L. Simon, The Ultimate Resource (1981) (arguing that scarcity accesses the most vital of all resources—human ingenuity).

27. *See* R.H. Coase, *The Institutional Structure of Production*, 82 Amer. Econ. Rev. 713, 713-14 (1992). Note, though, that production factors are often *not* divisible or substitutable. *See* Nicholas Georgescu-Roegen, *The Economics of Production*, 60 Am. Econ. Rev. 1, 8-9 (1970); *see infra* note 229 and accompanying text.

28. Depending on whether the focus is social utility and welfare, production/consumption functions, the theory of choice, or something else, economics' concept of "cost" bears very different meanings. *See* I.M.D. Little, A Critique of Welfare Economics (2d ed. 1957). The term "social cost" has long fared even worse. *See* Frank H. Knight, *Some Fallacies in the Interpretation of Social Cost*, 38 Q.J. Econ. 582, 584 (1924); Donald H. Regan, *The Problem of Social Cost Revisited*, 15 J.L. & Econ. 427 (1972); *infra* note 165 and accompanying text.

29. *See* David Popp et al., *Energy, the Environment, and Technological Change*, *in* 2 Handbook on the Economics of Innovation 873, 874, 883 (Bronwyn H. Hall & Nathan Rosenberg eds., 2010).

own general guidance on "economic" analysis has acknowledged the dilemma that estimating the costs that will result from any regulation entails estimating future technical change.[30] If firms can adjust their factors of production in response to external constraints, then the longer the time horizon in the estimate, the more likely it should include cost-avoidance efforts by affected firms.[31] Even during the earliest work on technology-based standard setting, this influence on the market for innovation that the standard itself exerts was a serious issue.[32] It has remained so ever since.[33]

Consider a hypothetical industry sector, *X*, comprised of three firms. One firm, *A*, is relatively diversified, having three lines of business, *X*, *Y*, and *Z*. A second firm, *B*, has only two of those business lines, *X* and *Y*. A third firm, *C*, is only in the business of *X*. Now suppose that, at prevailing prices, *A*'s two *profitable* lines of business are *Y* and *Z* but that it is losing money on *X*; that *B*'s only profitable business is *X*; and that *C* is just breaking even. (In some sense, *B* is outcompeting *A* and *C* (as to *X*).)

Assuming these firms comprise industry sector *X* and assuming the sector faces a new production constraint like a pollution control measure, any projection of the *sector's* costs will be uncertain—perhaps deeply so. The economic orthodoxy assumes that innovation allowing *X*'s production by nonpolluting means minimizes "social" costs while regulation protecting those *X* is polluting merely *transfers* costs.[34] A "static" analysis of the situation, though, does not even approximate an account of *X* as a competitive

30. *Cf.* U.S. EPA, EPA 240-R-00-003, GUIDELINES FOR PREPARING ECONOMIC ANALYSES 124-25 (2000) [hereinafter 2000 GUIDELINES], (acknowledging that "[b]enefit-cost models must predict what actions firms are likely to choose when attempting to comply with a new policy and what the compliance costs of those actions will be" but that those are likely to overestimate costs because firms can substitute away from the burdened production factors).

31. *See* U.S. EPA, GUIDELINES FOR PREPARING ECONOMIC ANALYSES 2010 8.3.1.1 (rev. ed. 2014) (2010) [hereinafter 2010 GUIDELINES]. Similar treatments of the issue date to the 2000 GUIDELINES—despite their supposedly exhaustive coverage. *Cf.* Michael A. Livermore, *Cost-Benefit Analysis and Agency Independence*, 81 U. CHICAGO L. REV. 609, 645 (2014) (noting that the "guidelines adopted by EPA in 2000 represented the first genuinely complete benefit-cost manual" and that "peer review played an important role" in their development).

32. *See* Nicholas A. Ashford et al., *Using Regulation to Change the Market for Innovation*, 9 HARV. ENVTL. L. REV. 419, 420-22 (1985); KNEESE & SCHULTZE, *supra* note 2, at 82 ("Any attempt to specify the costs of reducing air and water pollution is handicapped by the need to make some assumptions about technology.").

33. *Cf.* Adam M. Finkel, *The Cost of Nothing Trumps the Value of Everything: The Failure of Regulatory Economics to Keep Pace with Improvements in Quantitative Risk Analysis*, 4 MICH. J. ENVTL. & ADMIN. L. 91, 119 (2014) ("[R]isks are elusive, but at least they are not capable of intentionally changing their size, whereas costs can increase or decrease strategically and perhaps even in response to being studied!").

34. *See, e.g.*, PAUL A. SAMUELSON & WILLIAM D. NORDHAUS, ECONOMICS 126-30 (19th ed. 2009); E.J. MISHAN & EUSTON QUAH, COST BENEFIT ANALYSIS 99-118 (5th ed. 2007); CHARLES D. KOLSTAD, ENVIRONMENTAL ECONOMICS 271-72 (1999).

sector over time.[35] Competition entails minimizing costs.[36] Regulation adding costs to *X*'s production might spur (1) consolidation, *e.g.*, *A* and *C* sellout to *B*; (2) a market contraction, *e.g.*, demand decreases from a price increase; (3) innovations reordering *A*, *B*, and/or *C*'s factors of production; (4) new entrants replacing the incumbents; or (5) some combination of the above. A law putting *A* out of the business, however, saves *A* its operating losses from *X*.[37] A law compelling *A*, *B*, and *C* to buy a solution owned by *D* makes *D* profits.[38] And a duty that is cheaper for *C* to fulfill than *A* and *B* could allow *C* to outcompete them. So which of the foregoing will actually minimize all "costs"? Which is more probable in context? Should the costs of producing *X* be considered on average or at the margin? When should we evaluate them and for what interval? How competitive is *X*? Can any of the incumbents pass along added costs through a price increase? Despite the prevalence of its own technology-based standard-setting duties and decades of experience with estimating costs, EPA's generic guidance on "economic" analysis offers no insight into these questions. The vast majority of its

35. *See* Coase, *supra* note 27, at 717-18 (observing that moving from a zero transaction cost world to the real world instantly highlights legal entitlements, transaction costs, extant industrial organization, and other distortions); BURTON H. KLEIN, DYNAMIC ECONOMICS 20-24 (1977) (contrasting static and dynamic conceptions of efficiency); Herbert Hovenkamp, *Rationality in Law & Economics*, 60 GEO. WASH. L. REV. 293, 306-09 (1992) (applying Coase's hypotheses to bilateral monopoly contexts with results diverging from fictionalized accounts of perfectly competitive, equilibrating markets). EPA's most recent manual steers its analysts to "partial" equilibrium analysis, *i.e.*, the use of firms' compliance costs as the principal determinant of a regulation's "social costs," over what it casts as the more onerous "general" equilibrium analysis whenever "the scope of a regulation is limited to a single sector, or to a small number of sectors." *See* 2010 GUIDELINES, *supra* note 31, at § 8. Even that more limited form of inquiry should take account of cost avoidance, though.

36. *See* ALFRED MARSHALL, 1 PRINCIPLES OF ECONOMICS 328-68 (1890) (explaining increasing vertical integration as larger firms' capacities to minimize costs and maximize returns to scale); FRANK H. KNIGHT, RISK, UNCERTAINTY, AND PROFIT 308 (1921) (arguing that the entrepreneur is paid "the remainder out of the value realized from the sale of product after the deduction of the values of all factors in production which can be valued"); ARTHUR C. PIGOU, THE ECONOMICS OF WELFARE 329-35 (4th ed. 1952) (so-called externalities are externalized just to enhance profitability); MICHAEL E. PORTER, COMPETITIVE ADVANTAGE: CREATING AND SUSTAINING SUPERIOR PERFORMANCE 62-118 (1985) (focusing on firm costs).

37. In this connection it is illustrative that standard cost-benefit analysis wavers over the characterization of job losses as costs or benefits. *See* Ann E. Ferris & Al McGartland, *A Research Agenda for Improving the Treatment of Employment Impacts in Regulatory Impact Analysis*, *in* DOES REGULATION KILL JOBS? 170, 170-72 (Cary Coglianese et al. eds., 2013).

38. *See* Ashford et al., *supra* note 32, at 427. Profit should not exist in the world of equilibrium economics—even though it surely is what motivates real economic actors. *See* Weston, *supra* note 10, at 154 (calling profit a "nonfunctional" component of the standard theory); *see infra* notes 286-89 and accompanying text.

source literature is of the simple "cost-of-compliance" variety.[39] The vagueness of the economic concept of *cost*, coupled with the deep uncertainties of inducing innovation, may explain EPA's reticence.[40] But this should no longer suffice in a climate where regulation's costs loom so large.

The bulk of the work at this front has aimed to show that one type of regulatory tool or another is a better inducement to innovation and, thus, net social cost minimization.[41] But if cost estimation is as dependent upon the time slices and contexts under study as suggested above, then necessarily there is *some* chance that *any* environmental control might be innovation-inducing, at least *a priori*.[42] Consider three standard tools: *Rule 1* prohibiting pollution above a set mass per unit of output;[43] *Rule 2* taxing

39. *See* William A. Pizer & Raymond Kopp, *Calculating the Costs of Environmental Regulation*, *in* 3 HANDBOOK OF ENVIRONMENTAL ECONOMICS 1307, 1311-19 (Karl-Göran Mäler & Jeffrey R. Vincent eds., 2005). EPA's separation of "partial" equilibrium (wherein sectoral compliance costs are proxies for social costs) from "general" equilibrium approaches (wherein distortions like regulation are eventually assimilated into a wider economic equilibrium) is unalloyed to any indication of which is more likely *correct* in given circumstances. *See* 2010 GUIDELINES, *supra* note 31, at § 8.1. The source literature on which EPA relied noted that estimating technological change was the "most challenging" future work in estimating regulation's costs and that, though *much* more common, "partial" equilibrium analyses are generally inferior to "general" equilibrium analysis. *See* Pizer & Kopp, *supra* note 39, at 1343-44. Pizer and Kopp dismiss the "engineering approach" described below as "problematic when applied on a broad scale." *Id.* at 1312. Yet they also admit that partial equilibrium analysis is "wrong" when it misses "general equilibrium changes in output and prices and miss[es] potential welfare changes from altered production levels and distortions in other markets." *Id.* at 1326.

40. *Cf.* Finkel, *supra* note 33, at 118-21 (describing a general problem, with EPA included, of a failure or refusal to report uncertainties in cost estimates); Cooter, *supra* note 12, at 20-24 (arguing that costs accrued from trading cannot be estimated accurately without first knowing the strategic nature of the situation).

41. *See* Nathaniel O. Keohane et al., *The Choice of Regulatory Instruments in Environmental Policy*, 22 HARV. ENVTL. L. REV. 313, 319-25, 347-62 (1998) (summarizing literature). In fact, neoclassical economics' attention to environmental policy has remained anchored to a caricature of technology-forcing standards and the claim that they are not efficiency-maximizing.

42. *See* Yoram Bauman et al., *Does Technological Innovation Really Reduce Marginal Abatement Costs? Some Theory, Algebraic Evidence and Policy Implications*, 40 ENVTL. RESOURCE ECON. 507 (2008); DRIESEN, *supra* note 7, at 49-71; Daniel H. Cole & Peter Z. Grossman, *When Is Command-and-Control Efficient? Institutions, Technology, and the Comparative Efficiency of Alternative Regulatory Regimes for Environmental Protection*, 1999 WIS. L. REV. 887, 892-909 (1999); KOLSTAD, *supra* note 34, at 139-46; WILLIAM J. BAUMOL & WALLACE E. OATES, THE THEORY OF ENVIRONMENTAL POLICY 160-69 (2d ed. 1988); Wesley A. Magat, *The Effects of Environmental Regulation on Innovation*, 43 L. & CONTEMP. PROBS. 4 (1979). The related but distinct claim that regulatory costs tend to be *offset* by cost-savings which are prompted in the process, *see* Michael E. Porter & Claas van der Linde, *Toward a New Conception of the Environment-Competitiveness Relationship*, 9 J. ECON. PERSP. 97, 100-05 (1995), is examined below. *See infra* note 185 and accompanying text.

43. *See infra* notes 54-149 and accompanying text.

pollution by masses discharged;[44] and *Rule 3* issuing tradeable pollution allowances to the polluting firms.[45] Let us now assume *B* is the least polluting incumbent. Any of these three tools could conceivably put one/all of the incumbents out of the *X* business quickly or over time and that could change the dynamics considerably.[46] (Even diversified firms are typically positioned to subsidize losing lines of business for only so long and upstart *E* could always out-innovate {*A, B, C* . . .}.) *Rule 3* has remained the focus because, assuming *B*'s willingness to sell, *A* and *C* might compete for *B*'s excess allowances.[47] But why presume *B*'s willingness to sell to *A* or *C*?[48] *Rules 2* or *3* might induce *A*, *C*, or someone else to innovate, but so might *Rule 1*—and more directly. Indeed, any of the rules could, depending on omitted variables or contestable assumptions, prompt a search for new means of producing *X* without the pollution.[49] What will result in fact is too often unknowable *a priori*.[50] Part II introduces the technology-based approach to answering these questions beyond the *a priori*.

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44. *See* William J. Baumol, *On Taxation and the Control of Externalities*, 62 AM. ECON. REV. 307 (1972).

45. *See* J.H. DALES, POLLUTION, PROPERTY & PRICES: AN ESSAY IN POLICY-MAKING AND ECONOMICS (1968).

46. This is necessarily an empirical question. *See generally* Malloy, *supra* note 20, at 541-51. Where Pigovian taxes can easily fail to match incentives with their underlying purpose(s). *See* Peter A. Diamond, *Consumption Externalities and Imperfect Corrective Pricing*, 4 BELL J. ECON. & MGMT. SCI. 526 (1973) (proof demonstrating that corrective taxes often fail to improve welfare given real variabilities) changing what had been a social norm to what is, in effect, a "price" can dramatically alter the expected behaviors. *See, e.g.*, Uri Gneezy & Aldo Rustichini, *A Fine is a Price*, 29 J. LEGAL STUD. 1 (2000).

47. Dales' proposal of a tool like our *Rule 3* has dominated the literature on inducing innovation in pollution control. *See* DANIEL H. COLE, POLLUTION & PROPERTY: COMPARING OWNERSHIP INSTITUTIONS FOR ENVIRONMENTAL PROTECTION 130-53 (2002).

48. *B* could easily envision doing better with *A* and *C* going defunct. Or it might sell these rights to *A* or *C*'s neighbors. Finally, *B* might reserve these rights on the (mistaken) assumption that their value will increase over time. *See, e.g.*, Steven C. Salop & David T. Scheffman, *Raising Rivals' Costs*, 73 AM. ECON. REV. 267 (1983).

49. *See* DRIESEN, *supra* note 7, at 193-201. Whether the search ultimately benefits regulated incumbents, their vendor(s), or an upstart competitor, the cost outcome is the same—unless (as is often done) asymmetric assumptions are made about the subject markets. *See, e.g.*, Magat, *supra* note 42, at 18 ("To the extent that a regulatory agency mandates the widespread adoption of a new technology developed by a firm, the agency creates a widely-expanded market for that firm's innovation. However, given the inherent difficulty in appropriating the benefits from new abatement technology . . . it is highly unlikely that this incentive to innovate could dominate the other disincentives for abatement technology innovation.").

50. In their defense of cost-benefit balancing in financial regulation, Posner and Weyl answer this indictment by acknowledging that *all regulations* "have complex causal effects" and, thus, that all forms of cost estimation are in the same boat, roughly speaking. *See* Eric A. Posner & E. Glen Weyl, *Cost-Benefit Analysis of Financial Regulations: A Response to Criticisms*, 124 YALE L.J.F. 246, 251 (2015). Part IV argues that this may not be the case.

II. Technology's Cost-Availability: A Unique Question

A series of Supreme Court holdings construing the CAA and CWA have made it abundantly clear that how EPA may, must, or must not factor the cost of its standards into those standards is some function of *ad hoc* statutory interpretation as overseen by the judiciary and the Office of Management and Budget (OMB).[51] The executive discretion embodied in these mandates (with others) has long invited various forms of cost-benefit balancing which, since the 1980s, has been carried out by EPA pursuant to a series of executive orders.[52] Still, if all "costs" were equivalent before the law, technology's cost-availability would be just another entry in an overall cost-benefit accounting. And that is assuredly *not* the law.[53] This part summarizes what little legal doctrine has emerged distinguishing technology's cost-availability from cost-benefit optimization. Section A raises the CAA's key practices and Section B the CWA's.

A. *The Clean Air Act: Identifying Cost-Available Control Solutions*

There is some reason to think that if cost is not expressly included in a CAA standard-setting provision where other factors are named, that it should be *excluded* from the decision-making.[54] But in almost five decades, no generic principles have emerged by which the technological possibilities for targeted pollutants or their costs may or must be analyzed Act-wide.[55]

51. *See* Daniel A. Farber, *Taking Costs into Account: Mapping the Boundaries of Judicial and Agency Discretion*, 40 Harv. Envtl. L. Rev. 87 (2016). In this regard, an earlier hope for general "default principles" has dimmed considerably. *Cf.* Cass R. Sunstein, *Cost-Benefit Default Principles*, 99 Mich. L. Rev. 1651, 1667-68 (2001) (propounding five default principles for use with *Chevron* deference in deciding whether agencies may, must, or must not take cost into account). The Court has made this clear with respect to other statutes, too, most notably the Occupational Safety and Health Act. *See* Indus. Union Dep't., AFL-CIO v. Am. Petroleum Inst., 448 U.S. 607 (1980); Am. Textile Mfrs. Inst., Inc. v. Donovan, 452 U.S. 490 (1981). This study is limited to the CAA and CWA.

