

**The Law of the Test:
Performance-Based Regulation and Diesel Emissions
Control**

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The Law of the Test: Performance-Based Regulation and Diesel Emissions Control

Cary Coglianese and Jennifer Nash

Abstract

The Volkswagen diesel emissions scandal of 2015 not only pushed that company's stock and retail sales into freefall, but also raised serious questions about the efficacy of existing regulatory controls. The same furtive actions taken by Volkswagen had been taken nearly twenty years earlier by other firms in the diesel industry. In that previous scandal, the U.S. Environmental Protection Agency (EPA) discovered that diesel truck engine manufacturers had, like Volkswagen would later do, programmed on-board computers to calibrate their engines one way to satisfy the required emissions test. Those manufacturers had also programmed the on-board computers to re-calibrate the engines automatically to achieve better fuel economy and responsiveness when the trucks were on the road, even though doing so increased emissions above the mandated level. This Article provides an in-depth retrospective study of the federal government's efforts to regulate diesel emissions. In particular, it chronicles the earlier saga over heavy-duty diesel truck engines to reveal important lessons for regulators who use a regulatory strategy known as performance-based regulation. Endorsed around the world and used in many settings, performance-based regulation mandates the attainment of outcomes—the passing of a test—but leaves the means for doing so up to the regulated entities. In theory, performance standards are highly appealing, but their actual performance in practice has remained virtually unstudied by scholars of regulation. This Article's extensive analysis of U.S. diesel emissions control provides a new basis to learn how performance-based regulation works in action, revealing some of its previously unacknowledged limitations. Precisely because performance-based regulation offers flexibility, it facilitates, if not invites, private-sector firms to innovate in ways that allow them to pass mandated tests while confounding regulators' broader policy objectives. When regulating the diesel industry or any other aspect of the economy, policymakers should temper their enthusiasm for performance standards and, when they use them, maintain constant vigilance for private-sector tactics that run counter to proper regulatory goals.

Keywords: Regulation, Performance Standards, Air Pollution, Emissions Control, Volkswagen AG

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*“[N]o test can cover everything.”**

Introduction

When Martin Winterkorn, the chief executive officer of Volkswagen, announced to the world in the fall of 2015 that he was “deeply sorry” for having “broken the trust” of the public, he cast more than just his company’s leadership into question.¹ The deception his company perpetrated over emissions from millions of its diesel cars also revealed a striking failure of governmental regulatory leadership.² For the preceding seven years, the world’s largest automaker had sold cars with emissions control systems that satisfied regulators’ mandatory emissions tests when connected to laboratory devices but that emitted up to forty times more pollutants than allowed by law when driven on the road.³ To uncover this deception, it took only the initiative of a relatively tiny non-governmental organization and a handful of university researchers testing just three cars’ emissions on the road. These relatively simple actions ultimately revealed a massive corporate and regulatory failure that has led to Winterkorn’s resignation,⁴ the plummeting of Volkswagen’s stock value and market sales,⁵ hundreds of lawsuits by consumers claiming the company defrauded them,⁶ and federal and state lawsuits involving tens of billions of dollars in penalties for regulatory violations.⁷

* Motor Vehicle Certification Procedures, 39 Fed. Reg. 7545, 7548 (Feb. 27, 1974).

1. Press Release, Volkswagen, Statement of Prof. Dr. Martin Winterkorn, CEO of Volkswagen AG (Sept. 20, 2015), http://www.volkswagenag.com/content/vwcorp/info_center/en/news/2015/09/statement_ceo_of_volkswagen_ag.html.

2. See Virginia Harrison, *Move Over Toyota! Volkswagen Winning Global Sales Race*, CNN MONEY (July 28, 2015), <http://money.cnn.com/2015/07/28/investing/volkswagen-toyota-biggest-carmaker/>; Russell Hotten, *Volkswagen: The Scandal Explained*, BBC NEWS (Dec. 10, 2015), <http://www.bbc.com/news/business-34324772>.

3. See, e.g., *Notice of Violation*, U.S. ENVTL. PROTECTION AGENCY (Sept. 18, 2015), <http://www.epa.gov/sites/production/files/2015-10/documents/vw-nov-caa-09-18-15.pdf>; *Learn About Volkswagen Violations*, U.S. ENVTL. PROTECTION AGENCY (Jan. 12, 2016), <http://www.epa.gov/vw/learn-about-volkswagen-violations>.

4. See Jack Ewing, *Volkswagen C.E.O. Martin Winterkorn Resigns Amid Emissions Scandal*, N.Y. TIMES (Sept. 23, 2015), <http://www.nytimes.com/2015/09/24/business/international/volkswagen-chief-martin-winterkorn-resigns-amid-emissions-scandal.html>.

5. See, e.g., Alex Davies, *Volkswagen’s US Sales Plummet 25 Percent as Dieselgate Rolls on*, WIRED (Dec. 1, 2015), <http://www.wired.com/2015/12/volkswagen-us-sales-plummet-25-as-dieselgate-rolls-on/>; Benjamin Snyder & Stacy Jones, *Here’s a Timeline of Volkswagen’s Tanking Stock Price*, FORTUNE (Sept. 23, 2015), <http://fortune.com/2015/09/23/volkswagen-stock-drop>.

6. See Sara Randazzo, *U.S. Suits over Volkswagen Emissions To Be Weighed in San Francisco*, WALL ST. J. (Dec. 8, 2015), <http://www.wsj.com/articles/u-s-suits-over-volkswagen-emissions-to-be-weighed-in-san-francisco-1449612934>.

7. See, e.g., Julia Edwards & Georgina Prodhan, *VW Faces Billions in Fines as U.S. Sues for Environmental Violations*, REUTERS (Jan. 6, 2016), <http://www.reuters.com/article/us-volkswagen-usa-idUSKBN0UI1QP20160106>; Jack Ewing & Hiroko Tabuchi, *Volkswagen Scandal Reaches All the Way to the Top, Lawsuits Say*, N.Y. TIMES (July 19, 2016), <http://www.nytimes.com/2016/07/20/business/international/volkswagen-ny-attorney-general-emissions-scandal.html>; *Volkswagen To Spend up to \$14.7 Billion To Settle Allegations of Cheating Emissions Tests and Deceiving Customers on 2.0 Liter Diesel Vehicles*, U.S. DEP’T JUST. (June 28, 2016) [hereinafter U.S. DEP’T JUST.], <https://www.justice.gov/opa/pr/volkswagen-spend-147-billion-settle-allegations-cheating-emissions-tests-and-deceiving>. On October 26, 2016, U.S. District Judge Charles Breyer approved the \$14.7 billion settlement between federal and California regulators and vehicle owners. See David Shepardson, *U.S. Judge Approves \$14.7 Billion Settlement in VW Diesel Scandal*, REUTERS (Oct. 25, 2016), <http://www.reuters.com/article/us-volkswagen-emissions-idUSKCN12P22F>. The settlement does not resolve potential criminal liability for corporate officers, and senior management reportedly remain under investigation in the United States and Europe. Jack Ewing, *Volkswagen Emissions Scandal Inquiry Widens to Top Levels*, N.Y. TIMES (Nov. 6, 2016), <http://www.nytimes.com/2016/11/07/business/inquiry-in-emissions-scandal-widens-to-volkswagens-top-levels.html>.

Yet the Volkswagen scandal was hardly unforeseeable. To the contrary, it actually confirmed the aphorism that failure to learn from the past makes one destined to repeat it.⁸ Nearly twenty years earlier, the U.S. Environmental Protection Agency (EPA) had by happenstance uncovered a remarkably similar set of industry tactics deployed by the manufacturers of diesel truck engines. The engines at that time also satisfied required regulatory tests when connected to laboratory equipment, but once trucks with these engines operated for an extended time on the open road, the engines' on-board computers re-calibrated engine performance to optimize for overall responsiveness and fuel economy, not for emissions control. As a result, in just a single year, noncompliant diesel truck engines reportedly spewed more than a million excess tons of nitrogen oxides (NOx)—a key chemical in the creation of harmful ozone pollution and the principal pollutant released in excess by Volkswagen's tampered cars.⁹ According to a congressional report on this earlier emissions debacle, the diesel truck emissions that escaped regulatory control roughly equated to the volume of pollution that would have been produced by adding 65 million more cars per year to the nation's roads—and ultimately these excessive emissions may have even contributed to more than 4,100 premature fatalities from compromised air quality.¹⁰

Although the earlier debacle over diesel truck engines resulted in what was at the time the largest enforcement fine that the EPA ever imposed, the agency nevertheless failed to learn adequately from its experience in the 1990s and thus failed to detect the more recent Volkswagen deception. Part of the reason for this failure may well lie with an increasingly recognized lack of sufficient retrospective analysis in the regulatory process.¹¹ Part of the explanation also likely derives from an overconfidence that regulators around the world have placed in so-called performance-based regulation—or what we call here “the law of the test.”

Although all regulation is broadly “performance-based” in the sense of aiming to affect the performance of regulated entities, the regulations at the heart of both the diesel truck and Volkswagen scandals obligated manufacturers to achieve a specified outcome—that is, to pass an emissions test—while leaving it to each company’s discretion to determine how to attain that required outcome.¹² The flexibility of such a performance-

8. See George Santayana, *Reason in Common Sense*, in 1 THE LIFE OF REASON 284 (1905).

9. See *infra* notes 46, 153 and accompanying text.

10. See *Asleep at the Wheel: The Environmental Protection Agency's Failure To Enforce Pollution Standards for Heavy-Duty Diesel Trucks*, STAFF H. COMM. ON COM. (Mar. 2000).

11. See, e.g., Cary Coglianese & Lori D. Snyder Bennear, *Program Evaluation of Environmental Policies: Toward Evidence-Based Decision Making*, in DECISION MAKING FOR THE ENVIRONMENT: SOCIAL AND BEHAVIORAL SCIENCE RESEARCH PRIORITIES 246 (Garry D. Brewer & Paul C. Stern eds., 2005); Michael Greenstone, *Toward a Culture of Persistent Regulatory Experimentation and Evaluation*, in NEW PERSPECTIVES ON REGULATION 111 (David Moss & John Cisternino eds., 2009); Cary Coglianese, *Measuring Regulatory Performance: Evaluating the Impact of Regulation and Regulatory Policy*, ORG. ECON. CO-OPERATION & DEV. (Aug. 2012), http://www.oecd.org/gov/regulatory-policy/1_coglianese%20web.pdf; Reeve T. Bull, *Building a Framework for Governance: Retrospective Review and Rulemaking Petitions*, 67 ADMIN. L. REV. 265 (2015); Joseph E. Aldy, Report to the Administrative Conference of the U.S., Learning from Experience: An Assessment of the Retrospective Reviews of Agency Rules and the Evidence for Improving the Design and Implementation of Regulatory Policy (Nov. 17, 2014), <https://www.acus.gov/sites/default/files/documents/Aldy%2520Retro%2520Review%2520Draft%25202011-17-2014.pdf>.

12. We use the term “standard” throughout this Article interchangeably with “rule” and “regulation.” Furthermore, when we say that a performance standard imposes an obligation to achieve an outcome, this can mean either *delivering* a good outcome (e.g., passing a test of strength) or

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based approach gives regulated entities the ability to choose the least costly means of achieving the stated outcome, thus making these standards more cost-effective than ones that tell regulated entities exactly what they must do or what technologies to adopt. But performance standards can be effective only when the outcomes they achieve are similar to the outcomes they mandate. If regulators are not careful and vigilant, the flexibility that performance standards afford regulated entities may lead to outcomes that, as with both diesel emissions sagas, escape adequate regulatory attention and prove to be much less effective than intended.

The history of failure in overseeing diesel emissions control offers vital lessons not only for improving air pollution regulation but also for improving regulation more generally. In this Article, we look back on this history of diesel emissions control with an eye toward drawing out these important policy lessons. Against the seemingly universal acclaim offered for performance-based regulation, EPA’s experience with diesel emissions regulation reveals a series of pitfalls and limitations in the use of performance standards that have previously gone unacknowledged. Performance standards can foster a “teaching-to-the-test” mindset on the part of regulated entities that can result in perverse, unintended outcomes. As regulators respond to such outcomes by making testing more complex, performance standards can increase, rather than decrease, regulatory burdens. They can even at times limit flexibility in practice, notwithstanding that performance standards’ chief virtue lies in their flexibility. They certainly offer no guarantee against the emergence of conflict and litigation in the regulatory process, either. These and other limitations that emerge from our close inquiry into diesel emissions control make plain that performance standards are no panacea and that designing and implementing them well requires considerable care and vigilance.

Part I sets the stage for our study. It describes the performance-based regulatory paradigm, its chief characteristics, and its theoretical advantages. We also explain why this retrospective study of a major performance-based regulatory regime is so vital. The basic law-of-the-test approach we study here has been almost uniformly lauded and yet has so seldom been subjected itself to retrospective testing.¹³

In Part II, we proceed to our study of diesel emissions control. To provide a technical basis for understanding how diesel emissions tests have failed, we begin by explaining how the diesel engine contributes to air pollution problems in the United States and by reviewing the main ways air pollution from diesel engines can be reduced, from engine controls to fuels to tailpipe capture devices. We then chronicle the federal policies that have sought to reduce diesel emissions, principally focusing our attention on regulations addressing NOx emissions from heavy-duty diesel truck engines. These regulations have been performance-based for some time now, and the experience that the EPA has had in developing and enforcing these standards affords us the

*avoiding a bad outcome (e.g., not failing a test of weakness). Section I.A, *infra*, provides more developed definitional and conceptual overview of the law of the test.*

13. See *infra* notes 14-20 and accompanying text.

opportunity to assess the promise and the pitfalls of performance-based regulation in practice. We detail both the regulations leading up to the 1990 Clean Air Act Amendments, as well as the performance-based NOx standards and testing protocols that the EPA put in place after the pivotal 1990 legislative changes.

In Part III, we pay particular attention to the litigation that ensued in the mid-1990s over the way that manufacturers of diesel truck engines had chosen to comply with the EPA's NOx regulations. Although manufacturers built engines that passed the EPA's tests, they did so using controls that the EPA claimed circumvented the spirit of the standards and that, in use on the roads, emitted substantial levels of NOx vastly exceeding those contemplated by the regulators. We also discuss what happened after the EPA and the engine manufacturers settled their lawsuit, including showing how the agency's testing protocols have grown ever more complex—even while the same law-of-the-test strategy failed to detect the latest deception by Volkswagen.

In Part IV, we conclude by considering the implications that the experience with diesel emissions regulation holds for understanding the value and limitations of performance-based regulation more broadly. Especially given the paucity of research on how performance standards have operated in practice, this close examination of the EPA's diesel emissions regulatory scheme provides valuable lessons for regulators about what is realistic to expect from the reliance on performance-based approaches to regulation. Although we do not deny that the flexibility that performance standards promise can deliver more cost-effective outcomes in principle, we also show how that same flexibility can also lead to, if not even invite, creative responses by regulated entities that may meet the letter of the law but fail the purpose of the test. In contrast with the prevailing unbridled enthusiasm for performance-based regulation that seems to prevail among scholars and policy officials, this retrospective study of the law of the test in the realm of environmental regulation raises important questions and cautionary lessons for the use of performance standards across all regulatory domains.

I. The Performance-Based Regulatory Paradigm

Rarely, if ever, does the label “command-and-control” get used approvingly to describe regulation.¹⁴ No doubt this is because regulation is frequently derided for being too inflexible. Especially when government mandates that each and every regulated firm undertake identical action, regulation is deplored for its “one-size-fits-all” orientation that generates costly, if not at times counterproductive, results.¹⁵

As a result, if the problem with much of regulation lies with its rigidity, the solution presumably should rest with making it more flexible. The most widely affirmed way of making regulation flexible is for government to

14. “Command-and-control” is “almost always used to distinguish the writer’s (or speaker’s) own preferred approach from disparaged alternatives.” Cary Coglianese, *Debate: Collaborative Environmental Law*, 156 U. PA. L. REV. PENNUMBRA 289, 308 (2007).

15. See, e.g., EUGENE BARDACH & ROBERT A. KAGAN, *GOING BY THE BOOK: THE PROBLEM OF REGULATORY UNREASONABLENESS* (1982); PHILIP K. HOWARD, *THE DEATH OF COMMON SENSE: HOW LAW IS SUFFOCATING AMERICA* (1994).

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establish mandatory goals for everyone to achieve, or at least outcomes to avoid, while leaving it up to businesses to figure out how they can meet the required performance target.¹⁶ This performance-based approach to regulation has won, and continues to win, praise from policy leaders around the world and across the political spectrum.¹⁷

President William Clinton, for example, urged his regulatory agencies to “specify performance objectives, rather than specifying the behavior or manner of compliance that regulated entities must adopt.”¹⁸ President George W. Bush’s regulatory team followed by advising agencies that performance standards are “generally superior to engineering or design standards because performance standards give the regulated parties the flexibility to achieve regulatory objectives in the most cost-effective way.”¹⁹ President Barack Obama directed his administration to give preference to “[f]lexible [a]pproaches,” including the use of “performance objectives.”²⁰

Regulators and policy professionals working across a wide variety of policy areas—from banking to building codes, and from natural resources to nuclear power—offer widespread acclaim for the value of performance-based standards. Such nearly universal affirmation should hardly be surprising. The label “performance-based” is itself appealing; surely everyone would like regulation to perform well, which is what monikers like “performance standards” and “performance-based regulation” seem to imply.²¹ Moreover, the flexibility afforded by performance standards undoubtedly appeals to all lovers of liberty. Legal scholar and former White House regulatory official Cass Sunstein, for example, has argued that a regulatory strategy that relies on “flexible ‘performance standards’ . . . reduces costs [and] promotes freedom.”²² In a world in which so-called command-and-control regulation is so widely deplored, any type of regulation that is seen (even if oxymoronically) to “promote freedom” is destined to win over many hearts and minds.²³

Despite the lavish praise heaped on performance-based regulation, strikingly little empirical research has been produced to show how performance standards work in practice and how they compare with other types of regulation.²⁴ The usual reasons offered for preferring performance standards are axiomatic: namely, if

16. See, e.g., DANIEL J. FIORINO, THE NEW ENVIRONMENTAL REGULATION 199 (2006) (“In general, government should focus on setting demanding goals and leave firms more discretion in deciding how to meet them.”).

17. See Cary Coglianese, *Performance-Based Regulation: Concepts and Challenges*, in COMPARATIVE LAW AND REGULATION: UNDERSTANDING THE GLOBAL REGULATORY PROCESS 403, 404 (Francesca Bignami & David Zaring eds., 2016) (noting that “[e]nthusiasm for performance-based regulation extends far outside the United States” and giving examples from Canada, Mexico, the Organization of Economic Cooperation and Development, and the World Trade Organization).

18. Exec. Order No. 12,866, 58 Fed. Reg. 51,735, 51,736 (Oct. 4, 1993).

19. Off. of Info. & Regulatory Affairs, Circular A-4: Regulatory Analysis (Sept. 17, 2003) [hereinafter OIRA], https://www.whitehouse.gov/sites/default/files/omb/assets/regulatory_matters_pdf/a-4.pdf.

20. Exec. Order No. 13,563, 76 Fed. Reg. 3821, 3821-22 (Jan. 18, 2011).

21. See *supra* note 12 and accompanying text. Of course, sharp differences of opinion prevail about what constitutes good performance.

22. CASS R. SUNSTEIN, SIMPLER: THE FUTURE OF GOVERNMENT 11-12 (2013).

23. In this sense, performance-based regulation can be likened to “those wise restraints that make men free,” a well-known quotation attributed to law professor John MacArthur Maquire and enshrined on a plaque found in the Harvard Law School library.

24. See Cary Coglianese, Jeniffer Nash & Todd Olmstead, *Performance-Based Regulation: Prospects and Limitations in Health, Safety, and Environmental Protection*, 55 ADMIN. L. REV. 705, 708, 713 (2003) (noting the “dearth of empirical studies aimed at measuring the effectiveness of

government specifies the ends it seeks, then firms will necessarily be free to select the most effective or least costly options to achieve those ends. It is as nearly axiomatic that businesses will have better information than government will about the options that will work best for them.²⁵

Yet as compelling as these theoretical reasons for performance-based regulation may be, practice does not always live up to theory—or at least it sometimes can reveal other considerations that theory overlooks. To begin to build a stronger base of knowledge about performance standards in practice, we will trace in Parts II and III of this Article the development and implementation of a key example of performance-based regulation: the EPA’s control of emissions from heavy-duty diesel engines. The EPA has addressed this source of air pollution by issuing performance standards, setting emissions levels, and establishing testing protocols, but otherwise leaving it up to diesel engine manufacturers to determine how to meet the required tests. As we seek to draw potentially generalizable insights about regulation from the EPA’s experience regulating diesel emissions, it is first necessary to situate performance standards—or what we call the law-of-the-test approach to regulation—within the larger context of a regulator’s overall toolkit.

A. *Types of Regulatory Standards*

Although regulatory scholars have tended simply to assume that performance standards are superior to other types of regulatory instruments, the design of regulatory standards has not entirely escaped serious analysis. On the contrary, an expansive body of literature on regulatory instrument choice exists.²⁶ However, this literature gives vastly more attention to other types of regulatory instruments, such as information-disclosure regulation²⁷ or market-based mechanisms like emissions trading,²⁸ than to simple performance standards.

This literature on regulatory instrument design is also limited in that it lacks a single, well-accepted taxonomy of different types of regulatory standards. Scholar Kenneth Richards, for example, has compiled over

performance-based standards” and how “researchers have yet to subject performance-based standards to close empirical scrutiny”). One exception can be found in some empirical research on performance-based building code regulation in New Zealand, which reportedly contributed to a major economic crisis in that small country. *See, e.g.*, PETER MUMFORD, ENHANCING PERFORMANCE-BASED REGULATION: LESSONS FROM NEW ZEALAND’S BUILDING CONTROL SYSTEM (2011); Peter May, *Performance-Based Regulation and Regulatory Regimes: The Saga of Leaky Buildings*, 25 LAW & POL’Y 381 (2003).

25. *See* Cary Coglianese, Richard Zeckhauser & Edward Parson, *Seeking Truth for Power: Informational Strategy and Regulatory Policymaking*, 89 MINN. L. REV. 277 (2004).

26. For a survey and discussion of the literature on regulatory instrument choice, see Kenneth Richards, *Framing Environmental Policy Instrument Choice*, 10 DUKE ENVTL. L. & POL’Y F. 221 (2000). *See also* Cary Coglianese, *Listening, Learning, and Leading: A Framework for Regulatory Excellence*, PENN PROGRAM ON REG. 46-49 (2015), <https://www.law.upenn.edu/live/files/4946-pprfinalconvenersreportpdf>.

27. *See, e.g.*, ARCHON FUNG, MARY GRAHAM & DAVID WEIL, FULL DISCLOSURE: THE PERILS AND PROMISE OF TRANSPARENCY (2007); JAMES T. HAMILTON, REGULATION THROUGH REVELATION: THE ORIGIN, POLITICS, AND IMPACTS OF THE TOXICS RELEASE INVENTORY PROGRAM (2005); Carol Simon, *The Effect of the 1933 Securities Act on Investor Information and the Performance of New Issues*, 79 AM. ECON. REV. 295 (1989).

28. *See, e.g.*, JODY FREEMAN & CHARLES D. KOLSTAD, MOVING TO MARKETS IN ENVIRONMENTAL REGULATION: LESSONS FROM TWENTY YEARS OF EXPERIENCE (2006); Robert N. Stavins, *What Can We Learn from the Grand Policy Experiment? Lessons from SO2 Allowance Trading*, 12 J. ECON. PERSP. 69 (1998).