52. *See* Thomas O. McGarity, Reinventing Rationality: The Role of Regulatory Analysis in the Federal Bureaucracy (1991); Cass R. Sunstein, *The Office of Information and Regulatory Affairs: Myths and Realities*, 126 Harv. L. Rev. 1838 (2013).

53. *See, e.g.*, EPA v. Nat'l Crushed Stone Ass'n, 449 U.S. 64, 71 (1980); Chem. Mfrs. Ass'n v. Nat. Res. Def. Council, Inc., 470 U.S. 116, 129-33 (1985); Patricia Ross McCubbin, *The Risk in Technology-Based Standards*, 16 Duke Envtl. L. & Pol'y F. 1, 6-29 (2005).

54. *See* Whitman v. Am. Trucking Ass'n, 531 U.S. 457, 465-68 (2001) (concluding the analysis of cost as a factor in setting ambient air quality standards by remarking that "Congress . . . does not hide elephants in mouseholes"); *see also* Massachusetts v. EPA, 549 U.S. 497, 532-33 (2007); Honeywell Int'l, Inc. v. EPA, 374 F.3d 1363, 1372-73 (D.C. Cir. 2004).

55. *See, e.g.*, Michigan v. EPA, 135 S. Ct. 2699, 2707 (2015) (concluding that, under the circumstances and as to the exact language in CAA § 112(n)(1)(A), the choice of regulating only if "appropriate and necessary" must include *some* weighing of "cost"); *see also* Train

Of course, technological possibilities and cost have remained tightly linked in the CAA. The CAA, like the CWA, has often been called "technology *forcing*."[56] And the late tug-of-war on the Supreme Court over when costs may or must be factored into various CAA determinations[57] has provoked a voluminous literature that too often conflates technology's cost-availability with overall cost-minimization. While that tug-of-war remains unresolved,[58] it seems unlikely to end in a mandate for plain efficiency maximization.[59] Thus, a few basic points of departure stand out.[60]

CAA standards demanding that pollution be abated to the degree the "available" or "achievable" technology permits include CAA § 111's new source performance standards (NSPSs),[61] CAA § 112's national emission standards for "hazardous air pollutants" (HAPs),[62] CAA § 129's solid waste incinerator standards,[63] CAA's § 165's preconstruction requirements,[64] CAA

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v. Nat. Res. Def. Council, 421 U.S. 60, 90-91 (1975) (noting a lower court's holding that denying variances was a way the CAA aimed to "force" the development of technology); Int'l Harvester Co. v. Ruckelshaus, 478 F.2d 615, 629 (D.C. Cir. 1973) (noting that in finding a technology will be "available" when required EPA cannot engage in a "'crystal ball' inquiry" over sound projections that extant technology can be adopted at acceptable cost, can work, and can work reliably).

56. *See Train*, 421 U.S. at 91; *see also* D. Bruce La Pierre, *Technology-Forcing and Federal Environmental Standards Protection Statutes*, 62 IOWA L. REV. 771, 773-74 (1977); Note, *Forcing Technology: The Clean Air Act Experience*, 88 YALE L.J. 1713 (1979). Much of the "technology-forcing" talk of the 1970s was about the CAA's ambient environmental quality goals.

57. *See, e.g.*, EPA v. EME Homer City Gen., L.P., 134 S. Ct. 1584, 1606-07 (2014) (holding EPA may consider costs of abatement in determining which upwind states "contribute significantly" to downwind nonattainment); *Michigan*, 135 S. Ct. at 2707 (holding that EPA must afford "at least some attention to cost" in determining whether it is "appropriate and necessary" to regulate electricity generating boilers' pollution).

58. *See Michigan*, 135 S. Ct. at 2707; *EME Homer City*, 134 S. Ct. at 1603-06; *Massachusetts*, 549 U.S. at 528-35.

59. *But cf.* Richard L. Revesz, *Toward a More Rational Environmental Policy*, 39 HARV. ENVTL. L. REV. 93, 105-06 (2015) (arguing that both *EME Homer City* and *Michigan*, in light of several practical obstacles, aim at cost-minimizing regulation).

60. EPA's 2000 manual cites the executive orders on regulatory impact analysis (RIA) (among others) as their impetus, *see* 2000 GUIDELINES, *supra* note 30, at 5-7, and does not generally distinguish cost-availability analysis from cost evaluations required for RIAs. *Id.* OMB's general guidance, Circular A-4, at least includes the generic disclaimer that "[w]hen a statute establishes a specific regulatory requirement and the agency is considering a more stringent standard, you should examine the benefits and cost of reasonable alternatives that reflect the range of the agency's statutory discretion, including the specific statutory requirement." *See* OFFICE OF MGMT. & BUDGET, CIRCULAR A-4, § C (2003), https://www.whitehouse.gov/omb/circulars_a004_a-4.

61. *See* 42 U.S.C. § 7411(a)(1).

62. *See* 42 U.S.C. § 7412(d).

63. *See* 42 U.S.C. § 7429(a)(2).

64. *See* 42 U.S.C. § 7475(a).

§ 173's nonattainment permit requirements,[65] CAA § 111(d)'s residual existing source standards,[66] CAA § 202(a)(3)'s new motor vehicle standards,[67] CAA § 211's reformulated gasoline standards for nonattainment areas,[68] and CAA § 407(b)'s nitrogen oxides utility boiler controls.[69] The practical accessibility of various input, process, and/or capital changes has yielded a tangled web of precedents construing these mandates.

Where cost is a choice factor, distinctions typically emerge between potential solutions based on their (perceived) practicality.[70] Several common confusions usually follow not far behind. For a standard of performance to be practicable or *cost-available* it must somehow be within the financial reach of the targeted polluter(s). Cost-availability of this kind can be estimated with respect to a single firm, facility, or stack—or it can be estimated as to whole industrial sectors.[71] What is cost-available on average across a whole sector obviously differs from that of a single facility or firm. Regardless of whether the fit is from site-to-solution or from sector-to-solution where site idiosyncrasies are ignored,[72] cost avoidance remains the focal concern.[73]

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65. *See* 42 U.S.C. §§ 7501(3), 7503(a). CAA § 172 also requires all implementation plans in nonattainment areas to require "reasonably available control technology" of all existing sources. *Id.* at § 7502(c)(1).

66. *See* 42 U.S.C. § 7411(d).

67. *See* 42 U.S.C. § 7521(a)(3).

68. *See* 42 U.S.C. § 7545(c)(2)(A).

69. *See* 42 U.S.C. § 7651f(b)(1).

70. *See, e.g.*, EPA v. EME Homer City Gen., L.P., 134 S. Ct. 1584, 1603-06; Sierra Club v. EPA, 479 F.3d 875, 877-80 (D.C. Cir. 2007); Bluewater Network v. EPA, 372 F.3d 404, 410-11 (D.C. Cir. 2004); Ne. Md. Waste Disposal Auth. V. EPA, 358 F.3d 936, 944-47 (D.C. Cir. 2004); Sierra Club v. EPA, 325 F.3d 374, 377-79 (D.C. Cir.2003); Nat'l Petroleum Refiners Ass'n v. EPA, 287 F.3d 1130, 1139-46 (D.C. Cir. 2002); Husqvarna AB v. EPA, 254 F.3d 195, 201 (D.C. Cir. 2001); Nat'l Lime Ass'n v. EPA, 233 F.3d 625, 629-32 (D.C. Cir. 2000); Appalachian Power Co. v. EPA, 135 F.3d 791, 800-03 (D.C. Cir. 1998); Geo. E. Warren Corp. v. EPA, 159 F.3d 616, 623-24 (D.C. Cir. 1998); Nat. Res. Def. Council, Inc. v. Thomas, 805 F.2d 410, 428-34 (D.C. Cir. 1986); Nat. Res. Def. Council, Inc. v. EPA, 655 F.2d 318, 328-32 (D.C. Cir. 1981); Nat'l Lime Ass'n v. EPA, 627 F.2d 416, 429-34 (D.C. Cir. 1980); Essex Chemical Corp. v. Ruckelshaus, 486 F.2d 427, 433-34 (D.C. Cir. 1973); Portland Cement Ass'n v. Ruckelshaus, 486 F.2d 375, 387-88, 391-92 (D. C. Cir. 1973); Int'l Harvester Co. v. Ruckelshaus, 478 F.2d 615, 622-28, 641-43 (D.C. Cir. 1973).

71. In our example above, an end-of-pipe widget at *C*'s *X* facility (which is just breaking even at prevailing prices) could be cost-*un*available while still being deemed cost-available when averaged across the whole sector {*A, B, C . . .*}.

72. *See infra* notes 132-35 and accompanying text.

73. For example, EPA's approach to BACT reviews under CAA § 165(a)(2) has long taken the form of a "top-down method" wherein all possible control techniques are arrayed from most to least effective and assigned to the permit applicant based on an assessment of its financial and other capabilities. *See* John-Mark Stensvaag, *Preventing Significant Deterioration Under the Clean Air Act: The BACT Determination—Part I*, 41 ENVTL. L. REP. 11101, 11105

In *Portland Cement Association v. Ruckelshaus*,[74] the court construed the CAA's notion of "available technology" which is "adequately demonstrated" in an NSPS to reach solutions reasonably *projected* to be available when the standard was to come into effect.[75] One leading casebook called this the "margin for striving," while also observing that later cases left little of that margin to EPA.[76] Because EPA typically formats NSPSs by pollutant masses,[77] the cost-availability of any *conceivable* solution can bear on whether the standard is "achievable."[78] This can mean amending inputs as readily as it can one's process or capital.[79] In its 2015 NSPS for greenhouse gas (GHG) emissions from electric utility generating units (EGUs), for

(2011). Eliminating as "technically infeasible" any option identified by this method has more to do with the applicant's finances than any other consideration. *See* John-Mark Stensvaag, *Preventing Significant Deterioration Under the Clean Air Act: The BACT Determination—Part II*, 42 ENVTL. L. REP. 10024, 10037 (2012).

74. Portland Cement Assoc. v. Ruckelshaus, 486 F.2d 375 (D.C. Cir. 1973).

75. *Id.* at 391-92. After remanding EPA's standard for failing adequately to collect and analyze existing plant data, the panel reiterated its invitation to EPA that it approach "achievability" not by surveying extant industrial arrangements but rather by "extrapolations . . . and on testimony from experts and vendors made part of the record." *Id.* at 402; *see also* Essex Chem. Corp., 486 F.2d at 433. Yet, puzzlingly, the same court also held that "available," "demonstrated" technology was concretely proven technology. *See Essex Chem. Corp.* at 433 ("An adequately demonstrated system is one which has been shown to be reasonably reliable, reasonably efficient, and which can reasonably be expected to serve the interests of pollution control without becoming exorbitantly costly in an economic or environmental way.").

76. *See* ROBERT L. GLICKSMAN ET AL., ENVIRONMENTAL PROTECTION: LAW AND POLICY 483-84 (7th ed. 2015) (citing Nat'l Lime Ass'n v. EPA, 627 F.2d 416 (D.C. Cir. 1980)).

77. The CAA and CWA both allow standards to take multiple forms. *See* 42 U.S.C. § 7602(k) (defining emission limitation and standard to include "a requirement . . . which limits the quantity, rate, or concentration of emissions of air pollutants on a continuous basis, including any requirement relating to the operation or maintenance of a source to assure continuous emission reduction, and any design, equipment, work practice or operational standard"); 33 U.S.C. § 1362(11) (defining effluent limitation to mean "any restriction established . . . on quantities, rates, and concentrations of chemical, physical, biological and other constituents which are discharged from point sources . . . including schedules of compliance").

78. *Cf.* Lignite Energy Council v. EPA, 198 F.3d 930, 933 (D.C. Cir. 1999) (calling industry's argument that another input/process besides EPA's focal metric for setting the standard was "self-defeating" because that technique's availability might render use of EPA's more expensive means unnecessary).

79. *See, e.g.*, Nat'l Lime Ass'n v. EPA, 233 F.3d 625, 632-33 (D.C. Cir. 2000); Sierra Club v. Costle, 657 F.2d 298, 368-73 (D.C. Cir. 1981); *Essex Chem. Corp.*, 486 F.2d at 433. The courts have formulated the standard for weighing costs variously. *See Lignite Energy*, 198 F.3d at 933 ("exorbitant"); *Costle*, 657 F.2d at 383 (not "excessive" or "unreasonable"); New York v. Reilly, 969 F.2d 1147, 1150 (D.C. Cir. 1992) ("Because section 111 does not set forth the weight that should be assigned to [its] factors, we have granted the agency a great degree of discretion in balancing them.").

example, EPA claimed that the courts had endorsed the use of an NSPS to advantage—or at least *to not disadvantage*—nascent technologies not yet widely "demonstrated" in the industry.[80] Indeed, the original NSPS for coal-fired EGUs (long featured in the mountains of literature touting "flexible" tools) permitted either fuel switching or add-on equipment as individual circumstances dictated.[81] All the same, an NSPS can mean sectoral consolidation.[82] NSPS 'availability' is sector-based[83] and, once set, applies only to that sector.[84]

NSPSs were also where EPA first helped individual sources delay the applicability of a sectoral standard indefinitely if their facility updates did not result in new or increased emissions.[85] Providing that safe harbor, EPA maintained, would encourage innovations inside existing facilities' fence lines.[86] Ironically enough, this very set of assumptions gave us the *Chevron*

80. *See* Standards of Performance for Greenhouse Gas Emissions from New, Modified, and Reconstructed Stationary Sources: Electric Utility Generating Units, 80 Fed. Reg. 64,510, 64,537-41 (2015) [hereinafter Final EGU NSPS], (citing Sierra Club v. Costle, 657 F.2d 298, 321 (D.C. Cir. 1981)). This argument entangled EPA in construing a definition of "standard of performance" which Congress twice amended, first to include and then to exclude a set percentage threshold of emission reductions (instead of set cost thresholds). *See id.* at 64537 & n.124. At issue in the EGU GHG NSPS was the "availability" of "carbon capture and sequestration technology." *See infra* notes 252-71 and accompanying text. EPA estimated that its 1971 NSPS added an average of 15.8% in capital costs to the average plant and noted that the courts found that determination "reasonable." *See* Final EGU NSPS, 80 Fed. Reg. at 64,559-60.

81. *See, e.g.*, Bruce A. Ackerman & William T. Hassler, Clean Coal/Dirty Air (1981).

82. *Cf. Lignite Energy Council*, 198 F.3d at 935 (upholding EPA's use of sector-wide estimate of efficiencies on the grounds that EPA was setting a sector-based standard). This will often entail EPA's use of a sector's "baseline" data as available. *See, e.g.*, Nat'l Asphalt Pavement Ass'n v. Train, 539 F.2d 775, 784 (D.C. Cir. 1976) (rejecting industry's argument that many facilities had installed control technology reducing their emissions after the 1967 study on which EPA relied as having "no merit" because EPA used the study to quantify the uncontrolled emissions in the sector).

83. *See Nat'l Asphalt*, 539 F.2d at 786 (noting intervenor firm's claim that EPA's focal "control technologies can be installed and operated at reasonable cost" and that many facilities were prepared to install them); *see also Costle*, 657 F.2d at 330.

84. *See* PPG Indus., Inc. v. Harrison, 660 F.2d 628, 633-37 (5th Cir. 1981) (NSPS for steam generating electric utility boilers not applicable to cogeneration "waste heat" boiler).

85. *See* ASARCO, Inc. v. EPA, 578 F.2d 319, 328-30 (D.C. Cir. 1978) (invalidating flexible "bubble concept" used to define "stationary source" and "modification" for purposes of NSPS applicability on grounds that NSPSs themselves must be set taking cost of technology into account and because the record did not prove that the flexibility would lead to greater improvements than broad applicability of NSPSs); New York v. EPA, 413 F.3d 3, 11-18 (D.C. Cir. 2005) (reviewing history of EPA's definition of "stationary source" and "modification").

86. *Cf.* Nat. Res. Def. Council, Inc. v. Gorsuch, 685 F.2d 718, 725-28 (D.C. Cir. 1982) (rejecting EPA's reasoning for its "bubble concept"), *rev'd sub nom.* Chevron U.S.A., Inc. v. Nat. Res. Def. Council, Inc., 467 U.S. 837, 853-59 (1984). EPA had no proof that innovation

doctrine[87] and now leads routinely to 'arbitrariness' review, especially as to the record EPA compiles and the search it conducts.[88] Its own core guidance document, the *Air Pollution Control Cost Manual*, teaches its personnel that some control equipment investments are so large that vendor data is meaningless even if obtained because the influences on "total capital investment" at some installations are so numerous and diverse that vendors must "design, fabricate, and construct each control according to the specific needs of the facility."[89]

Another set of sectoral standards, the "maximum achievable control technology" (MACT) standards for HAPs, consists firstly of "minimum stringency" primary standards. For new sources, these standards track the performance of the single best-controlled source in that category.[90] For existing sources, they track an average of the best performing sources for which information can be obtained.[91] Cost has become an excluded factor in setting these so-called "MACT floors."[92] Yet with those floors set, EPA then determines, taking cost and other factors into account, whether any better performance is "achievable" in that category (or subcategory)[93] and, if

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would be encouraged by its "bubble" concept. Indeed, the market in question—wholesale electricity—seemed well suited to existing facilities being able to outcompete the NSPS-controlled "new" facilities. The Supreme Court instead treated it as a question of statutory construction. *See Chevron*, 467 U.S. at 858, 863-66.

87. *See* Thomas W. Merrill, *The Story of* Chevron*: The Making of an Accidental Landmark*, 66 ADMIN. L. REV. 253, 260-69 (2014).

88. *See, e.g.*, New York v. Reilly, 969 F.2d 1147, 1150-54 (D.C. Cir. 1992); Nat'l Asphalt Pavement Ass'n v. Train, 539 F.2d 775, 786-87 (D.C. Cir. 1976); Nat. Res. Def. Council, Inc. v. EPA, 863 F.2d 1420, 1431 (9th Cir. 1988); Hooker Chem. & Plastics Corp. v. Train, 537 F.2d 620, 636 (2d Cir. 1976).

89. *See* U.S. EPA, EPA/452/B-02-001, EPA AIR POLLUTION CONTROL COST MANUAL, § 2.5.4.1 (6th ed. 2002). This led to proposals of a "bubble concept" for water pollution control standards for a time too. *See* Emily L. Sherwin, *The Bubble Concept in Water Pollution Control*, 60 B.U. L. REV. 686, 695-96 (1980).

90. CAA § 112 MACT is unconventionally structured into two parallel provisions, § 112(d)(2) and § 112(d)(3), both of which pertain to new and existing sources, each of which defining its own type of stringency anchored in the notion of "achievable." *See* 42 U.S.C. §§ 7412(d)(2)-(3); Cement Kiln Recycling Coal. v. EPA, 255 F.3d 855, 861 (D.C. Cir. 2001).

91. Nat'l Lime Ass'n v. EPA, 233 F.3d 625, 629 (D.C. Cir. 2000) (quoting 42 U.S.C. § 7412(d)(2)-(d)(3)) (describing MACT floors as "minimum stringency" standards that are then followed up by "beyond-the-floor" standards EPA deems "achievable"); ROBERT J. MARTINEAU, JR., *Hazardous Air Pollutants*, *in* THE CLEAN AIR ACT HANDBOOK 227, 246-47 (Robert J. Martineau, Jr. & Robert P. Novello eds., 2d ed. 2004).

92. *See* Ass'n of Battery Recyclers, Inc. v. EPA, 716 F.3d 667, 673 (D.C. Cir. 2013); *Nat'l Lime Ass'n*, 233 F.3d at 640.

93. 42 U.S.C. § 7412(d)(2); Nat'l Ass'n for Surface Finishing v. EPA, 795 F.3d 1, 4-5 (D.C. Cir. 2015).

so, sets a "beyond-the-floor" secondary standard balancing costs against those other factors.[94]

MACT's compound approach has also been interpreted to mean achievable "under most adverse circumstances which can reasonably be expected to recur,"[95] a qualification that has complicated this already complex kind of standard still further.[96] The earliest judicial use of this *hard luck* gloss on achievability, *International Harvester v. Ruckelshaus*,[97] is remembered today for the judges' "diffident"[98] reweighing of the evidence at the behest of incumbent firms crying foul that only one of them could meet EPA's standard and then only in good conditions.[99] Today, EPA's discretion to set the parameters of its search for solutions usually insulates this sort of inquiry from searching review.[100] (And firms calling an achievability finding into

94. Nat. Res. Def. Council, Inc. v. EPA, 749 F.3d 1055, 1057 (D.C. Cir. 2014). If, "taking into consideration the cost of achieving such emission reduction, and any non-air quality health and environmental impacts and energy requirements, [EPA] determines [superior performance] is achievable for new or existing sources in the category or subcategory to which such emission standard applies," 42 U.S.C. § 7412(d)(2), EPA may set a more stringent limit beyond the "minimum stringency" MACT floor.

95. *See* Sierra Club v. EPA, 167 F.3d 658, 665 (D.C. Cir. 1999) (quoting Nat'l Lime Ass'n v. EPA, 627 F.2d 416, 431 n.46 (D.C. Cir. 1980)); *see also* Cement Kiln Recycling Coal. v. EPA, 255 F.3d 855, 859 (D.C. Cir. 2001). *Sierra Club*'s recourse to *National Lime*, a CAA § 111 new source performance standard challenge, ignored the fact that the two "achievability" thresholds functioned very differently in their respective standards. *Cf.* U.S. Sugar Corp. v. EPA, 830 F.3d 579, 606-10 (D.C. Cir. 2016) (distinguishing between what has been "achieved" and what is "achievable"). *Nat'l Lime*'s full account of CAA § 111 achievability was that [t]he statutory standard is one of achievability, given costs. Some aspects of 'achievability' cannot be divorced from consideration of 'costs.' Typically one associates 'costs' with the capital requirements of new technology. However, certain 'costs' (*e.g.*, frequent systemic shutdown to service emissions control systems or use of feedstock of a certain size or composition in order to meet the new emissions standards) are more intimately intertwined with 'achievability' than are the capital costs of new technology.
Nat'l Lime, 627 F.2d at 431 n.46 (citations omitted).

96. *See* Leslie Sue Ritts & Ben Snowden, *The Regulation of Hazardous Air Pollutants*, *in* THE CLEAN AIR ACT HANDBOOK 249, 269-73 (Julie R. Domike & Alec C. Zacaroli eds., 4th ed. 2016). Most add-on equipment today, given generations of testing and improvement in the field, is demonstrably better in reliability, serviceability, and cost-of-operation.

97. Int'l Harvester v. Ruckelshaus, 478 F.2d 615, 637-38 (D.C. Cir. 1973).

98. Judge Leventhal pled the panel's "diffidence" over second-guessing EPA no fewer than four times in his *International Harvester* opinion. Leventhal claimed to be as "diffident" later that year rejecting EPA's cement plant NSPS on the grounds that EPA had insufficiently investigated or analyzed prevailing conditions in reaching its achievability determination. *See* Portland Cement Ass'n v. EPA, 486 F.2d 375, 402 (D.C. Cir. 1973).

99. *See* RICHARD L. REVESZ & MICHAEL A. LIVERMORE, RETAKING RATIONALITY 135 (2008).

100. *See, e.g.*, Nat'l Ass'n of Clean Water Agencies v. EPA, 734 F.3d 1115, 1131 (D.C. Cir. 2013) ("Although EPA would ideally set MACT floors by surveying all existing [sources] and identifying the best performing . . . with hard data, we have not required EPA to go that far, recognizing that 'EPA typically has wide latitude in determining the extent of

question with their own inability to meet that standard rightly face strong headwinds in court.)[101] In the end, even those facing facility-specific technology-based constraints, like CAA § 165's "best available control technology" (BACT) reviews, must sometimes accept that their own factors of production are the real obstacle.[102]

B. *The Clean Water Act: The Meanings of 'Available'*

After *Entergy Corp. v. Riverkeeper, Inc.*,[103] there is some reason to think that the CWA's many different calls for "best" technologies at least *permit* the weighing of a technology's costs.[104] But that is a far cry from inferring, given the Act's many distinct references to technology's availability for various industrial applications (or the vague notion of cost), that a "best" technology mandate reduces to simple efficiency maximization.[105] The Supreme Court has made it too plain for too long that statutory factor balancing is not lightly to be converted into anything else[106] for us to infer so much from *Entergy*.[107]

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data-gathering necessary to solve a problem.'"); *see also* Sierra Club v. EPA, 167 F.3d 658, 662 (D.C. Cir. 1999) (citing Columbia Falls Aluminum Co. v. EPA, 139 F.3d 914, 923 (D.C. Cir. 1998), (using state regulatory data to determine what has been "achieved" in practice).

101. *See, e.g.*, Husqvarna AB v. EPA, 254 F.3d 195, 200-01 (D.C. Cir. 2001) (citing Nat. Res. Def. Council, Inc. v. Thomas, 805 F.2d 410 (D.C. Cir. 1986)); *cf.* BP Expl. & Oil, Inc. v. EPA, 66 F.3d 784, 794 (6th Cir. 1995) (CWA "best available technology" determination).

102. *Cf.* Sierra Club v. EPA, 499 F.3d 653, 657-78 (7th Cir. 2007) (considering a challenge to an EPA BACT review that did not mandate burning low sulfur coal because EPA thought it outside the scope of BACT and calling it a "borderline case" of agency arbitrariness); Alaska Dept. of Envtl. Conservation v. EPA, 540 U.S. 461, 485-96 (2004) (affirming EPA interpretation of BACT review under CAA § 165 as encompassing a "top-down" methodology whereby the best performing techniques, equipment and process modifications are arrayed against the costs to the emitter and only eliminated from consideration if they are cost-prohibitive).

103. Entergy Corp. v. Riverkeeper, Inc., 556 U.S. 208 (2009).

104. *See id.* at 225-26 (holding that the term "best" technology does not necessarily mean the most efficient at producing some good no matter the cost); *cf.* Sierra Club v. Costle, 657 F.2d 298, 325-26 (D.C. Cir. 1981) (interpreting the several factors expressly named in CAA § 111(a)(1) as specifying the meaning of "best" technology).

105. *Cf. Entergy*, 556 U.S. at 237 (Stevens, J., dissenting) ("Unless costs are so high that the best technology is not 'available,' Congress has decided that they are outweighed by the benefits of minimizing adverse environmental impact.").

106. *See, e.g.*, Citizens to Preserve Overton Park v. Volpe, 401 U.S. 402, 418-21 (1971); Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co., 463 U.S. 29, 43-44 (1983); Pension Benefit Guar. Corp. v. LTV Corp., 496 U.S. 633, 644-47 (1990); Massachusetts v. EPA, 549 U.S. 497, 528-35 (2007); Nat'l Ass'n of Homebuilders v. Defs. of Wildlife, 551 U.S. 644, 661-67 (2007).

107. Moreover, as the majority in *Michigan v. EPA* made clear in construing a CAA provision that did not even mention the word "cost," the Supreme Court's notions of "cost"

CWA standards demanding that pollution be abated at least as much as the available technology accomplishes include CWA §§ 301 and 306's "best practicable control technology currently available" (BPT),[108] "best conventional pollutant control technology," (BCT),[109] "best available technology economically achievable" (BATEA)[110] (for *existing* sources) and "best available demonstrated control technology" (BADT)[111] (for *new* point source dischargers).[112] It includes CWA § 307(a)'s toxic pollutant standards,[113] CWA § 316(b)'s "best technology available" standards for cooling water intakes,[114] and CWA § 402(p)'s "maximum extent practicable" standard for municipal and industrial stormwater discharge control.[115]

Early on, reviewing courts held that BPT for categories and classes of existing sources meant "the *average of the best* existing performance by plants of various sizes, ages, and unit processes within each industrial category."[116] And although the search for prevailing technology often extended outside the United States,[117] the cryptic boundaries of these sectors and the averag-

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and weighing costs are far more elastic than orthodox benefit-cost analysis has allowed. *See* Michigan v. EPA, 135 S. Ct. 2699, 2707-08 (2015).

108. *See* 33 U.S.C. § 1311(b)(1)(A).

109. *See* 33 U.S.C. § 1311(b)(2)(E). The so-called BCT "cost test" that arose in the wake of the 1977 amendments grew out of EPA's work to specify the cost of certain benchmark technologies for the common pollutants of total suspended solids, biochemical oxygen demand, and oil and grease. *See* Best Conventional Pollutant Control Technology; Reasonableness of Existing Effluent Limitation Guidelines, 44 Fed. Reg. 50,732 (1979).

110. *See* 33 U.S.C. § 1311(b)(2)(A).

111. *See* 33 U.S.C. § 1316(a)(1).

112. Unlike the CAA, which consolidates review of such standard settings in one court (the D.C. Circuit), the CWA's special statutory review provision allows any court of appeals to hear challenges to these technology-based standard settings. *See* 33 U.S.C. § 1369(b)(1).

113. *See* 33 U.S.C. § 1317(a)(1).

114. *See* 33 U.S.C. § 1326(b).

115. *See* 33 U.S.C. § 1342(p)(3)(B); Tualatin Riverkeepers v. Or. Dept. of Envtl. Quality, 230 P.3d 559 (Or. App. 2010).

116. Am. Meat Inst. v. EPA, 526 F.2d 442, 451 (7th Cir. 1975) (emphasis added) (quoting Sen. Edmund Muskie, in *A Legislative History of Water Pollution Control Act Amends. of 1972*, at 169-70 (1973)); *see also* Hooker Chems. & Plastics Corp. v. Train, 537 F.2d 620, 632 (2d Cir. 1976); *cf.* Am. Frozen Food Inst. v. Train, 539 F.2d 107, 118-19 (D.C. Cir. 1976) (statutory factors for identifying "practicable" and "industrial category" including "the age of the plants, their size, the unit processes involved, and the cost of applying such controls" amount to a "limited cost-benefit analysis in order to maintain uniformity within a class and category of point sources").

117. *See Am. Frozen Food*, 539 F.2d at 132 ("Technology in the modern world knows few boundaries—the United States-Canada boundary perhaps least of all."). On the searches EPA conducted, *see* Wesley A. Magat et al., Rules in the Making: A Statistical Analysis of Regulatory Agency Behavior 31-44 (1986). EPA was repeatedly challenged for finding (or inventing) a "model plant" at this step. *See* A. Myrick Freeman III, *Technology-Based Effluent Standards: The U.S. Case*, 16 Water Resources Res. 21, 24 (1980).

ing to be done continually challenged the enterprise even as this dimension rarely drew searching judicial scrutiny (either as a matter of arbitrariness or as to statutory interpretation).[118] Some of this is owed to the fact that Congress itself scheduled the original industrial sectors to be governed by BADT standards,[119] but deference has remained the norm.[120]

The CWA's factored determinations apply directly to effluent dischargers in the absence of applicable sectoral standards.[121] And whether individual facilities' or whole categories of dischargers' changes to their factors of production or control equipment are at issue, the standard setting requires calculating the costs of those expected changes and determining the manageability thereof under given circumstances.[122] At least one court developed its own distinctive theory of the CWA's phased approach to this cost-availability and the search for the performance benchmarks.[123] The courts of appeal divided, however, over whether BPT could require "internal altera-

118. From among "several thousand" effluent limitations pertaining to roughly forty industrial categories finalized by late 1977, La Pierre, *supra* note 56, at 808-09, the three dozen or so litigated to full judicial opinions concluded by then or in the years shortly following included *no* instances where a court reversed EPA's decision to subcategorize or its refusal to do so.

119. *See* Nat. Res. Def. Council, Inc. v. Train, 510 F.2d 692, 697 (D.C. Cir. 1975) (citing CWA § 306(b)(1)(A) listing 27 source categories to be prioritized for new source BADT standards).

120. *See, e.g.*, Citizens Coal Council v. EPA, 447 F.3d 879, 890-94 (6th Cir. 2006) (reversing earlier panel opinion and affording broad deference to EPA to subcategorize the coal mining sector according to age and condition of mines used).

121. The practice, known as "best professional judgment" (BPJ) permitting, tailors to the facility, pollutants, and the available technology, balancing the applicable statutory factors for the effluent in question. *See* 40 C.F.R. § 125.3(a)(2)(B) (2016). EPA counsels permit writers to use methods "consistent with the statistical approach EPA has used to develop effluent guidelines," including calculating maximum daily discharges "by multiplying the long-term average achievable by implementation of the model technology or process change by a daily variability factor determined from the statistical properties of a lognormal distribution." U.S. EPA, NPDES Permit Writers' Manual § 5.2.3.5 (Sept. 2010).

122. *Cf.* U.S. Steel Corp. v. Train, 556 F.2d 822, 843-46 (7th Cir. 1977) (testing the cost-availability of facility's installation of recycling operation and finding no cost-prohibitive barriers thereto); BASF Wyandotte Corp. v. Costle, 598 F.2d 637, 656-58 (1st Cir. 1979). In *United States Steel*, for example, EPA hired U.S. Steel's own process engineer to compare its plant to other, similar integrated steel mills and concluded that the reengineering proposed was cost-available. *See* 556 F.2d at 842-46.

123. *See* Weyerhaeuser v. Costle, 590 F.2d 1011, 1044-47 (D.C. Cir. 1978) (finding that CWA § 304(b)(1)(B) required a focused balancing of "total cost" of expected improvements against effluent reductions achieved and that § 304(b)(2)(B) BATEA later "relaxed" that comparison to one of unweighted "consideration" of costs); *cf.* Ass'n of Pac. Fisheries v. EPA, 615 F.2d 794, 805-06 (9th Cir. 1980) (noting *Weyerhaeuser*'s interpretation of the CWA's phased approach).

tions in production" as opposed to "end-of-pipe," add-on solutions.[124] But with the CWA's staged technology-based controls, the "average of the best"[125] for BPT was contrasted with BATEA standards (staged to arise six years later) which were to require "'a broader range of technological alternatives,' including techniques 'which exist in operation or which can be applied as a result of public and private research efforts.'"[126] BATEA solutions were to be based on the "best performer in any industrial category,"[127] keeping focal emphasis on the boundedness of an industrial category but with less emphasis on cost-availability.[128]

It was gradually established in the cases that if inter-sectoral technology transfers could, to a reasonable projection, work in the target sector, they were "available" within the meaning of BATEA and BADT.[129] To be sure, several highly integrated industries' trade groups opposed their standards at every step,[130] arguing that the adoption/diffusion of various technologies

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124. *See, e.g.*, FMC Corp. v. Train, 539 F.2d 973, 981 (4th Cir. 1976) (noting that "[i]n-process control measures may be required . . . if they are considered normal practice within the industry"); Tanners' Council of Am., Inc. v. Train, 540 F.2d 1188, 1191 (4th Cir. 1976) ("[BPT] effluent standards are to rely primarily on end-of-manufacturing treatment facilities but may include control technologies within the process if these measures are considered normal practice within the industry."); Am. Petroleum Inst. v. EPA, 540 F.2d 1023, 1033-34 (10th Cir. 1976) (recognizing disagreement among courts).