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a dozen competing schema for categorizing regulatory instruments from existing literature.²⁹ Thus, terminology varies across different schema of regulatory instruments, and even what different people mean by a term as seemingly straightforward as “performance-based regulation” can differ.³⁰ Despite the existence of varying schema and associated terminology, the concepts underlying these schema do bear sufficient similarity so that the main types of instruments can be much more clearly classified than they have tended to be to date. To begin with, by “regulatory instrument,” we mean (i) a rule or standard (a conditional or normative statement) (ii) backed up with consequences and (iii) issued in order to induce a desired change in behavior (iv) that in turn will lead to some improved state of the world.

For purposes of analytical clarity, we recognize that all regulatory instruments possess the following four characteristics:³¹

- *The Regulator.* Who is issuing the command?
- *The Target.* To whom (or what entity) is the command directed?
- *The Command.* What is the regulator telling the target to do or achieve (or not to do or not achieve)?
- *The Consequences.* What will happen to the target if the command is or is not followed?

The regulator is often a governmental entity, but for some purposes it could also be a trade association, insurance company, or other non-governmental entity. Targets can be individual actors, products, or discharge points, or they can be entire industrial facilities, corporations, or perhaps even sectors. In the diesel engine sagas, the EPA acts as the regulator and diesel engine manufacturers act as the targets.

What a regulator expects of targets can vary, but to generalize, the regulator’s command can take one of three forms:³²

- *Means standards.* A command can direct a target how to *act*. (e.g., “install a scrubber on a smokestack”). It can specify steps to take, behaviors to adopt, or technologies to use. We call such commands *means standards*,³³ as they direct regulated targets to adopt some specified means of achieving the desired ends.
- *Performance standards.* Alternatively, a command can direct a target what to *achieve* but leave it up to the target to select the means (e.g., “do not allow emissions from smokestack to exceed X level”). As

29. See Richards, *supra* note 26, at 284-85. He also finds that “the plurality of instruments and combinations thereof . . . have steadfastly defied economists’ and policy analysts’ prescriptions.” *Id.* at 223.

30. For example, sometimes regulators have used “performance-based regulation” to refer to what I have called management standards, even though most policy analysts and scholars use it, as we do here, to refer to performance standards. See Coglianese, *supra* note 17, at 409.

31. See Cary Coglianese, *Engaging Business in the Regulation of Nanotechnology*, in GOVERNING UNCERTAINTY: ENVIRONMENTAL REGULATION IN THE AGE OF NANOTECHNOLOGY 46 (Christopher J. Bosso ed., 2010).

32. For related discussions, see Cary Coglianese & David Lazer, *Management-Based Regulation: Prescribing Private Management To Achieve Public Goals*, 37 LAW & SOC. REV. 691 (2003); and Coglianese et al., *supra* note 24.

33. Other terms for this regulatory approach include specification or design standards or technology-based standards.

already noted, such a command specifies the ends rather than the means and is called a *performance standard*.

- *Management standards.* In some cases, regulators condition consequences neither on the adoption of particular means nor on the attainment (or avoidance) of particular ends, but instead direct targets to *think* or to *plan* (e.g., “develop a plan that is designed to reduce emissions from smokestacks”). When regulation conditions consequences on planning or related management activities, rather than on desired ends or actions directly linked to those ends, we call these *management standards*.³⁴

Of course, many other terms have been used to describe specific operative rules that fall into each of these categories. The labels are not so critical; the key takeaway is to recognize the core conceptual underpinnings of these three different categories of commands.³⁵

As these are different types of commands, the differences between them hold regardless of who the regulator or target may be. They also hold regardless of what the consequences associated with a regulatory instrument might be. Some consequences may be positive ones, such as when a regulator gives targets that adhere to the command a reward, subsidy, or exemption. More commonly, consequences will be negative, as when targets are subject to penalties or the shutdown of business operations.³⁶

As noted, the distinction between regulating means and ends is often thought to relate to the amount of discretion afforded regulated targets. That is, by using performance standards—or regulating through ends—the target is assumed to have greater discretion. But such a relationship is not always clear. Although performance-based regulations give targets flexibility with respect to how they go about meeting the stated ends, they are usually not flexible about what specific performance the targets must achieve—or by when. In other words, flexibility with means is not the same thing as flexibility with ends. Moreover, in some cases, the specified level of performance can only be achieved through a single, known technology or action—meaning that targets in such cases will have no greater degree of flexibility (at least in the short term) than if that means had been mandated.³⁷

34. See Coglianese & Lazer, *supra* note 32. As noted, sometimes regulators have used “performance-based regulation” to refer to management standards. See *supra* note 30.

35. Some might say our three distinctions fail to capture other important regulatory instruments, such as emissions permit trading or information disclosure. We believe all these alternative regulatory instruments are encompassed in the “trichotomy” we have presented. Emissions trading, after all, is a type of performance-based regulation—except not every target has to meet the same emissions level. And information disclosure can be variously a means to an end (e.g., lessening fraud) or an end itself (e.g., informed consumers). For further discussion, see Coglianese, *supra* note 17, at 408-10.

36. These consequences can also be imposed in different increments. Often regulators impose a fixed fine regardless of whether a target exceeds a standard by a little or a lot. But certain kinds of market-based instruments, such as emissions taxes, impose incremental or marginal “fines” that accumulate with the level of undesirable outcomes, such as pollution.

37. See, e.g., STEPHEN G. BREYER, REGULATION AND ITS REFORM (1982); Off. of Tech. Assessment, *Environmental Policy Tools: A User’s Guide*, U.S. CONG. (Sept. 1995), <https://www.princeton.edu/~ota/disk1/1995/9517/9517.pdf>. In some cases, although regulations take the form of performance standards, they may be based explicitly on what only one available technology can achieve. See Off. of Tech. Assessment, *supra*.

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The degree of flexibility embodied in performance standards can also vary depending on whether the targets are commanded to achieve the *ultimate* goal of the regulation, or instead to achieve some end-state that is *subsidiary* to the ultimate goal. As a general matter, a performance standard that articulates its command in terms of achieving the ultimate societal objective, such as preventing illness, will afford regulated targets considerably greater discretion in choosing how to meet that overarching goal than will a regulation that addresses the same goal by commanding regulated entities to achieve narrower, subsidiary outputs, such as reducing NOx emissions to below a stated level.

The degree of discretion that government should afford regulated industry is central to a persistent debate over the role of means standards in environmental law and other areas of regulatory policy. On one side are those who criticize means standards for treating every firm the same, regardless of their costs of pollution control. One concern is that one-size-fits-all means standards provide no incentive for firms to develop new technologies, while another concern is that means standards demand intensive information-gathering by government on “complex scientific, engineering, and economic issues regarding the feasibility of controls on hundreds of thousands of pollution sources.”³⁸ On the other side of this debate are those who defend means standards as easier to develop and implement, since all government needs to do is identify existing technologies that work and impose requirements that firms adopt them.³⁹ It may also be far easier to inspect facilities’ compliance with means standards, as an inspector may only need to see if the required technology is installed rather than measure the actual outputs of, say, individual smokestacks and discharge points.

Although we have no illusion that this debate can be settled by a single study of an important performance-based regulation, this Article aims to illuminate this debate by contributing to a clearer understanding of how different regulatory instruments have worked in practice.⁴⁰ Our focus is on assessing one major, but largely unexamined, type of regulation: performance standards.

B. Assessing Performance: The Law of the Test

In order to enforce performance standards, regulators need some way to determine whether regulated targets have met the applicable outcomes. For performance standards, then, the available methods of observation, testing, measurement, and monitoring merit attention as much as the operative performance-based command itself. This is because, in practice, the way the regulator decides to assess performance becomes part

38. Bruce A. Ackerman & Richard B. Stewart, *Reforming Environmental Law*, 37 STAN. L. REV. 1333, 1335-36 (1985).

39. See, e.g., Wendy E. Wagner, *The Triumph of Technology-Based Standards*, 2000 U. ILL. L. REV. 83, 94-103.

40. See Lori S. Bennear & Cary Coglianese, *Measuring Progress: Program Evaluation of Environmental Policies*, 47 ENV’T: SCI. & POL’Y FOR SUSTAINABLE DEV. 22 (2005).

of what any performance standard entails—even if the operative terms of a standard do not refer to assessment methods at all.

Methods of assessment can include: (1) direct, in-use measurement of actual outputs, whether continuously or at intervals; (2) testing under conditions thought to mirror real-world conditions; and (3) simulations analyzed using mathematical models of relationships among inputs, outputs, and various operational constraints. An example of direct, in-use measurement would be a continuous emissions monitoring device that collects and measures the level of pollutants that are being released from emissions sources during everyday operations. When direct, in-use measurement is not feasible, regulators can develop tests designed to mirror real-world conditions, and then measure the outputs of those tests. Compliance with automobile safety rules, for example, is determined by manufacturers conducting crash tests with dummies.⁴¹ When performance cannot be measured under real or even testing conditions, it must be estimated using simulations. To determine whether buildings meet performance-based fire safety codes, for instance, regulators obviously do not burn down the very buildings being regulated to see how resistant they are.⁴² Regulators increasingly turn to computer models of building construction and the behavior of fires to assess compliance with performance-based fire safety and building codes.⁴³ For some environmental problems, regulators may be able to draw inferences about outputs by measuring inputs, such as when levels of carbon dioxide (CO₂) emissions from emissions sources are estimated simply by determining the amount of carbon contained in the fuel being burned.⁴⁴

These methods of assessment matter not only for regulators, but also for researchers and evaluators of performance standards. After all, the extent to which a performance standard works effectively will be a function, at least in part, of how accurately and comprehensively the regulator is able to monitor the performance of regulated entities. A faulty thermometer, after all, will not detect temperatures at which food in a refrigerator will spoil. If a regulator's methods imperfectly determine whether firms are meeting the commanded outcomes, the actual outcomes of the firms' operations could very well satisfy the regulator's test, but still fail to achieve the outcomes directed in the regulation itself, or fail to address the problem motivating the regulation.

From an evaluation standpoint, performance standards can be said to have an impact when they generate a behavioral response by regulated targets that results in outcomes different from what would otherwise have occurred.⁴⁵ A researcher seeking to assess the *performance of* performance standards should consider broadly the

41. See, e.g., JOHN GRAHAM, AUTO SAFETY: ASSESSING AMERICA'S PERFORMANCE 71, 117 (1989).

42. Of course, they do test individual components by burning them in tests, and on occasion researchers may burn test models.

43. See Kathy Notarianni & Paul S. Fischbeck, *Performance with Uncertainty: A Process for Implementing Performance-Based Fire Regulations*, in IMPROVING REGULATION: CASES IN ENVIRONMENT, HEALTH, AND SAFETY 233-34 (Paul S. Fischbeck & R. Scott Forrow eds., 2001).

44. The EPA refers to this as the “mass balance approach.” U.S. Envtl. Prot. Agency, Recommended Procedures for Development of Emissions Factors and Use of the WebFIRE Database 2-2 to 2-3 (2013), <https://www3.epa.gov/ttn/chief/epac/procedures/procedures81213.pdf> (describing the use of fuel inputs in estimating emissions outputs and noting that “[f]or certain processes, a mass balance provides an easier and less expensive estimate of emissions than would be obtained by direct measurement”).

45. For a discussion of empirical evaluation methods, see LAWRENCE B. MOHR, IMPACT ANALYSIS FOR PROGRAM EVALUATION (2d ed. 1995).

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impact of a regulatory scheme on: (1) the *outcomes* embedded within the performance standard's command (e.g., SO₂ emissions below X level); (2) the *outcomes* that the performance standard is intended to achieve (e.g., reduced acid rain); and (3) *other* relevant or desired outcomes, even if not actually contemplated by the standard's terms or by its designers (e.g., side effects, compliance costs, and such). In short, the outcomes embedded in the performance standard are not necessarily the only outcomes of concern to a retrospective evaluator—or to the public.