125. Kennecott Copper Corp. v. EPA, 612 F.2d 1232, 1242 (10th Cir. 1979).

126. Am. Meat Inst. v. EPA, 526 F.2d 442, 462 (7th Cir. 1975) (quoting Legis. Hist., *supra* note 116, at 170); *cf.* Chem. Mfrs. Ass'n v. EPA, 870 F.2d 177, 226 (5th Cir. 1989) ("Congress intended these limitations to be based on the performance of the single best-performing plant in an industrial field.").

127. *Am. Meat Inst.*, 526 F.2d at 463; *see also* Am. Iron & Steel Inst. v. EPA, 526 F.2d 1027, 1057 n.67 (3d Cir. 1975) (noting EPA was to be given the "capability and the mandate to press technology and economics" to achieve the pollution reductions attainable); CPC Int'l Inc. v. Train, 515 F.2d 1032, 1047 n.32 (8th Cir. 1975) ("available control technology" is not confined only to technology that is "in actual, routine use somewhere").

128. *See, e.g.*, Tex. Oil & Gas Ass'n v. EPA, 161 F.3d 923, 929-31 (5th Cir. 1998) (describing the subcategorization of the "coastal" oil/gas well sector and its transition from BPT to BAT standards); *cf. Am. Iron & Steel Inst.*, 526 F.2d at 1059 (cost to be given even less weight in BADT for new sources than it is given for BATEA). On the BCT cost "test" that arose after EPA had settled the list of "conventional" pollutants and the standard solutions used for their removal. *See supra* note 109.

129. *See* Nat. Res. Def. Council v. EPA, 808 F.3d 556, 572-74 (2d Cir. 2015) (citing Kennecott v. EPA, 780 F.2d 445, 453 (4th Cir. 1986); Hooker Chems. & Plastics Corp. v. Train, 537 F.2d 620, 636 (2d Cir. 1976)). EPA's finding that some such retrofit was cost-available to the target facilities was also demanded by some courts. *See, e.g.*, American Iron & Steel Inst. v. EPA, 568 F.2d 284, 299-300 (3d Cir. 1977); *Am. Iron & Steel Inst.*, 526 F.2d at 1047-48.

130. *See, e.g.*, BP Expl. & Oil, Inc. v. EPA, 66 F.3d 784, 790-91 (6th Cir. 1995) (detailing the several standards and ensuing litigation in the oil and gas production well sector, specifically regarding produced water discharges).

throughout their sectors was cost-prohibitive.[131] Whether the costs of retrofits and/or capital replacement are *too* high, *i.e.*, not "available" or "achievable," has remained discretionary with EPA.[132] But even BPT, even when set individually,[133] could impose substantial costs on sources not meeting a performance norm observed in the industry.[134] As the Fifth Circuit opined years after BPT was supposed to have been phased out, it was never expected to be "cheap" just for being the most cost-conscious of the CWA's technology-based standards.[135] Wherever a standard or "average" performance can be derived, the ensuing pressures exerted by that mark can be substantial.[136] And as, for example, the offshore oil/gas drilling sector

131. *See, e.g.,* R.K. Clark, *Impact of Environmental Regulations on Drilling-Fluid Technology*, 46 J. PETROLEUM TECH. 804, 806-08 (1994) (describing the gradual substitution of water-based drilling fluids for more toxic and environmentally persistent predecessors); *cf. Tex. Oil & Gas Ass'n*, 161 F.3d at 930-33 (reviewing prolonged and litigious history of discharge standards from oil/gas wells in coastal waters); Nat. Res. Def. Council, Inc. v. EPA, 863 F.2d 1420, 1426-27 (9th Cir. 1988) (remanding EPA conclusion that it lacked needed evidence to require reinjection of produced water as "available technology" on the grounds that coastal operations in California and Alaska had proven reinjection was "technologically feasible" and the legislative history of CWA § 304 suggesting that "technologically feasible limitations" should be set as BATEA even without "precise cost figures").

132. *See* McCubbin, *supra* note 53, at 11-29. For example, in its famous cluster rule for pulp and paper manufacturers, dioxin-reducing shifts in production—to chlorine-free beaching processes—were resisted by the industry and its unions, chiefly with projections that such changes would close many more plants than a less stringent standard. *See* WILLIAM BOYD, THE SLAIN WOOD: PAPERMAKING AND ITS ENVIRONMENTAL CONSEQUENCES IN THE AMERICAN SOUTH 189-216 (2015). The EPA's adoption of the less stringent standard was upheld against all challenges. Nat'l Wildlife Fed'n v. EPA, 286 F.3d 554 (D.C. Cir. 2002).

133. Often, technology-based effluent limitations have been set either before a categorical standard was finished or for sources lacking any applicable categorical effluent limitation guidelines. *See, e.g.*, Trs. for Alaska v. EPA, 749 F.2d 549, 552-54 (9th Cir. 1984). Less often, EPA has issued "general permits" embodying such limits for dischargers in a given region. *See, e.g.*, Am. Petroleum Inst. v. EPA, 787 F.2d 965, 970-71 (5th Cir. 1986).

134. *See, e.g.*, U.S. Steel Corp. v. Train, 556 F.2d 822, 843-46 (7th Cir. 1977) (finding that BPT for integrated steel mill as use of a "recycling" system observed at other mills, including some of permittee's mills).

135. Chem. Mfrs. Ass'n v. EPA, 870 F.2d 177, 205 (5th Cir. 1989) (citing Legis. History, *supra* note 116, at 523), ("Congress anticipated that initially BPT might cause many plant closures and the loss of 50,000 to 125,000 jobs."); *see* David M. Driesen, *Distributing the Costs of Environmental, Health, and Safety Protection: The Feasibility Principle, Cost-Benefit Analysis, and Regulatory Reform*, 32 B.C. ENVTL. AFFS. L. REV. 1, 22-23 (2005) [hereinafter Driesen, *Distributing*]. The original design assumed the standards would be routinely updated. *See* ROBERT W. ADLER ET AL., THE CLEAN WATER ACT 20 YEARS LATER 138-39 (1993).

136. *See* DRIESEN, *supra* note 7, at 85-91 (arguing that "radical qualitative innovation" can be sacrificed or crowded out by "least cost" pursuit of short term goals like marginal pollution reductions).

showed in the BATEA standards for "produced" water,[137] pressures of the kind applied across areas with natural cost disadvantages can be disproportionate if competitive disparities are not somehow corrected.[138] Thus could an 'average of the best' put someone out of business if they were not solvent enough to make the needed changes or fortunate enough to have capital amenable to the retrofit.[139]

EPA's new source standards (BADT), thought to be more stringent than BPT and BATEA,[140] are typically limited in applicability to "greenfield" sites.[141] This tends to increase the number of "old" facilities gaining competitive advantage from EPA's actions.[142] CWA § 316(b)'s unique focus

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137. Produced water is "brought up from hydrocarbon-bearing strata with produced oil and gas [and includes] brines trapped with the oil and gas in the formation and possibly waters injected into the reservoir to increase productivity." Michael O. Waguespack, *Produced Waters in Coastal Louisiana*, 3 TUL. ENVTL. L.J. 7, 7 (1990).

138. *Cf. id.* at 16-21 (reporting data from coastal Louisiana production tending to show that produced water reinjection, though cost-available in Alaska and other coastal operations, was cost-unavailable to Louisiana wells because of legacy and other costs borne there); *see* Am. Petroleum Inst. v. EPA, 858 F.2d 261, 263-66 (5th Cir. 1988).

139. *See* Trs. for Alaska v. EPA, 749 F.2d 549, 554-60 (9th Cir. 1984) (challenge to EPA general permits for placer mines lacking "technology-based" BPT or BATEA standards, noting the plaintiffs' allegation that settling ponds were BPT, and denying as moot miners' challenge to such effluent limitations as a "taking" of their property in the form of their mining claims); Chem. Mfrs. Ass'n v. EPA, 870 F.2d 177, 203-64 (5th Cir. 1989) (considering and dismissing cost-availability and subcategorization objections to BPT, BATEA, BADT and pretreatment standards for chemicals sector); Citizens' Coal Council v. EPA, 447 F.3d 879, 898-900 (6th Cir. 2006) (upholding EPA's qualitative analysis of old versus new mine site utilization and stringency of standards intended to facilitate reuse of old mines); Nat'l Renderers Ass'n v. EPA, 541 F.2d 1281, 1290 (8th Cir. 1976) (speculating that EPA set BADT standard's stringency lower than BATEA based on its estimate that "no new plants would be built").

140. *See* WINSTON HARRINGTON, REGULATING INDUSTRIAL WATER POLLUTION IN THE UNITED STATES 5 (2003). In one instance, where the BADT standard seemed to permit "higher levels of effluent" than the BATEA standard, a court remanded the new source standard for EPA's explanation. *See Nat'l Renderers Ass'n*, 541 F.2d at 1289-90.

141. *See* 40 C.F.R. § 122.29(b)(1) (2016) (limiting the applicability of BADT standards at existing plants to complete reconstruction of existing units or the construction of wholly new, "substantially independent" facilities). EPA has occasionally adjusted the criteria used for determining 'substantial independence' in particular BADT standards. *See, e.g.*, Nat'l Wildlife Fed'n v. EPA, 286 F.3d 554, 568-69 (D.C. Cir. 2002); *see also* Citizens Coal Council v. EPA, 447 F.3d 879, 898-900 (6th Cir. 2006) (upholding EPA's qualitative analysis of old versus new mine site utilization and stringency of BADT standards intended to facilitate reuse of old mines); *Nat'l Renderers Ass'n*, 541 F.2d at 1290 (speculating that EPA set BADT standard's stringency lower than BATEA based on its estimate that "no new plants would be built").

142. In theory, any differentiation between old and new facilities distorts the market for capital replacement, endowing "old" capital "with a value that cannot be transferred," hence rendering new facilities "systematically more costly." Robert N. Stavins, *Vintage-Differentiated Environmental Regulation*, 25 STAN. ENVTL. L.J. 29, 42 (2006). The precise extent of this "old

on the *withdrawal* of water as an input factor and four-facet evaluation thereof ("location, design, construction and capacity")[143] are illustrative.[144] For over a decade, EPA struggled to create a standard that did not disproportionately burden identifiable industry segments, locations, or vintages of capital—a struggle that prompted challenge after challenge.[145] Of course, new or old, a facility withdrawing *less* water will reduce its impacts proportionately.[146] Retrofitting existing facilities with new intake mechanisms tends to be much cheaper than retrofitting them to recirculate their process water or reuse gray water sources.[147] EPA's eventual allowance of capital-specific solutions at existing facilities stemmed from cost-effectiveness studies, detailed knowledge of the relevant facility profiles and careful testing of proven solutions.[148] The water intakes rules highlight the key to cost-availability in the legal doctrine: it is rightly determined by the target polluters' industrial organization and how the benchmark performances identified can

plant effect" is subject to considerable uncertainty, though. *See infra* notes 258-62 and accompanying text.

143. 33 U.S.C. § 1326(b).

144. One important caveat about the intakes rules is in order. Though EPA prepared a full cost-benefit analysis (pursuant to executive order and OMB's insistence) in construing the CWA § 316(b) mandate—the issue litigated in *Entergy*—the final outcome of that analysis showed expected costs ($275-297 million) substantially outweighing benefits ($29-33 million) in the final rule. National Pollution Discharge Elimination System—Final Regulations to Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities, 79 Fed. Reg. 48,300, 48,304 (2014) [hereinafter Revised Final Intakes Rule]. It therefore could not have been a decisive factor.

145. *See* Revised Final Intakes Rule, 79 Fed. Reg. at 48,312-18 (recounting history). In an effort to create a single performance standard, EPA discovered that water intakes create two problems: impingement mortality and entrainment mortality. The solutions for each differ substantially, severely complicating a single performance standard that is cost-available for existing sources nationwide. *See* Winston Harrington, *The Cooling Water Intake Structures Rule*, *in* Reforming Regulatory Impact Analysis 160, 162-67 (Winston Harrington et al. eds., 2009).

146. *See* Douglas A. Kysar, *Fish Tales*, *in* Reforming Regulatory Impact Analysis 190, 192 (Winston Harrington et al. eds., 2009).

147. *See* Vincent C. Tidwell et al., *Transitioning to Zero Freshwater Withdrawal in the US for Thermoelectric Generation*, 131 Applied Energy 508, 513-14 (2014). "In 2005 thermoelectric power generation was the largest user of freshwater in the United States, withdrawing over 530 million cubic meters per day." *Id.* at 509.

148. EPA eventually divided its water intakes rules between those applicable to new units, *see* Final Rule—National Pollutant Discharge Elimination System: Regulations Addressing Cooling Water Intake Structures for New Facilities, 66 Fed. Reg. 65,256 (2001) [hereinafter Phase I Final Rule], those applicable to existing facilities withdrawing minimum 2 million gallons per day, and those for new offshore oil/gas production. *See* Revised Final Intakes Rule, 79 Fed. Reg. at 48,303-7 (2014); National Pollutant Discharge Elimination System—Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase III Facilities, 71 Fed. Reg. 35,006 (2006) [hereinafter Phase III Final Rule].

be met in their circumstances.[149] Part III isolates these two facets of every technology-based standard and suggests why separate attention to each often yields so much more than the sum of the parts.

III. Cost Availability? Frontiers and Boundaries

As skeptics of technology-based standards have long argued, industrial sectors are not "natural kinds"[150]: finding their boundaries is inescapably a matter of judgment. Industrial categories framed technology-based pollution standards in the U.S. even as the mass production economy waned and sectors grew increasingly fuzzy.[151] An economy's *productivity* broken into discrete sectors may be a macroeconomic sum, but it is given in increasingly microeconomic terms.[152] Yet instead of setting conduct constraints through equilibrium theory's algorithmic computation of prices and their resultant "social" costs and benefits, judging pollution abatements to be within financial reach in targeted sectors views "cost" not as a proxy for *harm* but rather as a motivational *force*.[153] Indeed, given their relative successes compared to other cost-factoring methods, cost-availability determinations may be the better way to gauge *real* harms to an economy given the comparatively direct connections between induced innovation, cost avoidance, and ultimately economic adaptation.[154] Diversified exchange economies may measure their aggregate productivity by their sectors—where competitors

149. Elements of this finding have been suggested by others before. *See* La Pierre, *supra* note 56, at 809-29; Note, *Technology-Based*, *supra* note 3, at 795-800; William F. Pedersen, Jr., *Turning the Tide on Water Quality*, 15 Ecology L.Q. 69, 82-85 (1988); Wendy E. Wagner, *The Triumph of Technology-Based Standards*, 2000 U. Ill L. Rev. 83, 88-91; Driesen, *supra* note 7, at 110-22.

150. Jonathan S. Masur & Eric A. Posner, *Against Feasibility Analysis*, 77 U. Chi. L. Rev. 657, 689 (2010).

151. *See* Michael J. Piore & Charles F. Sabel, The Second Industrial Divide: Possibilities for Prosperity (1984).

152. *See generally* Robert J. Gordon, The Rise and Fall of American Growth (2016). The so-called "integrated assessment models" (IAMs) used to forecast climate change damages all reduce welfare-equivalent consumption by sector-based multipliers. *See* Weitzman, *supra* note 24, at 16. This keeps the "social cost of carbon" (SCC) calculated from IAMs innately sensitized to sector-based growth projections.

153. *Cf.* Cooter, *supra* note 12 (developing and describing a bargaining model where opposing effective costs are used to encourage parties to bilateral transactions to deal effectively with one another); Malloy, *supra* note 20, at 551-86 (presenting a "scenario" analysis of innovation incentives in a multi-divisional chemical engineering firm and showing that "black box" theories of innovation firms ignore the paths costs and information actually travel).

154. *Cf.* Malloy, *supra* note 20, at 600 (finding that "tailored regulation" identifying firm-specific barriers to innovation can be much more accurate in the incentives it sets for cost minimization).

compete, production and consumption functions meet, and labor, capital, energy, and other factors combine to shape the goods and services delivering that economy's standard of living.[155] But finding sectoral boundaries is no easy task. Section A draws out some connections between industrial organization and innovation while Section B highlights the problematic concept of "cost" in contemporary theories.

A. *Industrial Organization: Innovation Pushed and Pulled*

Although the induced innovation hypothesis has been notoriously hard to test econometrically,[156] a positive, monotonic relationship between firm size and spending on research and development (R&D) has for many years been one of the more robust findings.[157] Spending does not neatly correlate with output or outcomes, of course, something economists studying innovation have long known.[158] And if the economic landscape includes multiproduct (multi-sector) firms, like *A* and *B* in our earlier hypothetical, the fungibility of capital within such firms severs any causal relationship between market power and innovation.[159] Indeed, compared to "our understanding of the influence of industry-level variables, our understanding of the role of firm-level variables is more primitive still."[160] Still, if every technology-based standard has involved EPA in identifying the industrial organ-

155. *Compare* Samuelson, *supra* note 34, at ch. 6 (observing that firms are needed to manage production efficiently and that they often take on similar structures and scales in industrial sectors), *with* Richard R. Nelson & Sidney G. Winter, An Evolutionary Theory of Economic Change 235-45 (1982) (presenting an informal model of economic growth as a selection process in which the more advanced, more capable firms employing better technology and techniques put less adapted firms out of business).

156. *See* Popp et al., *supra* note 29, at 880-81; Cohen, *supra* note 9, at 142.

157. *See* Cohen, *supra* note 9, at 193. "There is also reason to believe that the source of this relationship is the R&D cost-spreading incentive effects of firm size . . . The relationship between market structure and R&D remains, however, problematic." *Id.* at 193-94. Larger firms' cost-spreading and returns to scale have even featured in fairness arguments *against* technology-based standard setting. *See, e.g.*, Amy Purvis & Joe Outlaw, *What We Know About Technological Innovation to Achieve Environmental Compliance: Policy Issues for an Industrializing Animal Agriculture Sector*, 77 Am. J. Agric. Econ. 1237, 1242 (1995).