Under any relevant evaluation measure, a given performance standard's ultimate performance will undoubtedly be affected by a number of factors related to both its design and implementation, including: the nature of the problem that the standard seeks to address; the make-up, capacities, and motivations of the firms and individuals within the regulated sector; and the capacity and resources available to the regulator. Still, we would generalize that how well a performance standard will work in practice will be affected primarily by:

- *The accuracy of the regulators' assessment methods* in determining whether actual outcomes in use match the levels in the regulation, for reasons already noted. Assessment methods may be inaccurate because of a range of factors, including faulty instrumentation or modeling, infrequent or inaccurate monitoring and data collection, undetected evasive behavior of regulated targets, and so forth.
- *The sufficiency of the consequences* (e.g., penalties for noncompliance), both in terms of their probability and level. Even if the regulator can accurately assess individual firms' compliance, if it fails to monitor or respond when monitoring detects noncompliance, regulated targets will have little incentive to change their behavior.
- *The congruence in the relationship between outcomes*. In order to effect the desired ultimate outcome motivating the regulation, the outcome embedded within a performance standard must be related to that ultimate outcome of concern. Otherwise, even if the regulator could induce perfect compliance with the standard, there would be insufficient change in what the regulator (and society) ultimately cares about.

Given these factors, it is entirely conceivable that two otherwise similar performance-based standards could operate quite differently when implemented in different jurisdictions, across different time periods, or applied to different problems or sectors. Having these considerations in mind will help make sense of the EPA's experience developing and implementing diesel emissions regulations, and we return to them in our conclusion when drawing out implications from the agency's regulatory experiences. One of our principal conclusions is that the EPA's experience regulating diesel emissions suffered from weaknesses across all three factors affecting the success of performance standards, and in particular the accuracy of the agency's assessment methods. In other words, a chief challenge that performance standards pose for regulators is ensuring that the law of the test adequately brings about the fulfillment of the purposes of the law in action.

II. Regulating Diesel Engine Emissions

Diesel engine emissions have a significant impact on air quality throughout the United States. Although trucks and buses that use heavy-duty diesel engines represent no more than 2% of all motor vehicles on the roads in the United States, they emit approximately 20% of all NOx emissions—from *all* sources, even stationary ones.⁴⁶ They also emit significant quantities of particulates and other air pollutants. As a result, the stakes for air quality from diesel emissions are great, and any serious national strategy for addressing air pollution must include effective regulation of diesel engine emissions, especially from heavy-duty trucks.

Members of the public in the United States and elsewhere have recognized air pollution as a serious concern since at least the late nineteenth century. In 1892, for example, at the height of industrialization in England, the city of London experienced hundreds of additional deaths due to a serious smog inversion that lasted for three days.⁴⁷ Yet until the middle of the last century, just about the only public remedy available to those who suffered the ill effects of air pollution was the opportunity to file individual common law nuisance suit actions.⁴⁸ In 1952, London again experienced a severe smog inversion, this one lasting five days and resulting in as many as four thousand premature deaths.⁴⁹ Four years later, the British Parliament adopted its first air pollution control legislation, portending the new era of environmental regulation in the United States.

Concerns about air pollution began to grow much more salient in the United States, particularly in California, starting in the middle of the last century. The population and industrial expansion in California in the 1940s generated special pollution problems since the mountains around Los Angeles tend to trap polluted air. Starting in the 1940s, significant amounts of smog and other air pollutants began to settle in the Los Angeles basin, making it harder for individuals to breathe and irritating their eyes and lung passages.

At the time, most of the blame for air pollution centered on large industrial operations.⁵⁰ Regulatory officials and scientists thought that automobiles and trucks played only a minimal role in air pollution, in part because they assumed that smog came from SO₂ emissions. One report at the time indicated that cars emitted

46. The latest data on the number of heavy-duty diesel trucks on U.S. roadways are from 2002. In that year, there were about 235 million registered vehicles in the United States. See *National Transportation Statistics*, U.S. DEP'T TRANSP. (2016), http://www.rita.dot.gov/bts/sites/rita.dot.gov/bts/files/publications/national_transportation_statistics/html/table_01_11.html. Of these, only about 4 million were heavy-duty trucks. See *Controlling Fine Particulate Matter Under the Clean Air Act: A Menu of Options*, ST. & TERRITORIAL AIR POLLUTION PROGRAM ADMIN. & ASS'N LOC. AIR POLLUTION CONTROL OFFICIALS 189 (Mar. 2006) [hereinafter STAPPA & ALAPCO], <http://www.4cleanair.org/PM25Menu-Final.pdf>; Census Bureau, *United States 2002 Economic Census: Vehicle Inventory and Use Survey*, U.S. DEP'T COM. 12 (2004), <http://www.census.gov/prod/ec02/ec02tv-us.pdf>. On emissions, see STAPPA & ALAPCO, *supra* (“Exhaust from heavy-duty diesel engines accounts for about 20 percent of all NOx emissions, including those from nonroad diesel and stationary sources.”).

47. See K.C. Heidorn, *A Chronology of Important Events in the History of Air Pollution Meteorology to 1970*, 59 BULL. AM. METEOROLOGICAL SOC'Y 1589, 1591 (1979).

48. For a lucid discussion of the early common law approach to air pollution, see NOGA MORAG LEVINE, *CHASING THE WIND: REGULATING AIR POLLUTION IN THE COMMON LAW STATE* (2003).

49. See Heidorn, *supra* note 47, at 1593.

50. See Editorial, *Smog—Its Cause and Cure*, L.A. TIMES, Sept. 29, 1948, at A4 (attributing smog to sulfur dioxide emissions from refineries, utilities, and chemical facilities).

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only about 20 tons of SO₂ each day in Los Angeles, compared with about 800 tons emitted by industrial operations.⁵¹ Moreover, since smog had grown prevalent in the Los Angeles basin starting in 1943, when there were actually fewer cars registered than just a few years before (as auto travel was restricted because of World War II), the prevailing view held that “it hardly seems probable that a smaller number of cars, being used much less, suddenly could have created a great smog problem.”⁵²

By 1950, research by A. J. Haagen-Smit, a chemist at the California Institute of Technology, had revealed that smog results from a chemical reaction between hydrocarbons (HCs) and NOx in the presence of sunlight.⁵³ Since automobiles emit both HCs and NOx, they have since been considered a major cause of air pollution—as well as a major target in its reduction.⁵⁴ By the turn of the twenty-first century, the EPA would come to estimate that transportation sources in the United States contributed to 56% of NOx emissions and 47% of hydrocarbon emissions (or more precisely, emissions of volatile organic compounds (VOC))—the two principal precursors to ozone.⁵⁵ Transportation today continues to contribute similarly substantial proportions of ozone-creating pollutants and also accounts for about 25% of all the emissions of particulates or soot.⁵⁶

Even after Haagen-Smit’s discovery in the middle of the last century, however, it was not until much later that diesel engines came to be viewed as making anything but a relatively minor contribution to the air pollution problem in the United States. For one thing, only a small fraction of the automobile fleet has ever been made up of diesel-powered cars. For another, as recently as the mid-1960s, diesel engines powered only a small fraction of the trucks on the road.⁵⁷ Today, however, diesel engines propel about 95% of the largest trucks on the roads in the United States.⁵⁸

Over the years, as regulation has helped to spur dramatic decreases in automobile emissions, environmental regulators have also targeted heavy-duty diesel truck engines as a major source of air pollution. To understand the challenges facing regulators in designing and implementing diesel engine regulation, it is important to begin with some background on how the diesel engine operates before turning to the emissions that these engines

51. See Ed Ainsworth, *Chart Assembled To Show Progress in War on Smog: Impartial Report Given on Fight To Eliminate Smoke and Fumes*, L.A. TIMES, Nov. 22, 1948, at 2 (noting that “apparently the automobile gets a pretty clean bill of health as a smog creator”).

52. *Id.*

53. See JAMES E. KRIER & EDMUND URGIN, POLLUTION AND POLICY: A CASE ESSAY ON CALIFORNIA AND FEDERAL EXPERIENCE WITH MOTOR VEHICLE AIR POLLUTION 1940-1975, at 78-80 (1977). For a synopsis of Haagen-Smit’s work, see A. J. Haagen-Smit, *Chemistry and Physiology of Los Angeles Smog*, 44 INDUS. & ENGINEERING CHEMISTRY 1341 (1952).

54. For some early press accounts linking automobiles with smog, see Ed Ainsworth, *Smog Factor Traced to Auto Exhausts: Larson Says Ozone Is Classified in Findings by Three Scientists*, L.A. TIMES, Aug. 6, 1954, at A1; Dewey Linze, *Cars Lead in List of Smog’s Causes: Exhaust-Produced Hydrocarbons Top Producer of City Headache*, L.A. TIMES, Apr. 12, 1956, at 2; Dewey Linze, *Auto Fumes Declared Principle Cause of Smog: What To Do About It Is Scientists’ Worry; Devices Must Be Inexpensive and Efficient*, L.A. TIMES, Apr. 14, 1956, at 16; *No Peril to Health Seen in Smog Alert: Auto Exhaust Blamed for Ever-Increasing Nitrogen Oxides and Pollution in County*, L.A. TIMES, Dec. 21, 1960, at 25.

55. See National Air Quality and Emissions Trends Report, U.S. ENVTL. PROTECTION AGENCY 26, 33, 36 (1999).

56. See Our Nation’s Air: Status and Trends Through 2010, U.S. ENVTL. PROTECTION AGENCY 4 (2012). See also JEAN-PAUL RODRIGUE, THE GEOGRAPHY OF TRANSPORT SYSTEMS (3d ed. 2013).

57. See Andrew P. Morriss, Bruce Yandle & Andrew Dorchak, *Regulating by Litigation: EPA’s Regulation of Heavy-Duty Diesel Engines*, 56 ADMIN. L. REV. 451, 463 (2004) (noting “diesel trucks made up only 416,454 out of 16,998,546 trucks in use”).

58. See About Clean Diesel Trucking, DIESEL TECH. F. (last visited Oct. 19, 2016), <http://www.dieselforum.org/about-clean-diesel/trucking>. See also Morriss et al., *supra* note 57, at 463.

create and the major emissions control solutions available. We will then review the major steps the EPA has taken to regulate emissions from heavy-duty diesel truck engines, explaining how the law of the test was designed to combat the air pollution problems created by diesel emissions.

A. The Diesel Engine

A diesel engine operates much like an everyday gasoline-powered car. Pistons inside the engine's cylinders continuously move up and down, powering the crankshaft, which in turn propels the vehicle. The typical gasoline-powered automobile operates in four steps (or strokes):

- (1) The pistons move down to pull in a mixture of air and gasoline.
- (2) The pistons move up, compressing the air and gasoline.
- (3) The air-gasoline mixture is then ignited by spark plugs, and the resulting combustion pushes the pistons down.
- (4) The pistons move up, expelling the remaining byproducts from the combustion process as exhaust.

The diesel engine—so named for the German inventor, Rudolf Diesel, who perfected it in the 1890s—also depends on the ignition of a fuel-air mixture and follows a similar four-stroke cycle. But unlike the common gasoline-powered engine, the fuel in a diesel engine is self-ignited. Combustion occurs from the high pressure generated in the cylinder, rather than from an externally introduced electric spark. The fuel is not injected into the air in the cylinder until the air has already been highly compressed by the piston.⁵⁹

The diesel engine's compression ratio, which is the ratio between the volume of the cylinder when the piston is at the top of its stroke and the volume when the piston is at the bottom, can be about 1.5 to 2.5 times higher than in a typical gasoline-powered automobile engine.⁶⁰ Compressing the air to this greater extent generates heat needed to ignite the diesel fuel.

Since the heat that causes ignition in the diesel engine is much higher than that produced by the spark in the gasoline engine, diesel fuel must be much less volatile than gasoline. While the boiling range for gasoline is about 30° to 200° C, the range for diesel fuel is 170° to 340° C.⁶¹ Diesel is heavier and thicker—almost oily—as

59. Self-ignition can—and sometimes unexpectedly does—occur with gasoline engines. When the pressure gets too high in the piston chamber of a gasoline engine, knocking occurs as the fuel-air mixture ignites from excessive pressure. Octane measures how resistant a fuel is to self-igniting, with engine knocking less likely with higher-octane gasolines.

60. See BERNARD CHALLEN & RODICA BARANESCU, DIESEL ENGINE REFERENCE BOOK 473 (2d ed. 1999); Thorsten Raatz & Hermann Grieshaber, *Basic Principles of the Diesel Engine*, in DIESEL ENGINE MANAGEMENT: SYSTEMS AND COMPONENTS 18 (Konrad Reif ed., 2014) (“The compression ratio, ϵ , is generally between 16:1 and 24:1 in [diesel] engines for cars and commercial vehicles. . . . It is therefore higher than in gasoline engines ($\epsilon = 7:1 \dots 13:1$).”).

61. See CHALLEN & BARANESCU, *supra* note 60, at 99.

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it is much less refined than gasoline. A gallon of diesel not only weighs more than a gallon of gasoline, it also contains more energy. At the molecular level, diesel fuel contains about 50% more carbon than does gasoline.⁶²

As a result of their heavier, more carbon-rich fuel, diesel engines get better fuel economy than gasoline engines—upward of 20% to 30% better mileage. They also get better performance due to the higher compression ratio. In addition to delivering higher miles-per-gallon, because diesel is less refined, it has historically tended to cost less than gasoline.⁶³ Both the lower fuel costs and the better fuel economy make the diesel engine attractive for truck and bus fleet owners, since fuel costs represent a particularly significant outlay for vehicles that deliver tens of thousands of miles each year. Diesel engines also tend to last much longer than gasoline engines; they have fewer parts and are heavier. For all of these reasons, the diesel engine has long been a mainstay in the trucking industry.

The advantages of the diesel engine have not, of course, been sufficient to make diesels the technology of choice to most Americans for their automobiles.⁶⁴ With its heavier weight, the diesel engine costs somewhat more than a gasoline engine at the outset, and the fuel economy cost-savings from diesels have not proven a sufficient incentive for most ordinary drivers to make the upfront investment. In addition, while the diesel's higher compression ratio gives it more power, diesel engines do not accelerate as quickly as gasoline engines, and they can take longer to warm up in colder weather. For many years, the diesel engine was also somewhat noisier.⁶⁵

That said, diesels' popularity had been growing in the United States during the early part of the current century.⁶⁶ Until the Volkswagen scandal, sales of new diesel automobiles and sport utility vehicles had been increasing at a rate nearly ten times as fast as overall vehicle sales (although not as fast as hybrids), as more consumers grew concerned about global climate change and sought improved fuel economy.⁶⁷ In the immediate wake of the Volkswagen scandal, of course, sales of diesel automobiles plummeted.⁶⁸

62. See *id.*

63. See, e.g., David Kiley, *Diesel vs. Hybrid: From Detroit to D.C., and Back*, USA TODAY (June 11, 2004), http://usatoday30.usatoday.com/money/autos/2004-06-10-diesel-vs-hybrid_x.htm.

64. See, e.g., *The Diesel Dilemma: Diesel's Role in the Race for Clean Cars*, UNION CONCERNED SCIENTISTS 7-8 (2004); Dennis Huibregtse, Presentation at Power Systems Research, Global Strategies, Regional Tactics: Transforming the Heavy Truck Business (May 1, 2007).

65. *Id.*; see also WYLE LABORATORIES, TRANSPORTATION NOISE AND NOISE FROM EQUIPMENT POWERED BY INTERNAL COMBUSTION ENGINES 104 (1971) (noting that “diesel engines are typically about 10 dB noisier than gasoline engines”).

66. See Matthew de Paula, *Diesel Boom? Ownership of Diesel Cars Way Up, But Still a Fraction of U.S. Market*, FORBES (Apr. 30, 2013), <http://www.forbes.com/sites/matthewdepaula/2013/04/30/ownership-of-diesel-cars-up-but-still-a-fraction-of-market>. Diesel automobiles have been much more popular in Europe, where they have been commonplace since the 1990s. See John Vidal, *The Rise of Diesel in Europe: The Impact on Health and Pollution*, GUARDIAN (Sept. 22, 2015), <http://www.theguardian.com/environment/2015/sep/22/the-rise-diesel-in-europe-impact-on-health-pollution>.

67. See De Paula, *supra* note 66.

68. See Jeff Bennett, *Diesel Car Sales Tumble in U.S.*, WALL ST. J. (Feb. 18, 2016), <http://www.wsj.com/articles/diesel-car-sales-slow-significantly-1455825746>.

B. Diesel Emissions and Their Control

The combustion of fuel that powers the diesel engine has certain inevitable byproducts, released as exhaust emissions. As noted, the EPA has identified diesel engines as a significant contributor to the nation's air pollution problem. Diesel exhaust is comprised of a variety of pollutants, including most notably carbon monoxide, hydrocarbons, NOx, and particulates. NOx and particulates have proven exceedingly difficult to manage. Since the Clean Air Act of 1970, the EPA has created health-based ambient air standards for six pollutants: (1) carbon monoxide, (2) lead, (3) SO₂, (4) ozone, (5) NOx (itself a precursor to ground-level ozone), and (6) particulate matter. While levels of the first three pollutants have declined, ozone and particulate levels have remained high, such that nearly 45% of the U.S. population lives in areas with levels that the EPA considers unhealthful for one or both of these pollutants.⁶⁹

NOx is a brownish, highly reactive gas that is a by-product of combustion, created when the nitrogen in the air compressed in the diesel engine burns. As a rule of thumb, as engine temperatures increase, levels of NOx rise. Once released into the air as exhaust, NOx reacts with hydrocarbons in the presence of sunlight to form ozone (or O₃), a respiratory irritant known as smog.⁷⁰ During summer months, ozone levels in major metropolitan areas often reach levels deemed to be unhealthful. Exposure to ozone at levels found frequently in Los Angeles, Dallas, New York, Washington, D.C., and many other American cities during the summer can temporarily decrease lung capacity.⁷¹ In the northeastern United States in July and August, when ozone levels tend to be especially high, exposure can cause 10% to 20% of all respiratory-related hospital visits.⁷² Even among healthy adults who are least susceptible to ozone's effects, exposure can weaken immune systems and make people more vulnerable to respiratory diseases such as pneumonia. The EPA finds that exposure to elevated levels of ozone is also a likely cause of detectable levels of premature mortality.⁷³ Young children, senior citizens, and those with respiratory conditions face the greatest risks.

In addition to contributing to ground-level ozone, NOx is a respiratory irritant in its own right. Those who are exposed may experience sore throats, decreased lung function, and greater susceptibility to respiratory infections. Health effects are more pronounced for children, the elderly, and those whose respiratory systems are

69. See *State of the Air: 2015*, AM. LUNG ASS'N 6 (2015).

70. In the upper atmosphere, ozone protects humans from the sun's harmful radiation.

71. On the strong association between exposure to ozone and decreased lung capacity, see *Integrated Science Assessment for Ozone and Related Photochemical Oxidants*, U.S. ENVTL. PROTECTION AGENCY (2013) [hereinafter *Integrated Assessment*], http://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=511347.

72. See *Nonattainment Areas for Criteria Pollutants (Green Book)*, U.S. ENVTL. PROTECTION AGENCY (last visited Oct. 10, 2016), <http://nsdi.epa.gov/oar/oaqps/greenbk/o3co.html>.

73. See *Integrated Assessment*, *supra* note 71.

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already impaired with asthma or other conditions.⁷⁴ In addition to affecting human health, NOx can directly affect environmental conditions through its contribution to acid rain.⁷⁵

Particulates, more commonly known as dust, soot, and smoke, are the products of incomplete combustion in the diesel engine. Particulates, which can vary in size from visible soot to submicron particles, come from the unburned portions of the fuel. Tiny, fine particulates are of greatest concern because they are easily respirable and, when inhaled, can penetrate deep within the lung. In 1998, the State of California declared particulate emissions contained in diesel exhaust to be carcinogenic.⁷⁶ The EPA has similarly found evidence that exposure to the particulates in diesel exhaust can cause chronic lung disease, cancer, and premature mortality.⁷⁷

The federal government's role in controlling air pollution from heavy-duty diesel engines and associated health effects has grown substantially over the past half-century. For many years, federal regulators largely ignored the environmental impact of diesel engines, focusing on the more pressing problems of pollution from stationary sources and gasoline-powered motor vehicles. Initially, the federal role was mainly to support state programs. When government did start to regulate diesels, it first focused on the most obvious problems of smoke and odor. During the 1980s and 1990s, however, the federal government, through the EPA, imposed increasingly stringent emissions standards on additional types of emissions. As regulation of stationary sources and automobiles corresponded with the reduction in pollution from these sources, diesel's share in the nation's air pollution problem grew more prominent. Over the past several decades, the EPA has moved aggressively to control pollution from heavy-duty diesel engines because, as other sources of NOx emissions have been controlled, the proportion of overall ambient levels of ozone attributable to diesel engines has tended to increase. In tandem with the tightening of emissions standards for diesel engines, the EPA has devised and updated testing protocols in an effort to make emissions tests more closely approximate real-world conditions.

Manufacturers of heavy-duty diesel engines have used a variety of mechanisms to control emissions, including modifications to engine operating conditions, changes to fuel, and after-treatment. Until recently, manufacturers met government emissions standards through the first of these strategies, relying on electronic engine controls to keep pollution within regulatory limits by adjusting fuel injection techniques and timing, air

74. See Control of Air Pollution from Heavy-Duty Engines, 60 Fed. Reg. 45,580, 45,582-83 (Aug. 31, 1995) (advance notice of proposed rulemaking).

75. See *id.*

76. See Testimony of Dr. Alan C. Lloyd, Chairman, California Air Resources Board, Notice of Proposed Rulemaking on Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements 2 (June 27, 2000), <http://www.4cleanair.org/HDETst-LosAngeles-June2000.pdf>.

77. In 2013, the EPA formally recognized these health effects in the course of amending its national ambient air quality standard for particulates. See Control of Air Pollution from Heavy-Duty Engines, 78 Fed. Reg. 3086 (Jan. 15, 2013). The weight of the scientific research on the carcinogenic properties of diesel emissions is "strong," according to the EPA health assessments of diesel exhaust emissions. *Health Assessment Document for Diesel Engine Exhaust*, U.S. ENVTL. PROTECTION AGENCY 7-142 (2002). Other analysis of data underlying the EPA's assessment suggests that the relationship, if any, between diesel engine exhaust and cancer may be more complicated. See Suresh H. Moolgavkar et al., *Diesel Engine Exhaust and Lung Cancer Mortality: Time-Related Factors in Exposure and Risk*, 35 RISK ANALYSIS 663 (2015).

intake management, oil lubrication, and exhaust gas recirculation.⁷⁸ When the timing of the injection of the fuel is varied, the levels of NOx emissions vary too, depending on the temperature when the fuel enters the combustion chamber. Similarly, particulate levels vary with injection techniques and timing. For example, fine, homogeneous dispersion generally leads to more even and complete burning of the fuel and the release of fewer particles. Engine timing that introduces fuel into the chamber at higher temperatures in the compression cycle will also reduce particulate emissions.

Only more recently, as the EPA has tightened its standards further, have manufacturers started to use after-treatment—namely, devices to clean the exhaust after combustion. With manufacturers adopting particulate traps, nitrogen adsorbers, and other after-treatment technologies, the EPA now requires that heavy-duty diesel engines burn low-sulfur fuel, as the sulfur in fuel can interfere with the effectiveness of after-treatment devices.⁷⁹

A fundamental challenge that both regulators and manufacturers have had to confront has been how to reduce NOx and particulate emissions simultaneously. Particulates are products of incomplete combustion, while NOx forms when nitrogen in the air is sucked into the engine cylinder and, due to high temperatures, combines with oxygen. If manufacturers adjust diesel engines to operate at high temperatures in order to destroy particulates, they elevate NOx levels. Adjusting engine parameters to operate at lower engine temperatures reduces NOx emissions, but increases particulates. The existence of these tradeoffs only reinforces how complicated it can be to regulate diesel emissions. The EPA has long recognized the countervailing relationship between particulate and NOx control strategies and has urged “great care” in “balancing tradeoffs between NOx and particulate emissions.”⁸⁰ In a 1981 proposed rule, for example, the agency noted that achieving a 75% reduction target for NOx as mandated under the Clean Air Act Amendments of 1977 would require methods “such as retarded timing which increase fuel consumption and increase particulate emissions markedly.”⁸¹ The EPA even concluded that, “if diesels [were] to meet or even approach” the level required by the Act, “some increase in particulate emissions may have to result.”⁸²

An additional challenge facing regulators seeking to address pollution from heavy-duty diesel engines is that these engines are built to last. The EPA requires manufacturers to build engines with emissions controls that are sufficiently durable to function throughout the engine’s “useful life.” Throughout the 1980s, 1990s, and

78. See Control of Air Pollution from New Motor Vehicles: Proposed Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, 65 Fed. Reg. 35,466 (June 2, 2000).