158. *See* Cohen & Levin, *supra* note 9, at 1069.

159. *See* David J. Teece, *Technological Innovation and the Theory of the Firm: The Role of Enterprise-Level Knowledge, Complementarities, and (Dynamic) Capabilities*, *in* 1 Handbook on the Economics of Innovation 680, 688 (Nathan Rosenberg & Bronwyn Hall eds., 2005). It does not necessarily sever the ties between the timing of pollution abatement investments and other productive investments within the firm, of course. *See, e.g.*, Wayne B. Gray & Ronald J. Shadbegian, *Environmental Regulation, Investment Timing, and Technology Choice*, 46 J. Indust. Econ. 235, 237 (1998) (reporting finding "significant relationships" between amount and timing of pollution abatement investment and productive (non-abatement) investment, at least at the plant level).

160. Cohen, *supra* note 9, at 195.

ization underlying its targeted pollution and the benchmark solution(s) by which abatements will be mandated, then EPA should at least be looking for relationships that actually matter. This section identifies some preliminaries.

A *technological frontier* signifies what we can/cannot do whereas industry sectoral boundaries are defined by organizational and market dynamics. The former is often a work-in-progress,[161] but the latter can be pure happenstance. Both are impermanent (if also inertial) yet nevertheless ground the technology-based approach. They frame the opportunities for competitive and other pressures to induce welfare-enhancing innovation, *i.e.*, cost-avoidance.[162] Being so impermanent, however, their analysts are oriented to sensitivities that most cost-benefit analyses obscure or ignore.[163] This may explain the latter's clear tendency to *over*-estimate regulation's costs,[164] but it also suggests that technology-based cost-availability evaluations may be substantially more useful for what they do *and do not* represent.[165]

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161. *See* ROSENBERG, *supra* note 9, at 104-19 (describing the "superficially paradoxical" tendency toward slowed technological diffusion during periods of rapid technological advance). Coal-fired boilers, for example, steadily improved in efficiencies from 1900 when it took almost 7 pounds of coal to generate a kilowatt hour of electricity to less than a pound to generate it in the 1960s. *Id.* at 65. Indeed, total efficiency improvements in coal mining, transport, combustion, electricity conversion and transmission from 1907-1957 were *tenfold*. *Id.* at 66. Predictive modeling of continued further progress here comes down to the proper accounting for opportunity costs of innovation production, treatment of knowledge spillovers and appropriability, and the empirical data (if any) available for parameterizing the key relationships. *See* Kenneth Gillingham et al., *Modeling Endogenous Technological Change for Climate Policy Analysis*, 30 ENERGY ECON. 2734 (2008). But from those factors there is good reason to doubt coal's run will continue. *See infra* note 257 and accompanying text.

162. As Cohen found in his exhaustive literature review, the variables having at least some empirical support at the sectoral level include demand, appropriability, and the technological "opportunity conditions," *i.e.*, the sector's baseline opportunities for technical advance. *See* Cohen, *supra* note 9, at 168-93.

163. *See* Finkel, *supra* note 33, at 125-54 (cataloguing various paths cost-benefit analysis takes to ignoring or mishandling cost uncertainties); Farber, *supra* note 51, at 99-108 (finding the timing of cost considerations when opposed to benefits uneven at EPA); *cf.* Livermore, *supra* note 31, at 627 (noting that the largest percentage of EPA economists is in the Office of the Administrator where their influence is concentrated, like a "mini-OMB" within EPA, at the end of rulemaking processes).

164. *See supra* note 11 and accompanying text.

165. Judging as acceptable any projected costs and where they will fall need not entail weighing them in opposition to benefit estimations. Indeed, as Knight argued in response to Pigou's *Economics of Welfare* (decades before Coase), "[i]t is only when one commodity is given up in order that another may be produced by the use of the *common and divertible* productive energy that we ordinarily think of the variation of *cost*." Knight, *supra* note 28 at 594 (emphasis added). Thus, to convert *projected* firm costs into "social" costs before they are even realized is to obscure the more "universal meaning" of cost as "the sacrifice of a value

So how ought the analyst to align the relevant comparisons? If technology-based standard setting hinges on knowing which firms or firm types are best suited to innovate, it is surely a muddle. But if it starts from definite descriptions of production,[166] the discrete factors of that production,[167] and verified performance leaders[168] instead of a synthetic calculus derived more from algorithms than investigation, then the analyst cannot help but confront a fuller variety of costs in actual markets: the relevant tax distortions and/or vintage classes of capital, real trade-exposure or pressures to offshore, the market power, illiquidity, and/or insolvency of incumbents, innovations known to be on the horizon if not yet commercialized, learning-by-doing or other complementarities peculiar to the sector, and the kinds of processes, equipment, and professionals common therein. That analyst cannot help but confront the firm not as equilibrium theory's static-state placeholder—or even its dynamic cypher—but rather as a live experiment in practical problem-solving.[169] In that analyst's world, innovations flow from the pull of demand, the push of supply, and much in between.[170] In short,

alternative." *Id.* at 593. The use of cost in cost-availability stringency evaluations avoids at least that logical mistake.

166. The basic insight that individual firms' costs of compliance can vary widely is commonplace. *See, e.g.*, ALBERT L. NICHOLS, TARGETING ECONOMIC INCENTIVES FOR ENVIRONMENTAL PROTECTION 31 (1984). But it can motivate much more than a faith in Pigovian taxes or tradeable allowances. In the technology-based approach, it motivates EPA to become intimately familiar with particular firms and their operations. *See, e.g.*, National Emissions Standards for Hazardous Air Pollutant Emissions: Hard and Decorative Chromium Electroplating and Chromium Anodizing Tanks; and Steel Pickling-HCI Process Facilities and Hydrochloric Acid Regeneration Plants, 77 Fed. Reg. 58,220, 58,222-223 (2012) [hereinafter Final Chromium Rule] (having found 188 large plants, 394 small plants, about 70 of which were in California, and the exact tools used to achieve observed performances in each).

167. Labor, capital, energy and other basic inputs may be decomposable—which often motivates the argument that taxes are preferable to rules as instruments of social cost minimization. That flexibility is curbed substantially, however, when a single sector at a discrete point in time becomes the focus. *See infra* notes 272-76 and accompanying text.

168. As we have noted throughout, performance standards capture abatements made by add-on equipment, process, and input changes alike. *See supra* note 21 accompanying text.

169. *Cf.* Jacques H. Dreze, *(Uncertainty and) The Firm in General Equilibrium Theory*, 95 ECON. J. 1, 1 (1985) ("The firm fits into general equilibrium theory as a balloon fits into an envelope: flattened out! Try with a blown-up balloon: the envelope may tear, or fly away: at best, it will be hard to seal and impossible to mail . . . Instead, burst the balloon flat, and everything becomes easy."); Teece, *supra* note 159, at 686-89 (noting that many firms outsource their innovation and that the "innovation ecosystem" in which the firm exists exerts multiple, often conflicting influences on its choices).

170. As Bauman and colleagues showed with a formal model, it is only by assuming pollution abatements always take the form of end-of-pipe add-ons—rather than process or input changes—that the conventional wisdom can still hold pollution taxes and/or allowances (our *Rule 2* and *Rule 3*) induce more innovation than performance standards (like *Rule 1*). *See* Bauman et al., *supra* note 42, at 511-17. If analysts make the conventional assumptions about

the analyst should look for relevant differences and similarities not through the dogma of technical change and equilibrium but rather by bottom-up descriptions of observable facts and realistic possibilities.[171]

A focus like this has embedded EPA in a world where trade is not costless and so not necessarily efficient,[172] where 'path-dependence,' increasing returns, and network effects are often pronounced,[173] where individual firms' capabilities and so-called sunk costs can be anchors,[174] where short-run profits not only exist but define economic life,[175] and where the

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abatement costs, *e.g.*, innovation always lowers marginal abatement costs, they will expect—perhaps incorrectly—that performance standards will generally be both under- and over-controlling.

171. About all that can be said after decades of search on this front is that empirical tests and rigorous modeling have mostly rejected the orthodox claim, *see, e.g.*, Jacob Schmookler, *Economic Sources of Inventive Activity*, 22 J. ECON. HIST. 1 (1962), that demand alone *pulls* innovation. *See, e.g.*, Daron Acemoglu et al., *The Environment and Directed Technical Change*, 102 AM. ECON. REV. 131 (2012) (presenting a growth model where supply of the final good, produced from substitutable clean or dirty inputs, can, barring exhaustion of the inputs, tend toward environmental disaster without timely and appropriate policy intervention); Daron Acemoglu, *Directed Technical Change*, 69 REV. ECON. STUDS. 781 (2002) [hereinafter Acemoglu, *Directed*] (noting orthodox model wherein technical innovation follows from market signals and presenting an alternative model of technical change, its direction and pace demonstrating that "equilibrium bias" can systematically advantage certain factors of production once they get a head start on the competition). This 'necessity paradox' may even be reason enough to reject equilibrium theory itself. *See* Nicholas Kaldor, *The Irrelevance of Equilibrium Economics*, 82 ECON. J. 1237, 1245 (1972). What macroeconomic modelers face instead amounts to methodological turmoil. *See* Andreas Löschel, *Technological Change in Economic Models of Environmental Policy: A Survey*, 43 ECOLOGICAL ECON. 105, 116 (2002).

172. *Cf.* KLEIN, *supra* note 35, at 20-24 (arguing that only static analyses can presume perfect information leading to rational assessments of trade possibilities); NELSON, *supra* note 155; *cf.* YORAM BARZEL, ECONOMIC ANALYSIS OF PROPERTY RIGHTS 11-14 (2d ed. 1997) (noting a methodological divide between general equilibrium theory and the newer institutional theories where information costs and other frictions predominate).

173. *See* Elhanan Helpman & Manuel Trajtenberg, *Diffusion of General Purpose Technologies*, *in* GENERAL PURPOSE TECHNOLOGIES AND ECONOMIC GROWTH 85 (Elhanan Helpman ed., 1998); W. BRIAN ARTHUR, INCREASING RETURNS AND PATH DEPENDENCE IN THE ECONOMY 24-35 (1994); THRÁINN EGGERTSON, ECONOMIC BEHAVIOR AND INSTITUTIONS 3-32 (1990).

174. *See* David J. Teece et al., *Dynamic Capabilities and Strategic Management*, 18 STRATEGIC MGMT. J. 509 (1997); Benjamin Klein & Kevin M. Murphy, *Vertical Restraints as Contract Enforcement Mechanisms*, 31 J.L. & ECON. 265 (1988); NELSON, *supra* note 155, at 96-136; OLIVER E. WILLIAMSON, MARKETS AND HIERARCHIES: ANALYSIS AND ANTITRUST IMPLICATIONS (1975); Herbert A. Simon, *A Formal Theory of the Employment Relationship*, 19 ECONOMETRICA 293, 302-05 (1951) (presenting a model wherein uncertainty brings more decisions within firm boundaries than it pushes beyond them).

175. *See* Geoffrey T.F. Brooke, *Uncertainty, Profit and Entrepreneurial Action: Frank Knight's Contribution Reconsidered*, 32 J. HIST. ECON. THOUGHT 221, 228-34 (2010) (arguing that Knight's theory of entrepreneurial profit grounded in subjective expectations is a major critique of equilibrium theory); *see infra* notes 287-90 and accompanying text.

availability and cost of capital diverge substantially from the ideal.[176] Understanding cost-availability in that context means elevating inertial relationships over neoclassical dogmas. Doing so on a rolling basis is implicit in both facets of the task given the impermanence in those relations. Finally, it entails some measure of skepticism: to whatever extent EPA's finding and sharing of practical solutions converts them into something of a 'public good,' incumbent firms may be biased against investing in the search for ways to meet or exceed expectations.[177]

For example, EPA set its CWA effluent standards by weighing the (1) inputs used, (2) outputs produced, (3) process(es) employed, (4) age and size of capital equipment/facilities, and (5) the pollutant/waste constituents generated.[178] Its effluent standards requiring the "best available" technology EPA could deem "economically achievable" often involved identifying a "model plant,"[179] but it occasionally identified abatement solutions wholly foreign to the target sector where they were demonstrably transferable.[180] Transfers like this entail specific and detailed investigations. Mining operations' effluents put EPA to predicting likely future metal prices—showing the sector's expected solvency and liquidity and, thus, capacity to retrofit.[181] The investigation can even involve estimating the sector's likely management of legacy costs,[182] a particularly problematic projection given the possibility of bankruptcy protections.[183] More common is the in-depth assessment of substituting one (cleaner) factor for another.[184]

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176. *See, e.g.*, Ken S. Cavalluzzo & Linda C. Cavalluzzo, *Market Structure and Discrimination: The Case of Small Businesses*, 30 J. Money, Credit & Banking 771 (1998); Gary S. Becker, The Economics of Discrimination (1957).

177. Within-industry spillovers "reduce the incentive to engage in R&D, because a firm must share with its competitors the benefits of its investment." Cohen, *supra* note 9, at 181; *see also* Cohen & Levin, *supra* note 9, at 1089. On the other hand, controversy rages still today over identifying the properly "public" goods which the market systematically underproduces.

178. *See* La Pierre, *supra* note 56, at 810-11 (describing how EPA categorized industrial sectors for the CWA's BPT and BATEA standards); Magat et al., *supra* note 117, at 33.

179. *See* Freeman, *supra* note 117, at 24.

180. *See, e.g.*, Kennecott v. EPA, 780 F.2d 445, 450-55 (4th Cir. 1985).

181. *See, e.g.*, *id.* at 456-57; Rybachek v. EPA, 904 F.2d 1276, 1291 (9th Cir. 1990).

182. *See, e.g.*, Citizens' Coal Council v. EPA, 447 F.3d 879, 893-98 (6th Cir. 2006); Nat'l Wildlife Fed'n v. EPA, 286 F.3d 554, 562-66 (D.C. Cir. 2002).

183. *See infra* notes 268-60 and accompanying text.

184. *See, e.g.*, Final Rule—National Emission Standards for Hazardous Air Pollutants for Pulp and Paper Production; Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards: Pulp, Paper, and Paperboard Category, 63 Fed. Reg. 18,504 (1998) [hereinafter Final Cluster Rule]. The cluster rule for pulp and paper manufacturing put EPA to evaluating the elimination of elemental chlorine-based bleaching (and its substitutes)—which was the source of much of the worst pollution. Some firms' actual compliance strategies may have included switching off of bleached products. *See* Aaron

Perhaps most importantly, finding reach solutions of the kind which are achievable (or "available") while delaying their effective dates, allowing firms to devise their own least-cost approximations thereof, can synch regulatory and profit-making priorities, maximizing cost-avoidance opportunities.[185] One BATEA standard (for pulp and paper making) which also simultaneously set MACT standards for a suite of related HAPs provoked multiple reactions from the incumbent firms which could never have been predicted *ex ante*.[186] The capital equipment of pulp and papermaking, notoriously long-lived and adaptable,[187] drew these firms to shift product mixes[188] and sell off or shutter marginal plants,[189] yet also, in many cases, to adopt the benchmark solutions root and branch.[190] This was cost-as-motivational-force at work: with the set performance standard as the permit constraint, pollutant reductions went almost exactly as expected[191]—even as some firms' "costs" became others' profits in the ensuing shake-up.[192]

A. Elrod & Arun S. Malik, *The Effect of Environmental Regulation on Plant-Level Product Mix: A Study of EPA's Cluster Rule*, 84 J. Envtl. Econ. & Mgmt. (forthcoming 2017), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2342179.

185. To be sure, cost-benefit analysts prioritize delay in effective dates as a means of minimizing their "costs" for exactly this reason. *See, e.g.*, Circular A-4, *supra* note 60, at § C ("[A] regulation that provides sufficient lead time is likely to achieve its goals at a much lower overall cost than a regulation that is effectively immediately."). One of the chief tools Porter and van der Linde highlight in their account of firms' capacities to *offset* regulatory costs is synchronizing performance standards with a target's expected capital turnovers to maximize the incentive effects any given action can exert. *See* Porter & van der Linde, *supra* note 42, at 113. That will require more attention than just some arbitrary delay interval. For example, independent pressures to cut pollution might begin this process ahead of technology-based standard setting, thereby further improving cost-avoidance opportunities. *See* Wayne B. Gray & Ronald J. Shadbegian, Multimedia Pollution Regulation and Environmental Performance 3-18 (2015) [hereinafter Gray & Shadbegian, Multimedia].

186. Cynthia Morgan et al., Ex Ante *and* Ex Post *Cost Estimates of the Cluster Rule and MACT II Rule*, 5 J. Benefit Cost Analysis 195, 219 (2014) (finding through SEC disclosures that some firms accurately predicted their realized compliance costs, some substantially over-estimated those costs, and none substantially under-estimated them).

187. *See* Boyd, *supra* note 132, at 116-23

188. *See* Elrod & Malik, *supra* note 184, at 20.

189. *See* Morgan et al., *supra* note 186, at 216-18. The industry was already in the midst of a major consolidation throughout the cluster rule's proposal and finalization. *See* U.S. EPA, EPA 310-R-95-015, Profile of the Pulp and Paper Industry 13-14 (1995). EPA took what was thought to be the unprecedented step of offering credits of a kind to firms that had already reduced their dioxin discharges with various capital updates. *See* William Boyd, *Controlling Toxic Harms: The Struggle Over Dioxin Contamination in the Pulp and Paper Industry*, 21 Stan. Envtl. L.J. 345, 392 (2002).