79. See Assessment & Standards Div., *Small Entity Compliance Guide for “Control of Air Pollution from New Motor Vehicles: Heavy Engines and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements,”* U.S. ENVTL. PROTECTION AGENCY (last visited Oct. 10, 2016), https://www.epa.gov/sites/production/files/2015-06/documents/compliance-hd_engines.pdf.

80. Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines: Gaseous Emission Regulations for 1987 and Later Model Year Light-Duty Vehicles, Light-Duty Trucks, and Heavy-Duty Engines; Particulate Emission Regulations for 1987 and Later Model Year Heavy-Duty Diesel Engines, 49 Fed. Reg. 40,258, 40,269 (proposed Oct. 15, 1984).

81. Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines; Particulate Regulation for Heavy-Duty Diesel Engines, 46 Fed. Reg. 1910, 1913 (proposed Jan. 7, 1981).

82. *Id.*

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2000s, the EPA has increased its estimates of the “useful life” of a heavy-duty diesel engine. In 1971, the EPA estimated the useful life of a heavy-duty diesel engine to be 100,000 miles.⁸³ Later, the EPA revised this number to 290,000 miles,⁸⁴ and later still to 435,000 miles.⁸⁵ Until the early part of this century, the EPA had no means to test whether engines were maintaining emissions standards over their lives, short of requiring each owner to bring in his or her truck, remove its engine, and test emissions in a laboratory—something clearly not feasible. Consequently, the EPA was unable to know how long emissions control techniques or technologies lasted in use. In addition to the practical constraint associated with ensuring that trucks do not pollute more than allowed over their long lives, longevity of these engines has meant that older trucks stay on the road for many years. Advances in pollution control can thus take many years to come into force and begin delivering payoffs in terms of cleaner air.

The structure of the heavy-duty diesel engine industry—its integration, concentration, and customer base—also holds implications for regulation. In contrast with the automobile manufacturing industry, the heavy-duty truck industry has historically not been vertically integrated. That is, most heavy-duty diesel engine manufacturers do not manufacture and sell truck bodies, and those companies that do make truck bodies tend not to make engines.⁸⁶ This lack of integration complicates the process of engine redesign.⁸⁷ Any substantial change to the engine will have repercussions for design of the entire vehicle, but these changes will have to be implemented by separate organizations. Consequently, technological innovation in this part of the transportation sector has not always occurred easily.

Manufacturing of heavy-duty diesel engines also takes place in a concentrated industry. The top three manufacturers—Caterpillar, Cummins, and Navistar—control more than 50% of the market.⁸⁸ A more highly concentrated industry can make it relatively more manageable for government to regulate, as fewer firms need to be overseen.⁸⁹ However, heavy-duty diesel engine manufacturers do not directly serve retail-level consumers but instead serve other major businesses (the truck manufacturers) that in turn have other businesses as their

83. See Definition of “Useful Life” and Requirements for Maintenance Instructions, 36 Fed. Reg. 16,905 (Aug. 26, 1971).

84. See Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines; Gaseous Emission Regulations for 1985 and Later Model Year Light-Duty Trucks, Gaseous and Evaporative Emission Regulations for 1985 and Later Model Year Heavy-Duty Engines, and Emission Regulations for 1978 and Later Model Year Motorcycles, 48 Fed. Reg. 52,170, 52,171 (Nov. 18, 1983).

85. See Control of Emissions of Air Pollution from Highway Heavy-Duty Engines, 61 Fed. Reg. 33,421 (proposed June 27, 1996) [hereinafter 61 Fed. Reg. 33,421]; see also Control of Emissions of Air Pollution from Highway Heavy-Duty Engines, 62 Fed. Reg. 54,694 (Oct. 21, 1997) (finalizing the revision in the definition of useful life to 435,000 miles).

86. See Morris et al., *supra* note 57, at 451.

87. See *id.* at 452; Anthony M. Fiore, *Industry Surveys, Heavy Equipment & Trucks*, STANDARD & POOR’S (Apr. 5, 2007), http://www.netadvantage.standardandpoors.com/NASApp/NetAdvantage/showIndustrySurveyPDF.do?task=showIndustrySurvey&code=het&type=pdf&ate=pdf/het_0407.pdf.

88. See Brandon Ruiz, *Heavy-Duty Diesel Engine Manufacturing in the US*, IBIS WORLD INDUSTRY REP. (2014), <http://clients1.ibisworld.com/reports/us/industry/majorcompanies.aspx>. Other major companies include General Electric and Detroit Diesel, now a subsidiary of Daimler AG. *Id.*

89. Relatedly, and unlike in the automobile industry, foreign competition has not traditionally been significant in manufacturing of heavy-duty diesels. See Fiore, *supra* note 87. The major companies in the industry have historically been based in the United States. In more recent years, however, the industry has confronted global pressures and pursued international market opportunities. Consolidation has taken place between U.S.-based corporations and foreign manufacturers, while both production facilities and customer bases have shifted in a global direction. See Ruiz, *supra* note 88.

customers (the trucking companies). This structure changes the dynamics of regulatory compliance and enforcement. Unlike Volkswagen and other automobile manufacturers, heavy-duty diesel truck engine manufacturers do not face the same kinds of reinforcing market pressures for regulatory compliance that companies selling directly to millions of retail customers do.⁹⁰

The very kind of business consequences and public relations ramifications that Volkswagen has experienced presumably should have provided an additional deterrent against that company flouting the law. Although even that additional deterrent was apparently not sufficient to check Volkswagen's behavior, it does seem to have affected how the company has acted after the initial allegations of illegalities became public. Compared to the heavy-duty diesel engine manufacturers that faced similar charges in the 1990s, Volkswagen has acted much more swiftly and resolutely to address its legal difficulties, including by making public apologies. Most members of the public undoubtedly never became aware of, or cared much about, the accusations against the heavy-duty diesel truck engine manufacturers, while a very large fraction of the public heard about the Volkswagen scandal.

C. Early Efforts To Regulate Motor Vehicles: 1959-1970

The regulation of diesel emissions today has grown from the much deeper roots of motor vehicle regulation more generally. The first major instance of motor vehicle emissions regulations in the United States occurred in 1959 when the California Assembly enacted legislation requiring the state Department of Public Health to establish air quality standards for motor vehicles. At the time, states—particularly California—were the primary environmental regulators, while the federal government's role was to shore up state efforts. Federal air pollution control activities focused mostly on providing research and technical expertise to support state pollution control programs.⁹¹

These roles started to shift in the 1960s. In 1966, California established mobile source emissions standards for hydrocarbons and carbon monoxide, raising concerns among automakers that a patchwork of state standards would impose significant costs for products manufactured for a national market. The federal Air Quality Act of 1967 addressed this concern by preempting state efforts to establish mobile source emissions standards, with the exception of California. For mobile sources, this same allocation of regulatory authority—federal primacy, with an exception for California—remains to this day under the 1970 Clean Air Act and its progeny. The federal EPA

90. It is generally accepted that firms face more than just regulatory pressures to manage the environmental impacts of their operations and products; they also confront social and economic pressures. Among the economic pressures can be customer demands for responsible regulatory compliance and environmental protection. See NEIL GUNNINGHAM ET AL., SHADES OF GREEN: BUSINESS, REGULATION, AND ENVIRONMENT (2003); FOREST L. REINHARDT, DOWN TO EARTH: APPLYING BUSINESS PRINCIPLES TO ENVIRONMENTAL MANAGEMENT (2000).

91. See, e.g., Air Pollution Control Research and Technical Assistance Act of 1955 § 2, Pub. L. No. 84-159, 69 Stat. 322.

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issues the principal nationwide mobile source emissions standards, with an exception for California, which is allowed to set its own standards (and other states can choose to adopt California's standards if they prefer).

When it comes to the regulation of diesel engine emissions, for many years, neither state nor federal regulators directly addressed them. During the 1950s and 1960s, diesel-powered vehicles were relatively rare and contributed only a small fraction of the pollutants responsible for the health and visibility problems of the time. As a result, state and federal lawmakers concerned about air pollution directed their attention elsewhere. The federal Motor Vehicle Air Pollution Control Act of 1965 gave the Secretary of the Department of Health Education and Welfare (HEW) a broad mandate to address “the emission of any kind of substance, from any class or classes of motor vehicles or new motor engines, which in [the Secretary’s] judgment cause or contribute to, or are likely to cause or contribute to air pollution which endangers the health or welfare of any person.”⁹² However, the HEW regulations that followed from this legislative grant of authority only addressed emissions from cars.

When lawmakers did finally act to address pollution from diesel engines, they focused on the most obvious manifestations of the pollution problem from diesel trucks: black smoke and foul odor. The federal Air Quality Act of 1967 authorized HEW to establish smoke emissions standards for diesel engines. Those standards were performance-based, stipulating that diesel engine exhaust should not obscure the transmission of a beam of light by more than 20%, except for brief “peak” periods.⁹³ That act also helped establish the basic framework for regulating other diesel emissions that still applies today: namely, pollutant-specific performance standards coupled with detailed procedures for testing performance.

D. Regulating Heavy-Duty Diesel Engine Emissions: 1970-1990

The passage of the federal Clean Air Act of 1970 was a key event in the regulation of all sources of air pollution. The Act mandated ambitious reductions of critical pollutants from motor vehicles, such as a 90% reduction in levels of carbon monoxide and hydrocarbons by 1975, and a similar reduction in NOx levels by 1976. Congress authorized states to regulate reductions in emissions from vehicles already on the roads using inspection programs and transportation control plans, but gave the federal EPA clear authority to regulate pollution from new vehicles.

The Act led to a series of broad-ranging environmental rules, among them a few that addressed controls for diesel engine exhaust. In 1972, the federal EPA took action to control NOx, carbon monoxide, and hydrocarbon

92. Motor Vehicle Air Pollution Control Act § 302(a), Pub. L. No. 89-272, 79 Stat. 992, 992 (codified as amended at 42 U.S.C. § 7401 (2012)).

93. See David F. Merrion, *Heavy Duty Diesel Emissions, Fifty Years: 1960 to 2010*, AM. SOC’Y MECHANICAL ENGINEERS (2002). The EPA later promulgated these standards in Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines, 36 Fed. Reg. 22,448, 22,452 (Nov. 25, 1971).

emissions from heavy-duty diesel engines.⁹⁴ The standards were performance-based, limiting carbon monoxide emissions to 40 g/BHP-hr and imposing a combined limit of 16 g/BHP-hr for hydrocarbons and NOx.⁹⁵ The standards required manufacturers to test prototype engines' emissions using a protocol known as the "steady-state" test—basically running each engine type through thirteen separate modes of operation (i.e., different speeds and torques) specified by the EPA and averaging the emissions results collected by an analyzer connected to the exhaust.⁹⁶ The EPA understood that diesel manufacturers would meet emissions standards by adjusting engine operating parameters. For example, in its September 1972 final rule, the EPA acknowledged that manufacturers would need to retard injection timing to meet the NOx standard.⁹⁷

The EPA proposed more stringent emissions standards in 1976.⁹⁸ It also proposed to toughen its testing procedures, requiring new types of analyzers for measuring pollutants in exhaust. Manufacturers objected to the EPA's proposed rules, arguing that they needed more time to meet the rules' new instrumentation and testing requirements. In its final rule, the EPA allowed manufacturers to continue to use existing testing protocols through the 1979 model years, but required manufacturers to adopt the new procedures thereafter.⁹⁹

The following year, Congress adopted the Clean Air Act Amendments of 1977, which again called for dramatic reductions in air pollution from mobile sources, including specifically mandated reductions from heavy-duty engines. Congress extended the deadlines for meeting the general motor vehicle reductions called for by the 1970 Act, but it also mandated a 90% reduction in hydrocarbon and carbon monoxide emissions from heavy-duty engines beginning with the 1983 model year and a 75% reduction in NOx emissions by 1985.¹⁰⁰ These amendments further required the EPA to promulgate a standard for control of particulate emissions for vehicles manufactured in 1981 and thereafter.¹⁰¹

The EPA responded to Congress' mandate in 1979 with a proposed rule that, instead of calling for more stringent emissions standards, defined a new testing procedure to replace the steady-state test.¹⁰² That new procedure, known as the transient test, required manufacturers to test emissions in the laboratory during a 20-

94. The new federal rules were identical for most part to those California had enacted just the previous year, except the effective date: 1974, instead of 1973.

95. See Heavy-Duty Engines, 37 Fed. Reg. 18,262, 18,264 (Sept. 8, 1972). For these and other emissions limits for heavy-duty diesel engines, regulators have used grams of emissions per brake horsepower-hour—g/BHP-hr—which basically tracks the relationship between emissions and the amount of work the engine exerts, as measured by a dynamometer or friction brake applied to the vehicle's drive shaft.

96. *Id.* at 18,269-70.

97. *Id.*

98. See Control of Air Pollution from New Motor Vehicle Engines: Certification and Test Procedures, 41 Fed. Reg. 21,292 (May 24, 1976).

99. See Control of Air Pollution from New Motor Vehicles and Motor Vehicle Engines; Certification and Test Procedures, 42 Fed. Reg. 45,132 (Sept. 8, 1977).

100. Congress permitted the EPA to establish a less rigorous standard if the 75% reduction level could not be reached "without increasing cost or decreasing fuel economy to an excessive and unreasonable degree." Clean Air Act Amendments of 1977 § 202(a)(3)(C), Pub. L. No. 95-95, 91 Stat. 685, 765 (1977) (codified at 42 U.S.C. § 7521).

101. *Id.* § 224. Congress called on the EPA to reach "the greatest degree of emission reduction achievable" after giving "appropriate consideration to the cost . . . , and to noise, energy, and safety factors associated with the application of such technology." *Id.* § 202(a)(3)(A)(iii).

102. See Control of Air Pollution from New Motor Vehicles and Motor Vehicle Engines, 44 Fed. Reg. 9464 (Feb. 13, 1979) [hereinafter 44 Fed. Reg. 9464].

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minute “driving cycle” specified by the EPA.¹⁰³ Not only did the test analyze emissions during different modes (like the steady-state test), but it also analyzed emissions while the cars shifted between modes, when the engines might release more emissions.¹⁰⁴

The EPA considered the transient test, a product of more than five years of research at the agency, an essential component of its diesel control program. The EPA argued that the 1977 Amendments’ target of a 90% reduction compared to baseline levels had already been largely realized for hydrocarbon and carbon monoxide emissions.¹⁰⁵ Attaining the goals articulated in the Amendments for particulates and NOx, however, would require a substantial effort, and the EPA believed the existing testing protocol would be inadequate for that purpose. In supplementary information included in its proposed rule, the EPA explained its motives in greater detail: “As the emission standards become more stringent the motivation to design around the test procedures will be increased In fact, even at current levels, the steady-state procedures do not provide an accurate assessment of true, real world reductions.”¹⁰⁶

The EPA needed a more accurate test to ensure compliance with the tough new particulate and NOx standards it was working to develop. The transient test, it maintained, would provide that accuracy.

Engine manufacturers “roundly criticized” the EPA’s proposal for the transient test, arguing that it was not justified, failed to represent “real life operation,” and was not valid.¹⁰⁷ In its final rule, adopted in 1980, the EPA retained the transient test it had proposed, concluding that it was “necessary and appropriate.”¹⁰⁸ The agency also prescribed new emissions standards for heavy-duty diesel engines to be achieved using the transient test: reducing NOx to 10.7 g/BHP-hr, carbon monoxide to 15.5 g/BHR-hr, and hydrocarbons to 1.3 g/BHP-hr, all to be effective by 1984.¹⁰⁹ The EPA allowed manufacturers to continue to use the steady-state test for one more year, until 1985, provided they could meet a more rigorous emissions standard.¹¹⁰

Spurred by the 1977 Amendments’ mandate that the EPA regulate particulate emissions, in 1981 the EPA proposed a performance-based particulate standard of 0.25 g/BHR-hr. In the background to the proposed rule, the EPA noted that heavy-duty diesel engines emit more than twice the particulate emissions of gasoline-powered engines of comparable size.¹¹¹ Regulations coming into effect in 1984 for gasoline-powered engines would in effect require manufacturers to use catalytic converters to control emissions, reducing particulates from

103. *Id.*

104. We discuss the transient testing protocol further in Section II.F, *infra*.

105. See 44 Fed. Reg. 9464, *supra* note 102, at 9466.

106. *Id.* at 9465.

107. Control of Air Pollution from New Motor Vehicles and Motor Vehicle Engines; Gaseous Emission Regulations for 1984 and Later Model Year Heavy-Duty Engines, 45 Fed. Reg. 4136, 4147 (Jan. 21, 1980) [hereinafter 45 Fed. Reg. 4136].

108. *Id.*

109. See *id.* at 4137.

110. See *id.* at 4138.

111. See Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines; Particulate Regulation for Heavy-Duty Diesel Engines, 46 Fed. Reg. 1,910 (Jan. 7, 1981).

that source by 95% to 98%. However, no comparable requirement was in place for diesel-powered engines. “Without regulation,” the agency noted, “heavy-duty diesels will emit 40 - 100 times the particulate emitted by the . . . 1984 and later model year gasoline engines.”¹¹²

In addition, the agency anticipated significant growth in the use of diesel engines over the coming years. At the time of the 1981 proposed rulemaking, the EPA estimated that one-third of heavy-duty engines were powered by diesel. It predicted that, by 1995, that percentage would nearly double.¹¹³ Air quality would likely deteriorate significantly, particularly in urban areas and near busy highways.¹¹⁴ Recall that the EPA’s regulation of diesel exhaust had focused to this point on gaseous emissions—NOx, carbon monoxide, and hydrocarbons. HEW had regulated smoke emissions from diesels in the late 1960s, but the EPA viewed those controls as crude tools for achieving the ambitious particulate goals laid down in the 1977 Amendments.

To meet its new 0.25 g/BHR-hr proposed particulate standard, the EPA expected that manufacturers would have to use a trap-oxidizer technology. Trap-oxidizer technology was already substantially established, so from the EPA’s perspective, the proposed rule was “technology forcing” only in that it required the adoption of a technology that manufacturers otherwise would not have used.¹¹⁵ The agency acknowledged, however, that manufacturers would need to adapt trap-oxidizers substantially for use in heavy-duty diesel engines.¹¹⁶

The proposed particulates rule also included provisions for testing these emissions.¹¹⁷ The EPA proposed that manufacturers add particulate measurement instruments to the transient test and measure particulate emissions simultaneously with gaseous emissions.¹¹⁸

Less than two weeks after proposing its new particulate standard, on January 19, 1981, the EPA publicly announced plans to tighten its standard for NOx.¹¹⁹ The EPA calculated that the 1977 Clean Air Act Amendments’ mandate for a 75% reduction in overall NOx emissions translated into an emissions standard for heavy-duty diesel engines of 1.7 g/BHP-hr.¹²⁰ The EPA had been concerned, however, that a standard set at this level would not be technologically feasible, and it had sought help from industry in choosing a more realistic standard. Based on confidential information it received from engine manufacturers, the EPA announced in its

112. *Id.* at 1910.

113. *See id.* at 1911.

114. *See id.*

115. *Id.* at 1915.

116. *See id.* at 1919.

117. *See id.* at 1918.

118. *Id.* The EPA had crafted the transient test knowing that it would soon propose more stringent standards for particulates and NOx. It maintained that the transient test protocol was suitable for the new standards; all that was required was additional instrumentation.

119. *See Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines; Gaseous Emission Regulations for 1985 and Later Model Year Light-Duty Trucks and 1986 and Later Model Year Heavy-Duty Engines*, 46 Fed. Reg. 5838 (Jan. 19, 1981) (advance notice of proposed rulemaking).

120. *See id.*

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advance notice of proposed rulemaking on NOx that it would consider a standard of 4.0 g/BHP-hr to be appropriate, and it would probably make this standard effective one year after the congressional target (1986).¹²¹

After announcing these regulatory plans in early 1981, the EPA's efforts to regulate particulates and NOx from heavy-duty diesel engines seemed to lose momentum. A new President—Ronald Reagan—had assumed office, and the agency took no formal regulatory action to finalize its plans to control either pollutant in 1982 or in 1983. Frustrated by the agency's inactivity, the Natural Resources Defense Council, an environmental group, filed suit against the EPA in 1984. In September 1984, the U.S. District Court for the District of Columbia ordered the EPA to propose rules to control NOx pollutants within 30 days and to issue final rules on NOx and particulates by March, 1985.¹²²

The agency met the court's deadlines.¹²³ In its proposed NOx rule, the EPA estimated that, within a decade, heavy-duty diesel engines would contribute over one-third of all NOx emissions.¹²⁴ The need to control these emissions, the agency reported, would be essential for meeting the EPA's National Ambient Air Quality Standards (NAAQS) for NOx and ozone. In its final rule, however, the EPA backtracked, stating that "the environmental need for reductions in NOx emissions is not as immediate."¹²⁵ It also established NOx performance standards that were less stringent than those it had suggested in its 1981 advance notice of proposed rulemaking, adopting limits of only 6.0 g/BHP-hr beginning in 1989, and 5.0 g/BHP-hr beginning in 1991.¹²⁶ For particulate emissions, the EPA established a standard of 0.60 g/BHP-hr in 1988, and a 0.25 g/BHP-hr standard in 1991.¹²⁷ The Engine Manufacturers Association (EMA) promptly sued the EPA for failing to provide manufacturers four years of lead-time as required by the Clean Air Act. In a November 1986 decision, the D.C. Circuit decided for the EMA, holding that the initial 6.0 g/BHP-hr NOx standard could not go into effect until 1990.¹²⁸

Figure 1 summarizes federal regulation of heavy-duty diesel engine emissions during the 1970s and 1980s. Prior to 1974, the only federal emissions regulations that applied to diesels concerned their smoke. From 1974 to 1990, though, federal regulations became increasingly stringent, particularly for carbon monoxide. Federal controls for NOx did not come into force until 1984, and for particulates until 1988. The EPA's requirement that

121. See *id.* at 5845.

122. See *Natural Res. Def. Council v. Ruckelshaus*, 21 Env't Rep. Cases (BNA) 1953 (D.D.C. Sept. 14, 1984).

123. See *Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines: Gaseous Emission Regulations for 1987 and Later Model Year Light-Duty Vehicles, Light-Duty Trucks, and Heavy-Duty Engines; Particulate Emission Regulations for 1987 and Later Model Year Heavy-Duty Diesel Engines*, 49 Fed. Reg. 40,258 (Oct. 15, 1984) [hereinafter 49 Fed. Reg. 40,258]; *Control of Air Pollution From New Motor Vehicles and New Motor Vehicle Engines; Gaseous Emission Regulations for 1987 and Later Model Year Light-Duty Vehicles, and for 1988 and Later Model Year Light-Duty Trucks and Heavy-Duty Engines; Particulate Emission Regulations for 1988 and Later Model Year Heavy-Duty Diesel Engines*, 50 Fed. Reg. 10,606 (Mar. 15, 1985) [hereinafter 50 Fed. Reg. 10,606].

124. See 49 Fed. Reg. 40,258, *supra* note 123, at 40,261.

125. See 50 Fed. Reg. 10,606, *supra* note 123.

126. *Id.* at 10,623. The EPA found that the 4.0 g/BHR-hr standard would be technologically infeasible to meet in the 1991-93 period.