190. *See* Final Cluster Rule, 63 Fed. Reg. at 18,517.

191. *See, e.g.*, Gray & Shadbegian, Multimedia, *supra* note 185, at 17.

192. EPA was well aware that delaying implementation too long, e.g., five years, would simply defer the inevitable consolidation. *See* Final Cluster Rule, 63 Fed. Reg. at 18,550 (noting that a five-year delay would introduce greater uncertainties given the boom-bust

Finally, if outputs remain roughly constant while inputs, equipment, and/or processes shift (as happened, for example, in steel manufacturing with the advent of mini-mills and the electric arc furnace),[193] benchmarking performances can present a unique challenge.[194] Sub-categorization is always an option, but EPA can easily find itself an unwitting participant in a market struggle, politicizing its work and undermining its own authority.[195] A version of this trap (among others) seems to have ensnared EPA's "Clean Power Plan" (CPP)—a complex effort to spur states to reduce the "carbon intensity" of their wholesale electricity markets by way of their own preferred, cost-minimizing means.[196] As Part IV shows, however,[197] technology-based standard-setting must often, as the CPP did, align sectors on the basis of *output* notwithstanding diverging modes of production. EPA faces a choice in such cases over where to aim its signals: at the production factors, the control techniques, or some one-off synthesis of the two. EPA has often identified robust, adaptable solutions like selective catalytic reduction,[198] electrostatic precipitation[199] or, in the water context, settle/filtration tanking and lagooning,[200] the incremental improvement of which can be facilitated by induced diffusion.[201] Even these solutions can be tailored to input,

cycle in pulp and paper markets without necessarily reducing any resulting costs of compliance). It was also aware that some plants, given their idiosyncrasies of location, were not amenable to retrofitting no matter the delay allowed. *See* Gray & Shadbegian, *supra* note 159, at 238.

193. *See* Matthias Ruth, *Technology Change in the US Iron and Steel Production*, 21 RESOURCES POL'Y 199, 205-07 (1995).

194. Several of the inputs and wastes generated by an integrated steel mill, *e.g.*, metallurgical coke, ore, and associated wastes, are no part of mini-mills. Hence EPA's most recent BATEA for steel mills targeting effluent generated from coking drew challenge only from the coke/coal trade group. *See* American Coke & Coal Chems. Inst. v. EPA, 452 F.3d 930, 932 (D.C. Cir. 2006). Mini-mills have taken market share from integrated mills for over three decades—and promised to do so from the start. *See* U.S. EPA, EPA 310-R-95-005, PROFILE OF THE IRON AND STEEL INDUSTRY 13 (1995); *cf.* PIORE & SABEL, *supra* note 151, at 208-11 (calling mini-mills a kind of "flexible specialization"). And although mini-mills still do not produce all of the goods integrated mills can, they are much less capital-intensive to open, to operate, and to idle awaiting demand. PROFILE OF IRON AND STEEL INDUSTRY, *supra* note 194, at 13-26.

195. *See infra* notes 275-76 and accompanying text.

196. *See infra* notes 249-71 and accompanying text.

197. *See infra* notes 261-70 and accompanying text.

198. *See* AIR POLLUTION COST MANUAL, *supra* note 89, at § 4.2.

199. *See id.* at § 6.

200. *See* U.S. EPA, EPA/600/R-11/088, PRINCIPLES OF DESIGN AND OPERATIONS OF WASTEWATER TREATMENT POND SYSTEMS FOR PLANTS OPERATORS, ENGINEERS, AND MANAGERS § 8.1-8.5 (2011).

201. If diffusion is weak, the key to its acceleration may be the very improvements that would stem from widespread adoption. *See* Popp et al., *supra* note 29, at 899-910. EPA originally believed this was the case with flue gas desulfurization (FGD) scrubbers for boil-

factor, process, geographic, or other kinds of variability, however.[202] Holding all targets in a sample to the same standard can entail costs that cost-benefit hawks typically think are *excess* costs.[203] But it is an empirical question whether such costs outweigh the (excess) costs of taxes, allowances (our *Rules 2* and *3*), or anything else.[204] Moreover, without at least *some* of these "costs" burdening production, *no* social signal is sent calling up responsive, *innovative* adaptations.[205] And without knowing all the possible adaptations, the analyst is simply prejudging which response(s) is the one worth inducing.[206] Thus, given the uncertainty of the cost-minimization possibilities, sectoral boundaries and technological frontier estimates ordinarily should

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ers, industrial furnaces, and steam electric power generating units. *See* Note, *Forcing Technology*, *supra* note 56, at 1722-24. Its efforts to that end were quickly submerged in a bitter political brawl over the economic winners and losers of that induced diffusion. *See* ACKERMAN & HASSLER, *supra* note 81. Eventually, the CAA and EPA's vintage-differentiation between "new" (FGD-required) and existing (not required) plants grew into a major disincentive to retire old equipment in favor of newer, more efficient—but also more stringently regulated—units. *See* RICHARD L. REVESZ & JACK LIENKE, STRUGGLING FOR AIR: POWER PLANTS AND THE "WAR ON COAL" (2016).

202. *Compare* Small Refiner Lead Phase-down Task Force v. EPA, 705 F.2d 506, 525-37 (D.C. Cir. 1983) (reviewing EPA's treatment of "small" refineries, their access to capital to acquire the needed equipment, and the reasonableness of the predictive model EPA employed), *with* Revised Final Intakes Rule, 79 Fed. Reg. at 48,339 (rejecting closed cycle cooling as nationwide "best technology available" for existing water withdrawals on grounds that land availability, expected energy penalties and consequent air emissions, and remaining useful plant life varied so substantially facility-by-facility). In one of the few truly longitudinal studies of energy efficiency improvements induced by energy prices, Newell and colleagues found a correlation, albeit one severely complicated by other factors and various indivisibilities, between the price of energy services and the energy efficiency of goods offered for sale. *See* Richard G. Newell et al., *The Induced Innovation Hypothesis and Energy-Saving Technological Change*, 114 Q.J. ECON. 941, 970-71 (1999).

203. *See, e.g.*, Masur & Posner, *supra* note 150, at 682-83.

204. *See supra* notes 46-50 and accompanying text.

205. *Cf.* Porter & van der Linde, *supra* note 42, at 99 ("[R]egulation signals companies about likely resource inefficiencies and potential technological improvements."); Acemoglu, *Directed*, *supra* note 171, at 783 (finding that irrespective of the elasticity of substitution between factors, an increase in the relative abundance of a factor creates some measure of technical change biased toward that factor); BAUMOL & OATES, *supra* note 42, at 61-63 (when costs of internalizing an externality are uncertain, the choice between Pigovian taxes and tradeable allowances is indeterminate). Of course, the precision of that signal hinges on several factors, chief among which are the format, applicability, and stringency of the standard set. *See infra* notes 292-293 and accompanying text.

206. Guesses like this are to be avoided on virtually *any* account of cost factoring. *Compare* CIRCULAR A-4, *supra* note 60, at 17, 27 (all cost estimates should be explicable, transparent, monetized where possible, and qualitatively rationalized if not), *with* DRIESEN, *supra* note 7, at 93-105 (arguing that markets are an example of good but not great adaptive efficiency for their sustaining diverse and constant experimentation pursuing innovation while opaque government decision-making are the opposite).

seek the best targets for any ensuing cost/signals.[207] This is doubly important if we understand costs as the enemy of profits: to whatever extent a firm is experiencing costs it cannot avoid, that is one kind of profit opportunity or another. Section B shows how judgments of this kind are invariably aided by the "engineering" investigations technology-based standard setting entails[208]—investigations that cost-benefit accounting too often foregoes.

B. *Theory Versus (Realized) Costs*

Resources for the Future and others have shown that *ex ante* evaluations continue to over-estimate the costs of complying with EPA standards compared to *ex post* 'ground-truthing' where it is done.[209] The unpredictability of cost avoidance is an evident source of error.[210] Even after-the-fact costs can be deeply uncertain.[211] Firms strive to avoid costs, but quantifying their (expected) successes or failures has turned out to be an intractable problem.[212] For example, some firms have been known to adopt solutions set out

207. *See infra* notes 249-51 and accompanying text.

208. Pizer & Kopp, *supra* note 39, at 1312.

209. *See* Richard D. Morgenstern, The RFF Regulatory Performance Initiative: What Have We Learned? (RFF DP 15-47) 30-35 (Oct. 2015) (reporting the results of nine retrospective studies by RFF researchers); Morgan, *supra* note 186, at 195; Joseph E. Aldy, Learning from Experience: An Assessment of the Retrospective Reviews of Agency Rules and the Evidence for Improving the Design and Implementation of Regulatory Policy (2014).

210. *See, e.g.*, Morgenstern, *supra* note 209, at 13. In Pigovian terms, the divergence between private and social costs—the "externality"—by itself explains neither the existence, scope, nor behavior of actual firms. *See* Carl J. Dahlman, *The Problem of Externality*, 22 J.L. & Econ. 141, 150-56 (1979). Some even argue that firms' interaction with their own factors of production yields innovation that, in its rate, direction, and value is irremediably stochastic. *See, e.g.*, Rosenberg, *supra* note 9, at 123. But if vertical integration—like production itself—is aimed at profit-making, it necessarily implies *cost avoidance* regardless of the sense in which costs are finally valued. Business strategists press this point instinctually. *See, e.g.*, Porter, *supra* note 36, at 64 ("The behavior of a firm's costs and its relative cost position stem from the value activities the firm performs in competing in an industry. A meaningful cost analysis, therefore, examines costs within these activities and not the costs of the firm as a whole.").

211. For example, most of the efficiency gains made from the tradeable SO_2 allowances created by the 1990 CAA amendments apparently stemmed from the spatial disparities between plants near low sulfur coal and those far from it. *See* Curtis Carlson et al., *Sulfur Dioxide Control by Electric Utilities: What Are the Gains from Trade?*, 108 J. Pol. Econ. 1292, 1320 (2000) (finding that spatial disparity explains most of the allowance trading that actually occurred). The relative magnitude of those gains compared to gains achieved under the 1970s NSPSs, however, has been questioned. *See* Margaret R. Taylor et al., *Regulation as the Mother of Innovation: The Case of SO_2 Control*, 27 L. & Pol'y 348 (2005) (arguing that most of the innovation in controlling SO_2 emissions came before 1990).

212. *See* Pizer & Kopp, *supra* note 39, at 1342 ("Without a randomized experiment to understand the consequences of new regulation, it is impossible to speak confidently about the costs borne by firms.").

in technology-based proposals—aiming to gain the early mover advantage—only to shift the technology baseline when EPA is finalizing the standard.[213] Of course, this source of error plagues cost-availability judgments no more than it does cost-benefit balancing.[214] The difference is that cost-availability evaluation may do better still.

Modern theories of the firm are more aptly described as theories of the *boundaries* of the firm—what firms optimize that markets do not.[215] To view the median firm as existing just as it does in order to minimize both its exchange and production costs[216] is to view industrial organization as a permanent disequilibrium.[217] It raises the notorious distinction between "marginal" and "average" costs[218]—a quagmire in economic theory going back generations.[219] But it does not much aid our sense of what will probably result from set production constraint(s) like our technology-based standards.[220] Knowing that firms typically "learn by doing" and thereby turn production into its own means of cost avoidance does not quantify that

213. *See* Final Cluster Rule, 63 Fed. Reg. at 18,517-518.

214. *Cf. id.* at 18,550 (noting EPA uncertainty in expected cost estimates, no matter how used). The difference, of course, is that benefits uncertainty will also detract from the standard's confidence level.

215. *See* Robert Gibbons, *Four Formal(izable) Theories of the Firm?*, 58 J. ECON. BEHAV. & ORG. 200, 201-04 (2005) (tracing four distinct groups of theories explaining firm scale and scope and the incentives to integrate). Of course, if the long-run cost curves of the firms in a sector are horizontal, "the size of each firm is indeterminate." BLAUG, *supra* note 12, at 436. But if the size of each firm is indeterminate, so is the number of firms in each industry—thereby casting doubt on the large numbers property of "perfect competition." *Id.*

216. *See, e.g.*, Armen A. Alchian & Harold Demsetz, *Production, Information Costs, and Economic Organization*, 62 AM. ECON. REV. 777 (1972); *cf.* Ronald H. Coase, *The Nature of the Firm*, 4 ECONOMICA 386 (1937) (firm size depends on the costs of organizing different entrepreneurs versus the exchange costs of using prices to do so).

217. *Cf.* Richard N. Langlois, *Transaction-cost Economics in Real Time*, 1 INDUST. & CORP. CHANGE 99, 105 (1992) (arguing that the "reigning" theories of the firm provide "illuminating snapshots of possible institutional responses to a momentary situation," but do not contextualize those responses in the passage of time).

218. "Instead of being *differentiating* in [the sense Adam Smith articulated] . . . an innovation may be *integrating*, in the sense that the new way of doing things—a new machine, say—performs in one step what had previously needed two or more steps." *Id.* at 117 (emphasis in original).

219. *See* BLAUG, *supra* note 12, at 586-95.

220. A variety of theories has long critiqued the neoclassical view of firms that they are *merely* profit-maximizing modes of production. *See* Oliver Hart, *An Economist's Perspective on the Theory of the Firm*, 89 COLUM. L. REV. 1757, 1757-65 (1989).

effect.[221] Nor does it provide usable boundaries within which the effect should be expected.[222]

Still, this sort of microeconomics diverges dramatically from the orthodoxy that prices reliably balance supply and demand,[223] that unprofitable competitors fail,[224] and that technological progress is (relatively) constant.[225] In the orthodox variants of cost-benefit analysis, setting a performance standard involves methodological circularities of one severity or another.[226] If it is of the "general" equilibrium variety, the circularity comes from using prices to calculate utility functions in an exercise grounded in the conviction that markets do not accurately price utility.[227] If it is some

221. *But see* ROSENBERG, *supra* note 9, at 120-40 (arguing that many classes of capital equipment could be studied for their predictable 'learning by using' returns). Arrow is celebrated for being first to formalize shifting production functions from the very activity of production. *See, e.g.*, ROBERT M. SOLOW, LEARNING FROM "LEARNING BY DOING": LESSONS FOR ECONOMIC GROWTH (1997) (explaining the influence of Kenneth J. Arrow, *The Economic Implications of Learning by Doing*, 29 REV. ECON. STUDS. 155 (1962)) [hereinafter SOLOW, LEARNING]. But Arrow's results proved too much, so to speak, and implied that 'bounded learning by doing' is the only realistic possibility. *See id.* at 10-21.

222. *See* SOLOW, LEARNING, *supra* note 221, at 34-41 (explaining Arrow's model as a provocation, not a description of growth).

223. *See* Kaldor, *supra* note 171, at 1242-44. *But see* Coase, *supra* note 27, at 713-14 (calling both the traditional focus on price and the industrial organization tradition "blackboard economics" for their low evidence-to-theory ratios); *cf.* BARZEL, *supra* note 172, at 11 ("In the [traditional] model, when equilibrium is disturbed a new equilibrium is instantaneously attained because, given zero transaction costs, the cost of adjustment is zero . . . commodities are made up of strictly identical specimens, people are fully informed regarding the exchanged commodities, the terms of trade are always perfectly clear, and trade is instantaneous.").

224. *Cf.* DRIESEN, *supra* note 7, at 93-94 (analyzing Amazon.com's long-term unprofitability and uninhibited capacity to raise capital). Regulation can, of course, create such distortions. *Cf.* Jonathan Remy Nash & Richard L. Revesz, *Grandfathering and Environmental Regulation: The Law and Economics of New Source Review*, 101 NW. U.L. REV. 1677 (2007) (describing vintage-differentiated regulatory standards' practical effect in US firms' investment and operating decisions); Stavins, *supra* note 142, at 42.

225. *Cf.* Elhanan Helpman & Manuel Trajtenberg, *A Time to Sow and a Time to Reap: Growth Based on General Purpose Technologies*, *in* GENERAL PURPOSE TECHNOLOGIES AND ECONOMIC GROWTH 55 (Elhanan Helpman ed., 1998) (finding that "general purpose technologies" which become extremely pervasive and sustain continued improvements in performance do so by fostering complementarities within their user sectors and account for a disproportionate share of total economic growth over time).

226. It will also entail the risk of two dimensions of uncertainty: that of risk/benefit estimates and that of cost estimates. *See* Finkel, *supra* note 33, at 110.

227. *See* MISHAN & QUAH, *supra* note 34, at 87-93; *cf.* MATTHEW D. ADLER & ERIC A. POSNER, NEW FOUNDATIONS OF COST BENEFIT ANALYSIS 161 (2006) (wrestling with the incompleteness of "overall welfare" given the limited range of goods encompassed); LITTLE, *supra* note 28, at 8-22 (struggling to find Pigou's or Marshall's theory of value and welfare consistent with their 'law of diminishing marginal utility' and concluding that their "positive economics" has no coherent concept of utility).

"partial" equilibrium exercise, it comes from assuming that a sector's givens, including its pollution abatement opportunities, are independent of the broader economy.[228] Assessing a technical solution's costs, and thus its cost-availability, for a sector's actual incumbent firms (or even a single, unique establishment) sheds those circularities for the value judgment that the true social harms to be avoided in regulation stem from production's observed *indivisibilities* like job losses, stranded capital, unique firm capabilities, and other functions of scale or scope.[229] Indeed, employment losses have often counted among the strongest reasons against a strict efficiency criterion for pollution standards.[230] There is no algorithm that can solve for indivisibilities.[231] The inertia in technological frontier and/or sectoral boundary estimates described above consists in these indivisibilities. Their discovery typically comes in a bottom-up search focused more on messy, nonstandard contexts than on long-challenged theorems or their calculus.

Part IV argues that, looking ahead, there is progress still to be made in improving and broadening the mandate for such searches and specifically for the use of cost-availability judgments over cost-benefit balancing for some of our toughest environmental challenges.

IV. Improved Cost-Availability, Mainstreamed

Our statutes' unique approaches to weighing costs have long included, implicitly or explicitly, the aim of inducing innovation to better minimize *all* costs.[232] As the first parts of this essay showed, though, the unpredict-

228. *See* Ian Steedman, *Sraffian Interdependence and Partial Equilibrium Analysis*, 12 Cambridge J. Econ. 85 (1988) (showing that Marshall's partial equilibrium theory fails just from the assumption of produced inputs).

229. *Cf.* Kaldor, *supra* note 171, at 1237 (arguing that equilibrium theory is "barren and irrelevant as an apparatus of thought" in its failure to account for increasing returns or for indivisibilities in production); Herbert E. Scarf, *The Allocation of Resources in the Presence of Indivisibilities*, 8 J. Econ. Persp. 111, 115 (1994). Such a value judgment is perfectly coherent as a matter of first order ethics. *See* Elizabeth Anderson, Value in Ethics and Economics 210-11 (1993) (arguing that some non-commodity values are "political goods" best secured through democratic institutions of voice, equity and deliberation). Each of us experiences our own life as indivisible in this sense even if we perhaps should not. *See* Derek Parfit, Reasons and Persons 281-82 (1984).

230. *See* Driesen, *Distributing*, *supra* note 135, at 3; Masur & Posner, *supra* note 150, at 695-96; *cf.* Richard D. Morgenstern, *Analyzing the Employment Impacts of Regulation*, *in* Does Regulation Kill Jobs? 33, 37 (Cary Coglianese et al. eds., 2013) (finding in analysis of CAA and CWA pollution abatement expenditure data that employment showed statistically insignificant increase as expenditures rose).

231. *See* Scarf, *supra* note 229, at 116. That is, no algorithm exists to do so simply through pricing. Scarf presents an alternative "neighborhood theory" of finding optimality. *See id.* at 118-27.

232. *See supra* notes 39-41 and accompanying text.

ability of actual firms and innovation, coupled with the intractability of the economic concept of cost, has made inducing cost-saving innovations a rather uncertain enterprise.[233] Of course, different policies' effects on innovation are literally all around us. Ironically, this nexus has become clearest in the media program vesting the most authority in EPA by its sheer scope and complexity: the CAA's MACT standards.[234] Defining boundaries for either of our purposes—identifying a solution or evaluating its costs—has lately become a treacherous affair for MACT.[235] On the one hand, "[t]hat different industries may be subject to different standards and that [EPA] need not bear the burden of explaining those differences is clear."[236] On the other hand, the notion of an available (or 'achievable') benchmark presumes at least some degree of integrity in the comparison's parameters.[237] For example, in assessing the best performing facilities from a nationwide sample where all of the best performers were located in a single state, how should those leaders be counted against those (ostensible laggards) who faced no stringent local standards forcing their hand?[238] Or in constructing a category of HAP emitters, many of whom would eventually face controls im-

233. *See supra* notes 48-50 and accompanying text.

234. "Hazardous air pollutants" (HAPs) include virtually all regulated air pollutants—the exceptions being the criteria pollutants, greenhouse gases, and ozone depleting substances—and § 112(a) regulates them at relatively low volumetric thresholds. *See* Martineau, *supra* note 91, at 230-35.

235. EPA has had several MACT standards remanded for insufficient explanation of a categorization decision. *See* Nat. Res. Def. Council, Inc. v. EPA, 489 F.3d 1250, 1257-61 (D.C. Cir. 2007); Ne. Md. Waste Disposal Auth. v. EPA, 358 F.3d 936, 947-50 (D.C. Cir. 2004); Chem. Mfrs. Ass'n v. EPA, 217 F.3d 861, 865 (D.C. Cir. 2000); Davis Cty. Solid Waste Mgnt. v. EPA, 101 F.3d 1395, 1406-11 (D.C. Cir. 1996). The importance of subcategorizing was evident as soon as MACT got underway. *Cf.* Martineau, *supra* note 91, at 248:

> The importance of subcategorization cannot be underestimated. The way EPA subcategorizes, if it does at all, can significantly affect the floor determination for the source category, and thereby dramatically affect the ultimate MACT standard's degree of stringency. If one sector of a particular industry segment has better pollution control equipment than another segment [sic] in the same source category, the highly controlled units will drive the floor determination and thus set a minimum standard for the rest of the source category.

236. Nat'l Lime Ass'n v. EPA, 627 F.2d 416, 447 n.108 (D.C. Cir. 1980). This has remained true in the MACT context. *See, e.g.*, U.S. Sugar Corp. v. EPA, 830 F.3d 579, 656-57 (D.C. Cir. 2016) (deferring to EPA's subcategorization of boilers by the fuel types used even though boilers were permitted to fuel-switch from year-to-year and change categories of controls as a result).

237. *See* Masur & Posner, *supra* note 150, at 682-83.

238. *See* Nat'l Ass'n for Surface Finishing v. EPA, 795 F.3d 1, 9 (D.C. Cir. 2015). California's restrictions on electroplating finishers made them significantly better than their counterparts elsewhere. *See* Final Chromium Rule, 77 Fed. Reg. at 58,230-32. With that data in hand, once it re-opened the "beyond-the-floor" hexavalent chromium standard, EPA then found that the costs of mandating California's stringent filtration standards outweighed the

posed by a separate but overlapping NSPS standard yet to be finished but who, when so governed by that NSPS would then drop out of the 'MACT pool' from which costs and technology were being counted,[239] how should EPA count or average those performances? Or from a MACT pool of boilers and industrial furnaces of varying sizes, purposes, feedstocks, and pollution equipment, some of which controlled certain HAPs well but none of which controlled all HAPs well, should EPA set MACT floors pollutant by pollutant or by subcategorizing the sources?[240]

Each of the above discoveries indicates some kind of *endogeneity* or dependence. In the first instance, variations in state/local law made the sources of a sub-jurisdiction into noticeable outliers—yet performance leaders all the same.[241] In the second instance, an accident of sequencing in two overlapping standards drew the boundaries of the performance average into question.[242] Finally, in the last instance, the significance of pollution control efforts to the overall enterprise forced the standard setter into having to choose how to compare performances: by production factors or by control equipment?[243] In all three, constructing the benchmark(s) highlighted the observed technical variations' *social* drivers. As we have agreed throughout, technological frontiers and the possibilities for their extension have always turned to some degree on policy choices—not solely the invisible hand of accumulated or projected technical progress. But highlighting the degree to which the performances driving technology-based standard setting actually reflect underlying policies draws out the intentional influences (in one form or another) exerted on the direction and pace of technical change. It also foregrounds the judgments entailed in constructing the sectoral boundaries and technological frontiers being used. Section A contrasts two long-run

benefits of doing so nationally, and set the (cost-conscious) beyond-the-floor standards only after controlling for the California operations statistically. *Id.* at 58,225-28.

239. *See* Portland Cement Ass'n v. EPA, 665 F.3d 177, 184-86 (D.C. Cir. 2011); *see also U.S. Sugar Corp.*, 830 F.3d at 593-94.

240. *See U.S. Sugar Corp.*, 830 F.3d at 610-11; *see also* Sierra Club v. EPA, 167 F.3d 658, 669 (D.C. Cir. 1999).

241. *See* Final Chromium Rule, 77 Fed. Reg. at 58,231-32 (observing that California restrictions on chromium emissions are achieved with chromium plating and chromic acid anodizing facilities registering their observed performances at high cost). The related but distinct issue of using subnational jurisdictions' permitted emissions levels as *evidence* of achievability rightly requires verifying the operation of actual sources within those jurisdictions. *See* Sierra Club v. EPA, 353 F.3d 976, 989 (D.C. Cir. 2004).

242. Logically, figuring the costs of a later-in-time standard (if not always its technological achievability) will turn on the practical impact upon covered sources of any earlier-in-time standard(s). *See Portland Cement*, 665 F.3d at 184-86; *see also U.S. Sugar Corp.*, 830 F.3d at 593-94.

243. *See also* Sierra Club v. EPA, 479 F.3d 875, 880-81 (D.C. Cir. 2007); Cement Kiln Recycling Coal. v. EPA, 255 F.3d 855, 861-67 (D.C. Cir. 2001).

case studies, the 2015 NSPS for electricity generating units (EGUs) and their greenhouse gases (GHGs) and EPA's water intakes rules, to schematize these influences and the judgments they entail. Section B offers some general lessons for using technology-based standards to induce innovation.

A. *The Relevance of Indivisibilities and Endogeneity*

EPA often finds that production governed by a performance standard improves its efficiencies over time.[244] There may be no predicting these improvements. Indeed, it is often impossible to sort out the causes of observed efficiency gains after the fact.[245] But for what gains should technology-based standards aim? Detecting (or hypothesizing) endogeneity after the fact is a long way from confidently predicting innovations that will follow from one standard or another. We also concluded above that the real harms to be avoided in regulation typically stem from indivisibilities in production like job losses, stranded capital, *etc.*, and that these all combine to form a kind of *inertia* to which the standard setting should be sensitive.[246] So-called "transition relief," *e.g.*, grandfathering, has been a stock response, although severe difficulties have attended that choice too.[247] Finally, if outputs remain roughly competitive while inputs, equipment, and/or processes are shifting, as has been the case in wholesale electricity markets,[248] one mode of production may become significantly disfavored simply for emitting the target pollutant(s). As already mentioned, these challenges intersected in the 2015 NSPS for GHGs from fossil fuel-fired EGUs.

As price increases shift a product's cost/value ratio, they can eventually undermine the product itself.[249] In that case, keeping the product in the technological fold may become impossible as better ways of meeting de-

244. *Cf.* Final Chromium Rule, 77 Fed. Reg. at 58,231 (concluding that, the mere discovery in a technology review that some facilities using the benchmark solution(s) identified in an earlier MACT standard are doing better than expected is insufficient reason by itself to reopen that MACT standard).

245. *See supra* note 211 and accompanying text.

246. *See supra* notes 169-77 and accompanying text.

247. *See* Richard L. Revesz & Allison L. Westfahl-Kong, *Regulatory Change and Optimal Transition Relief*, 105 Nw. U.L. Rev. 1581, 1594-621 (2011) (arguing that transition relief can dampen incentives to anticipate legal change).

248. *See* Final EGU NSPS, 80 Fed. Reg. at 64,524-527.

249. *See, e.g.*, Newell et al., *supra* note 202 (tracing changes in consumer appliances market caused by fluctuating energy costs and the consumer preference changes that resulted); *see also* Elrod & Malik, *supra* note 184 (finding evidence that some product switching at the establishment level resulted from EPA's cluster rule).

mand overtake it. To electricity generation, coal is a produced input[250] and, in most technology-based standard setting, process and input changes have always been an option.[251] As EPA found in its 2015 EGU NSPS, factor productivity can be so tied to costs that *any* constraint will decisively favor alternative inputs.[252] Coal-fired EGUs attaining a certain combustion efficiency and capturing their GHG emissions would, according to best estimates, be undersold at wholesale rates by some existing nuclear and renewable producers and by most existing and future natural gas producers.[253] The innovations shifting coal's cost/value ratio may or may not have been independent of regulatory action (although to whatever extent coal's *other* costs were "internalized" by regulation, it was at best a qualified independence).[254] But an aggregate cost-benefit analysis could logically find negligible costs caused by the GHG constraint *per se*.[255] Indeed, by EPA's projections those same hypothetical future units would *still* be undersold by natural gas producers even without the GHG NSPS—especially with continued low growth in overall demand and subsidized renewable genera-

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250. Partial equilibrium modeling of the sector is therefore "wrong" in Pizer and Kopp's words, *see supra* note 39, at least to the extent that that input's price is affected by demand. *See* Steedman, *supra* note 228.

251. In the CWA: *See* Waterkeeper All., Inc. v. EPA, 399 F.3d 486, 501-02 (2nd Cir. 2005); Citizens Coal Council v. EPA, 447 F.3d 879, 895 (6th Cir. 2006). In the CAA: *See* Sierra Club v. EPA, 353 F.3d 976, 988 (D.C. Cir. 2004) (reviewing and affirming EPA's assumption that cleaner feedstocks would be substituted); Sierra Club v. EPA, 499 F.3d 653, 656 (7th Cir. 2007).

252. *See* Final EGU NSPS, 80 Fed. Reg. at 64,543-92. Coal's many costs include various air pollutants (sulfur dioxide, nitrogen oxides, particulates, heavy metals and GHGs), Revesz & Lienke, *supra* note 201, at 10-11, water pollutants (cooling water intakes' impingement and entrainment, biocides, acidic and alkaline runoff, sediment, and fly ash) and substantial post-extraction landscape reclamation. *See* Patrick C. McGinley, *From Pick and Shovel to Mountaintop Removal: Environmental Injustice in the Appalachian Coalfields*, 34 Envtl. L. 21, 24-27 (2004).

253. This resulted from a comparison of cost-at-proposal estimates using the "levelized cost of electricity" (LCOE)—a summary metric determining the viability of any generating source. Final EGU NSPS, 80 Fed. Reg. at 64,626-28, 64,545-46; *see also* U.S. EPA, Regulatory Impact Analysis for the Final Standards of Performance for Greenhouse Gas Emissions from New, Modified, and Reconstructed Sources: Electric Utility Generating Units § ES.3 (EPA-452/R-15-005) (2015) [hereinafter RIA for EGU NSPS].

254. *See* Final EGU NSPS, 80 Fed. Reg. at 64,628-32 (reviewing NSPS interactions with other regulatory requirements).

255. *See id.* at 64,563-64 (noting that EPA considered the costs of its NSPS at the national and the individual source level). That could be equally true for employment effects, as well. *See* Joseph E. Aldy & William A. Pizer, *The Employment and Competitiveness Impacts of Power-Sector Regulations*, *in* Does Regulation Kill Jobs? 70, 70 (Cary Coglianese et al. eds., 2013) (finding minimal gross and net employment impacts from various CAA air pollution control standards in US manufacturing sectors).

tion.[256] Just the capital equipment costs to achieve state-of-the-art heat rate efficiencies was, as projected, too costly.[257] Accounting for existing coal-fired EGUs' grandfathering advantages,[258] it seemed to EPA that technology and the shrinking demand for energy services were combining to cut *new* coal generation out of the market.[259]

A finding of negligible aggregate expected costs (because the factor is expected to be outcompeted in any event) is not, however, a finding that the solution identified is cost available.[260] Indeed, zero marginal profitability *with that factor* could imply the opposite. Yet firms constantly substitute inputs and physical capital as their cost/value ratios change, often doing so

256. Final EGU NSPS, 80 Fed. Reg. at 64,513. This led EPA to the conclusion that its final NSPS would cause "negligible CO_2 emission changes, quantified benefits, and costs by 2022 . . . ." *Id.* at 64,515. For cost-benefit purposes, that conclusion was decisive and EPA developed it fully in the RIA. *See* RIA FOR EGU NSPS, *supra* note 253, at § 4.1-4.5.5. Experience thus far, with the CPP stayed judicially, has borne out the projections. *See* Jack Fitzpatrick, *Coal Plants Are Shutting Down, With or Without the Clean Power Plan*, MORNING CONSULT (May 3, 2016) https://morningconsult.com/2016/05/03/coal-plants-shutting-without-clean-power-plan/.

257. *See* Final EGU NSPS, 80 Fed. Reg. at 64,515, 64,558-62 (LCOE of new integrated gasification combined cycle (IGCC) units versus alternatives not competitive with NGCC, competitive with some nuclear); International Energy Agency—Coal Industry Advisory Board, *Power Generation from Coal: Measuring and Reporting Efficiency Performance and CO_2 Emissions* (2010), [hereinafter *Generation from Coal*], https://www.iea.org/ciab/papers/power_generation_from_coal.pdf. The IEA found that global average efficiency rates for existing coal-fired generating stations was about 33.5% in 1971, had risen only to about 35.1% by 2007 and that new plants should be >40% efficient, but that capital stock turnover was unlikely without policy inducement. *Id.* at 57-61. Unlike its preceding century where coal combustion grew continuously more efficient, *see supra* note 161, coal's present and projected future make it what business strategists call a "cost driver" for firms in the business of selling electricity wholesale. *Id.* at 45-56 (analyzing fuel variability, ash quality and quantity, carbon intensity, cooling water demands, and flue gas scrubbing as cost drivers in coal combustion).

258. According to Revesz and Lienke, if not for the vintage-differentiated standards advantaging "existing" coal-fired EGUs in their conventional pollutant emissions, most of the Nation's existing coal-fired EGUs would probably have been shuttered by 2015 because of those emissions. *See* REVESZ & LIENKE, *supra* note 201, at 152-54.

259. *See* Final EGU NSPS, 80 Fed. Reg. at 64,524-25 (noting falling but stable natural gas prices and underlying technology, market distortions by policy interventions, growing supply of renewables, and continuing fall in demand relative to population growth).

260. The same forces leading to vertical integration, after all, could leave some large firms saddled with high costs. *See* Scarf, *supra* note 229, at 127. Thus, EPA took care also to find the emission standard "achievable" within the meaning of CAA § 111(b). *See* Final EGU NSPS, 80 Fed. Reg. at 64,573 & n.356 [hereinafter "Achievability TSD"], (citing U.S. EPA, Technical Support Document (TSD): Achievability of the Standard for Newly Constructed Steam Generating EGUs (EPA-HQ-OAR-2013-0495-11771), https://www.regulations.gov/document?D=EPA-HQ-OAR-2013-0495-11771).

only after first movers have shown the way.[261] So EPA compared the projected costs of carbon capture[262] plus state-of-the-art heat-rate efficiencies to the capital costs imposed by *past* NSPSs and concluded that the expected costs of *partial* carbon capture were "reasonable."[263] What constitutes "reasonableness" under this sector's circumstances, though? According to a "broad consensus,"[264] the sector is undergoing profound shifts along with the technologies of energy production and consumption.[265] EPA's investigations confirmed that firms in the wholesale electricity business could and likely will shift off of coal inputs,[266] even for so-called base load demands,[267] notwithstanding coal's long predominance.[268] It found that the

261. Technology-based performance standard setting utilizing a "model plant" operating in a commercial context—assuming some 'hard luck' is included in the assumptions—neutralizes arguments that 'it cannot be done.' But whether it can be done commercially under varied circumstances is the issue under both CAA and CWA practice. *See supra* notes 95-99, 122 and accompanying text. EPA met the 'hard luck' objections to its EGU NSPS's carbon capture demonstration establishment at length in its rulemaking. *See* Final EGU NSPS, 80 Fed. Reg. at 64,556-73.

262. EPA's model plant running a carbon capture system commercially was a retrofit of an existing coal-fired EGU. *See* Final EGU NSPS, 80 Fed. Reg. at 64,549.

263. *See* Achievability TSD, *supra* note 260, at 5; *cf.* Final EGU NSPS, 80 Fed. Reg. at 64,575 ("Much like carbon capture scrubbers today, the technology to capture and remove SO_2 from power plant flue gases was new to the industry and was not yet widely deployed at large coal-burning plants when the EPA first promulgated the 1971 [NSPS]."); *id.* at 64541 (citing Sierra Club v. Costle, 657 F.2d 298, 343 (D.C. Cir. 1981)). Given one of the model plant's recorded start-up difficulties, EPA reduced the carbon intensity performance rate to reflect "partial" carbon capture averaged over a 12-month period. *See id.* at 64,549-50; 64,574.

264. Final EGU NSPS, 80 Fed. Reg. at 64,524.

265. *See* Thomas Covert et al., *Will We Ever Stop Using Fossil Fuels?*, 30 J. ECON. PERSP. 117, 126-34 (2016).

266. *See* Final EGU NSPS, 80 Fed. Reg. at 64,515.

267. Base load is that quantity of supply constantly flowing, regardless of peaking demands. Until important problems with storage are solved, LCOE estimates for wind and solar will remain higher than those for natural gas, nuclear fission, and even some existing coal. *See* RIA FOR EGU NSPS, *supra* note 253, at 2-1—2-43; Covert, *supra* note 265, at 127-31. The increasing adaptability of natural gas combined cycle (NGCC) generation and that fuel's superior GHG-to-megawatt ratio, however, is undermining coal's position regardless of storage's technological frontier.

268. *See* Final Rule—Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, 80 Fed. Reg. 64,662, 64,796 (2015) [hereinafter CPP Final Rule] (noting a continual trend since 2000 of fossil fuel generation shifting from coal and oil to NGCC units). It is entirely consistent with the CAA as amended that coal-fired electricity generation could eventually end. *Cf.* REVESZ & LIENKE, *supra* note 201, at 88-111 (noting the progression of restrictions on coal that have followed from CAA implementation); Craig N. Oren, *Struggling for Context: An Appraisal of "Struggling for Air"*, 46 ENVTL. L. REP. 10838, 10838 (2016) ("[C]oncern about the effects of coal-fired power plants and efforts to control those effects go back at least 25 years, rather than being a 'War on Coal' launched by the Barack Obama Administration.").

strongest firms in that market are those selecting the most advantageous generating, transmission, and distribution factors over the medium- to long-term.[269] Profits turned on their doing so.[270] If the advantages of the technology-based approach are to be pressed fully, "reasonableness" in this context should turn on the precision of the signals being sent throughout a sector as EPA finds it: every firm will be under competitive pressures of one sort or another, every firm will be engaged in at least some (incompletely) pragmatic problem-solving.[271]

The instructive contrast is the water intakes rules. When EPA investigated the sectors utilizing cooling water withdrawn from surface waters of the United States, it found cost-available engineering solutions only for reducing impingement mortalities, *i.e.*, at the intake, and used those to set an inclusive performance standard there.[272] But among the 1,000+ facilities covered by its standard, the costs and challenges of retrofitting to reuse water and/or switching to waterless factors (limiting so-called "entrainment" mortalities) varied considerably in both magnitude and technical scope.[273] Parts of the thermoelectric sector were particularly dependent on high-volume withdrawals,[274] *i.e.*, those segments of it not yet converted to natural gas combined cycle (NGCC) generation.[275] The segments of the industry not switching to NGCC clearly had powerful motives given all of the pushes in that direction. Any *reason* to ignore those frictions, *i.e.*, impose a dry cooling standard for the whole category, would have had to outweigh or

269. *See* RIA FOR EGU NSPS, *supra* note 253, at 2.2.1—2.3.2.

270. As EPA acknowledged in its CPP cost analysis, firms' switching to NGCC or zero-emission renewables face important contractual and other indivisibilities at specified facilities and/or turnover rates. *See* CPP Final Rule, 80 Fed. Reg. at 64,795-802. This was a "transition cost" that benefit-cost analysts would have otherwise ignored. *See* Ferris & McGartland, *supra* note 37, at 176-77. CAA § 111(b)'s concern for cost availability kept the matter important. *See* CPP Final Rule, 80 Fed. Reg. at 64,721-36.

271. *See* Charles F. Sabel, *A Real-Time Revolution in Routines*, *in* THE FIRM AS A COLLABORATIVE COMMUNITY: RECONSTRUCTING TRUST IN THE KNOWLEDGE ECONOMY 106 (Charles Hecksher & Paul S. Adler eds., 2006).

272. *See* Revised Final Intakes Rule, 79 Fed. Reg. at 48,340-41 (finding that modified traveling screens are the "best technology available" for reducing impingement mortality at existing units).

273. *See* Revised Final Intakes Rule, 79 Fed. Reg. at 48,332-34.

274. *See id.* at 48,356 (noting highly variable costs for retrofitting). "An entity that owns multiple facilities could be adversely affected because of the cumulative burden of [multiple costly retrofits]." *Id.* at 48,399.

275. In a 2015 technology assessment, the Government Accountability Office (GAO) found that installed NGCC capacity is predominantly air-cooled. *See* U.S. GOVT. ACCOUNTABILITY OFF., TECHNOLOGY ASSESSMENT: WATER IN THE ENERGY SECTOR: REDUCING FRESHWATER USE IN HYDRAULIC FRACTURING AND THERMOELECTRIC POWER PLANT COOLING 43-50 (GAO-15-545)(2015), [hereinafter "GAO"], http://www.gao.gov/assets/680/671913.pdf.

to exclude them as a consideration.[276] Section B shows how that tight a focus is the signature strength of technology-based standard setting.

B. *Pushing a Technological Frontier: Energy Services in Transition*

Costs and cost avoidance are hard to predict at a sectoral scale. The shift to NGCC, wind, and solar factors currently in progress in wholesale electricity markets might address GHG and water problems simultaneously.[277] Indeed, a dry cooling standard in the intakes rules might have eased much of the thermoelectric sector's vulnerabilities to drought—which have been a growing problem in several regions.[278] But where the barriers hindering a fuller conversion to NGCC and/or renewables were to be found remained uncertain.[279] In reality, energy services markets are among the most complex and least predictable in the world.[280] The orthodox answer—modeling these uncertainties with various subjective probability parameters in some series of equilibrium algorithms—is a "conceptual, rather than practical" solution.[281] The stock response when the probability estimates prove wrong is that they were provisional.[282] But equilibrium theory's indifference to hard problems of causation like energy demand elasticities[283] leaves

276. GAO found from its consultation with experts in the thermoelectric sector that retrofitting existing facilities with dry cooling or recirculating cooling towers could be prohibitively expensive for several reasons. *See* GAO, *supra* note 275, at 44-45 (citing space availability, pressurized unit incompatibilities and other causes of cost anomalies at certain establishments).

277. The mix of NGCC-to-renewables phasing out coal is one particular endogeneity modelers agree might be considerable. *See* Gillingham et al., *supra* note 161, at 2736.

278. *See* Tidwell et al., *supra* note 147, at 515; *cf.* GAO, *supra* note 275, at 1 (noting water stress and drought as the principal justifications for the water withdrawal technology assessment).

279. *See* CPP Final Rule, 80 Fed. Reg. at 64,799-802. NGCC capacity's GHG advantages are in the near- to medium term (phasing out coal), yet wind and solar accounted for roughly 70% of new capacity in 2015. *Id.*

280. *See* Steve Sorrell & John Dimitropoulos, *The Rebound Effect: Microeconomic Definitions, Limitations and Extensions*, 65 ECOLOGICAL ECONS. 636, 636-38 (2007). Many of the notorious feedback (or "rebound") effects in energy markets where demand rises as technology improves efficiency—whether of the single commodity variety. *See* J. Daniel Khazzoom, *Economic Implications of Mandated Efficiency in Standards for Household Appliances*, 1 ENERGY J. 21 (1980), or the multiple commodity variety; Peter H.G. Berkhout et al., *Defining the Rebound Effect*, 28 ENERGY POL'Y 425 (2000)—continue to evade rigorous quantification. Sorrell & Dimitropoulos, *supra* note 280, at 645 (conjecturing that such rebound effects are probably *over*-estimated).

281. Ferris & McGartland, *supra* note 37, at 173.

282. *See* Gilboa et al., *supra* note 24, at 175-77 (describing a Bayesian approach to probabilities in economic modeling).

283. *See* Sorrell & Dimitropoulos, *supra* note 280, at 638-39.

its users to ignore the very observed "indivisibilities" and nonlinearities so crucial to finding real cost-avoidance opportunities.[284] The technology-based approach views these discoveries as the basis of expectations that a standard's costs can be minimized in actual markets. In the end, the vagueness of the economic concept of cost at least permits aiming for as much.[285]

Before developing his noted theory of induced innovation,[286] Sir John Hicks attempted to rehabilitate some nascent work on uncertainty and profit begun by Frank Knight and others.[287] Hicks argued that profit's place as a residual somewhere between (or beyond) wages and rents was a profound amendment to equilibrium theory so long as it was attributed not to the act of risk-taking—as Knight and others had argued—but rather to the profit-taker's *success* in having navigated the practical exigencies of production in competitive markets.[288] On this theory, profits are but the mirror image of costs in an economy that is constantly churning.[289] Equilibrium modeling presupposes that we can track how our actions guide that churn. Yet we cannot—leaving a paradox of equilibrium economics to those cost-

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284. This may reflect cost-benefit's use of "cost" as a proxy for harm. A proxy, no matter how well designed, is always just a proxy. *Cf.* ADLER & POSNER, *supra* note 227, at 160 (acknowledging that certain death is not an infinite utility loss merely because there must be an infinite willingness to pay to avoid it). But escaping the oversimplified theories of induced innovation and observing the disparities among industrial sectors combine to discredit the "notion of a smooth, convex, well-defined [curve] in most microeconomic theorizing in which the structure of relative factor prices yields a determinate solution to the choice of technique problem under all circumstances," ROSENBERG, *supra* note 9, at 233, a notion entrenched in cost-benefit orthodoxy.

285. By definition, the useful life of physical capital eventually comes to an end. Thus, the CPP's assumption that generation shifts among affected EGUs could eventually result in coal's elimination—barring the use of GHG capture—need not have entailed shifting costs. Indeed, EPA's projection of net employment gains from the CPP as monetizable "benefits," *see* CPP Final Rule, 80 Fed. Reg. at 64,928-29, at least implied the assumption that averaging utilities was acceptable. *See id.* at 64,928 (concluding that employment losses in the electricity generating sector would be offset by employment gains elsewhere, especially demand-side energy efficiency).

286. *See supra* notes 25-26 and accompanying text.

287. *See* John R. Hicks, *The Theory of Uncertainty and Profit,* 32 ECONOMICA 170 (1931).

288. *See* Hicks, *supra* note 287, 173-87. One can plausibly interpret Knight himself as having held a similar view. *See* Stephen F. LeRoy & Larry D. Singell, Jr., *Knight on Risk and Uncertainty,* 95 J. POL ECON. 394, 397-401, 405 (1987). Indeed, even Marshall—the father of partial equilibrium analyses—allowed that, over a long run control of production could yield unaccounted-for residuals to the most successful competitors. *See* BLAUG, *supra* note 12, at 354-55.

289. *Cf.* Brooke, *supra* note 175, at 230 (Knight's world was static because the sum of all payments to the owners of the factors of production plus entrepreneurial profits was constant whereas Hicks saw profit stemming from a dynamic economy where all of the above is churning); BARZEL, *supra* note 173, at 148 (noting that the "public domain" from which positive value commodity attributes may be captured and priced is in constant flux).

benefit champions who think it should calibrate our environmental standards for us. In reality, technological innovation is both the opportunity to profit and a cost of trying to do so. As Paul Romer put it,

> instructions for working with raw materials are inherently different from other economic goods. Once the cost of creating a new set of instructions has been incurred, the instructions can be used over and over again at no additional cost. Developing new and better instructions is equivalent to incurring a fixed cost. This property is taken to be the defining characteristic of technology.[290]

Technology in this light is both a fixed cost and a means of *cost avoidance*. Technological information like this can be costly to produce and/or process, and how costly it is at any given time depends upon the valence of the information and the ability of the agent to evaluate and use it.[291]

The aim of prompting innovation as a consequence of cost avoidance points to those agents who are already succeeding somehow. Setting any technology-based standard involves discretionary judgments as to that standard's (1) applicability, (2) format, and (3) stringency.[292] Most often the standard will traverse, implicitly or explicitly, the sources' prevailing inputs,[293] processes or work practices,[294] and any physical capital (for either production or emissions control)[295] in each of these three facets. How real firms will adjust to the standard and to each other's reactions—and thus what market shifts to anticipate—are all uncertain. *Ex ante* cost estimates are, for this reason and others, subject to severe confidence limits stemming from how quickly (and intentionally) the future can diverge from our projections of it. Experience with technology-based standard setting for new versus existing sources has not yielded much precise quantification of what the advantage (e.g., of grandfathering) is worth,[296] but it has generally confirmed the intuition that market behaviors are often patterned by what those making capital decisions anticipate from an *overall* regulatory cli-

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290. Paul Romer, *Endogenous Technological Change*, 98 J. Pol. Econ. S71, S72 (1990).

291. Cohen, *supra* note 9, at 195.

292. *See supra* notes 77, 156-92 and accompanying text. This is not to say that technology-based standard setters will have been aware of these three dimensions (or the information needs they entail), *see* Adler et al., *supra* note 135, at 164-65, nor of the complementarities among them. *See* Revesz & Westfahl-Kong, *supra* note 247, at 1615-18 (finding that the provision of "transition relief" in vintage-differentiated performance standards and the stringency of those standards should be decided simultaneously).

293. *See supra* note 78 and accompanying text.

294. *See supra* notes 89 and accompanying text.

295. *See supra* notes 272-76 and accompanying text.

296. *Cf.* Stavins, *supra* note 142, at 49-56 (concluding that precise valuation of "existing source" status not possible from extant data)

mate.[297] For all its complexity, the Obama Administration's CPP was grounded in a bottom-up analysis of the costs to incumbent firms and electricity ratepayers of making cost-available adjustments to extant electricity generating portfolios, combined with the tools amenable to state use for lowering the costs of doing so in the aggregate.[298] It reflected a technology-based approach to inducing and supporting innovation in one of our least predictable markets. The CAA linked the EGU NSPS to the CPP quite tightly: without it, EPA had no authority to call for CPP plans from participating states in the first place.[299] As the political winds have turned against the CPP, analytical nuts and bolts within the CPP and EGU NSPS have been lost, perhaps for good. But the tactics honed in those rulemakings, like those used in the intakes rules and elsewhere, are not only still serviceable: they may represent our best hope for finding consensus actions against systemic problems like climate change.

Conclusion

Formal cost-benefit analysis has attracted a powerful following and a powerful critical literature. Understanding cost as a decision factor aligned against stringency in environmental performance standard setting views cost as a proxy for harm or damage to production. But mainstream economics has moved on from that understanding of this essential yet vague concept, as did the unique approach EPA has fashioned to evaluating the costs of its performance standards in real industrial sectors pursuant to the CAA, CWA, and similar statutes. EPA's method, perhaps best characterized as induced cost avoidance, skips straight to what firms can be doing now and over the short- to medium-term to minimize all costs of production and consumption, whether priced or not. This uniquely American approach to pollution control holds within it a potential we cannot afford to ignore or consign to the past.

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297. *See* Revesz & Westfahl-Kong, *supra* note 247, at 1617 (finding that "sequential optimization" in performance standards can distort the relevant comparisons given firms' own efforts to avoid costs); Gray & Shadbegian, *supra* note 159, at 254 (finding weak tendencies for existing pulp and paper plants to keep operating where a state's relative regulatory stringency is low and expected to remain so); Aldy & Pizer, *supra* note 255, at 85 (finding that annual volatility in manufacturing sectors was likely much more influential than any regulatory costs the firms bore).

298. *See* CPP Final Rule, 80 Fed. Reg. at 64,663-67. EPA's "building block" approach to supporting that transition, (1) improving efficiencies at existing coal facilities, facilitating the switch (2) to NGCC units and (3) to zero-emitting renewable capacity, made use of performance standards quantified at the national, regional, and individual state levels. *See id.* at 64,563-82.

299. *See* 42 U.S.C. § 7411(d)(1) (authorizing EPA to prescribe regulations for existing sources only if an NSPS would apply "if such existing source were a new source").