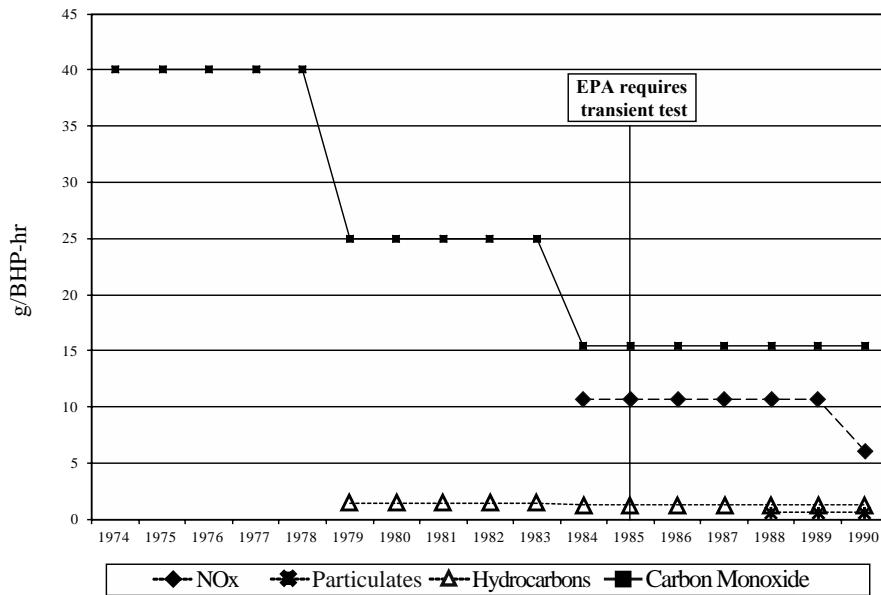
127. *Id.* at 10,606.

128. *Nat. Res. Def. Council v. Thomas*, 805 F.2d 410 (D.C. Cir. 1986).

manufacturers test emissions using the transient test in 1985 meant that performance testing came somewhat closer to representing real-world conditions.

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Figure 1: U.S. EPA Standards for Heavy Duty Diesel Engine Emissions,
1974-1990



E. The 1990 Clean Air Act and Beyond

Although air quality across the United States had generally improved during the 1970s and 1980s, ozone pollution continued to be a serious health concern. Air pollution levels frequently exceeded the NAAQS for ozone on summer days in urban areas. Heavy-duty diesel engines contributed to the ozone problem by emitting large quantities of ozone precursors, namely hydrocarbons and NOx. In 1990, Congress adopted major amendments to the Clean Air Act, including provisions that addressed emissions from heavy-duty diesel engines. Specifically, Congress ordered the EPA to establish standards for carbon monoxide, hydrocarbons, NOx, and particulates, ensuring that they would “reflect the greatest degree of emission reduction achievable through the application of [available] technology . . . , giving appropriate consideration to cost, energy, and safety factors.”¹²⁹

As the EPA tightened its standards for mobile source emissions, it did so through rules that provided manufacturers flexibility in how they achieved them. During the period from 1990 to 1995, the EPA issued rules allowing manufacturers to average, bank, and trade credits in reductions of emissions of NOx and particulates

129. Clean Air Act Amendments of 1990 § 201, Pub. L. No. 101-549, 104 Stat. 2399, 2472 (codified at 42 U.S.C.A. § 7521(a)(3)(C) (West 1995)).

from different engine models.¹³⁰ The rules also permitted manufacturers to sell engines that exceeded the EPA standards, provided that they paid a non-conformance penalty set at a level intended to reduce the financial advantage from noncompliance.¹³¹ The averaging, banking, and trading provisions allowed a manufacturer whose vehicles' emissions were below the standards to apply those extra reductions as a credit toward emissions from some of the manufacturer's other models, as long as average emissions across all the manufacturer's engine types fell below the EPA standard. A manufacturer could also bank reduction credits for another model year to use to meet the EPA standard at a later time, or it could even trade or sell extra reductions to another manufacturer. Non-compliance penalties allowed a manufacturer to pay a penalty but still sell vehicles that exceeded an emissions standard when a more stringent standard became substantially difficult for the manufacturer to meet.

The EPA's flexible stance with heavy-duty diesel engine manufacturers reached a milestone in 1995 when the agency entered into an agreement with all of the major engine manufacturers and the California Air Resources Board.¹³² Under the agreement, called the Statement of Principles, all the parties agreed that heavy-duty diesel engine manufacturers would reduce NOx emissions by half. Manufacturers would be able to choose between two standards. They could meet either a combined non-methane hydrocarbon (NMHC) and NOx standard of 2.4 g/BHP-hr, or a combined NMHC and NOx standard of 2.5 g/BHR-hr standard with a NMHC cap of 0.5 g/BHP-hr. The Statement of Principles also outlined a plan for developing technology to achieve an even more rigorous NOx standard of 1.0 g/BHP-hr and a particulate standard of 0.5 g/BHP-hr. In addition, manufacturers agreed to study the durability of engine controls to ensure that emissions stayed within required limits throughout an engine's life, which the EPA estimated to be 435,000 miles.¹³³

In return for manufacturers' agreement to meet tightened requirements by 2004 and to study further reductions, the EPA agreed not to change the particulate standard, which at the time stood at 0.1 g/BHP-hr, and not to change testing procedures.¹³⁴ While manufacturers might ordinarily have opposed the more stringent NOx standards, the principles gave them a clear sense of what to expect from future regulation in California and at the federal level. For all parties, the principles provided "certainty and stability,"¹³⁵ as well as the promise of cleaner air. The EPA formalized the Statement of Principles in a final rule in October 1997.¹³⁶

130. See Certification Programs for Banking and Trading of Oxides of Nitrogen and Particulate Emission Credits for Heavy-Duty Engines, 55 Fed. Reg. 30,584 (July 26, 1990).

131. See, e.g., Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines; Nonconformance Penalties for Heavy-Duty Engines and Heavy-Duty Vehicles, Including Heavy Light-Duty Trucks, 58 Fed. Reg. 68,532 (Dec. 28, 1993).

132. This was included as an appendix in Control of Air Pollution From Heavy-Duty Engines, 60 Fed. Reg. 45,580 (Aug. 31, 1995) (advance notice of proposed rulemaking).

133. Control of Air Pollution from Heavy-Duty Engines, 60 Fed. Reg. 45,580, 45,600 (Aug. 31, 1995).

134. See *id.* at 45,602.

135. *Id.*

136. See Control of Emissions of Air Pollution from Highway Heavy-Duty Engines, 62 Fed. Reg. 54,694, 54,700 (Oct. 21, 1997).

F. EPA's Testing Protocol

The environmental performance of heavy-duty diesel engines is a function of both the stringency of the emissions standard and the testing procedures that manufacturers must follow to assess compliance with that standard. Throughout the two-and-a-half decades in which the EPA has regulated emissions from these engines, the EPA's rules have specified both emissions limits and testing procedures. In its smoke emissions rule published in 1971, for example, the EPA described a numerical standard and a performance test that diesel exhaust must meet: opacity no greater than 40% during acceleration and 20% during lugging,¹³⁷ and, after an idling period, manufacturers must operate the engine through three acceleration and lugging modes of specified time periods.¹³⁸

Of course, the EPA's ultimate concern lies with the effects of emissions spewed by trucks and buses as they travel on highways and city streets. But testing emissions from trucks and buses as they operate on the roads has posed particular challenges for the EPA. Until the mid-2000s, no feasible method existed to test emissions from heavy-duty diesel engine-powered *vehicles*. Instead, manufacturers had to test *engine* emissions in a laboratory setting with the engine sitting on a block rather than in a vehicle. The inability to test vehicles in use has resulted in important implications for the EPA's performance-based regulation of heavy-duty diesel engine emissions.

As noted in Section II.D, the EPA's initial testing protocol for its first gaseous emissions standards for heavy-duty diesel engines required manufacturers to remove the engine from its chassis and mount it on a dynamometer in a laboratory. The engine would then be run through a 13-mode cycle intended to simulate "a truck driving pattern in a metropolitan area,"¹³⁹ with tubes connected to measure the emissions produced. Each mode within this "steady-state test" represented the engine operating at a specified speed and load.

When the EPA subsequently adopted its transient test in 1980, it amounted to a major breakthrough in making the test a much closer approximation to real-world driving conditions.¹⁴⁰ The transient test required manufacturers to test emissions from engines running at a continually changing set of speed/torque conditions, a far more comprehensive procedure than the 13-mode steady-state test.¹⁴¹ The EPA based its transient test on driving conditions in New York and Los Angeles. The test began with speed/torque ratios intended to replicate stop-and-go non-highway driving in New York, and was followed by speed/torque ratios modeled on slow but steady driving in urban Los Angeles. After these two slow phases, the test then called for conditions similar to crowded highway driving in Los Angeles. It ended with a repeat of the stop-and-go New York driving

137. See Exhaust Emissions (Heavy Duty Diesel Engines), 36 Fed. Reg. 22,452 (Nov. 25, 1971).

138. Test Procedures for Engine Exhaust Emissions (Heavy Duty Diesel Engines), 36 Fed. Reg. 22,470-22,474 (Nov. 25, 1971).

139. Heavy-Duty Engines, 36 Fed. Reg. 19,402 (Oct. 5, 1971).

140. See 45 Fed. Reg. 4136, *supra* note 107, at 4147.

141. See 44 Fed. Reg. 9464, *supra* note 102.

conditions. The test was carried out twice, once with a cold start and once with a warm start, with a twenty-minute interval between the two cycles.

Although this transient test was a much more complete test than the former steady-state testing protocol because it sampled emissions even during transitions from different driving conditions, the transient test was still artificial. Manufacturers still measured emissions from engines that ran only for about forty minutes total in a laboratory setting under a defined set of parameters—rather than longer-term monitoring of vehicles in-use.¹⁴² The implications of this testing protocol became increasingly evident after 1998, when the EPA decided to file an enforcement action against the manufacturers of heavy-duty diesel engines, charging them with systematically gaming the agency’s performance-based regulatory system.

III. The NOx Lawsuit and Its Aftermath

The fact that the EPA’s protocol calls for testing engines in a lab, rather than monitoring trucks on the road, calls to mind the common wisdom that the law “on the books” often differs from the law “in action.” Behind the EPA’s performance-based regulation of diesel emissions was the assumption that more stringent standards would lower ambient levels of harmful pollutants by lowering emissions from trucks and buses on the roads. The EPA also assumed that truck and bus emissions in use would decrease when new engines met lower levels of emissions under the laboratory tests. These assumptions came to be starkly questioned in the mid-1990s in the context of the EPA’s regulation of NOx emissions from heavy-duty diesel truck engines. The saga of the EPA’s major enforcement action against the manufacturers of these engines offers insight into performance standards’ own performance “in action.”

A. The Political Economy of Diesel Emissions

Under the Clean Air Act and its subsequent amendments, the federal government has taken a classic performance-based approach to mobile source emissions. For each vehicle model (or, in the case of diesels, each engine type), manufacturers must submit results from testing that complies with the testing protocol. Only vehicles that meet the standards under the test can be sold, which the EPA declares by issuing a certificate of conformity. In addition, several broader features of the Clean Air Act played a role in the political economy behind the EPA’s efforts to target manufacturers of heavy-duty diesel engines for enforcement action. Given the way the Clean Air Act is structured, tough enforcement of the EPA’s NOx performance standards would not only deliver cleaner air to the public, but would also deliver a windfall to the many regulated stationary sources

142. See 45 Fed. Reg. 4136, *supra* note 107, at 4139.

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of air pollution located across the United States.¹⁴³ For these reasons, state governments pressured the EPA to target NOx emissions from diesel engines.

Central to the Clean Air Act's regulatory structure are federal ambient air quality standards for six "criteria" pollutants (i.e., carbon monoxide, lead, NOx, ozone, particulates, and sulfur dioxide). No individual or business is directly regulated by these NAAQS, but they play a key role in driving much of the air pollution regulation that does impinge on industry across the country.¹⁴⁴

The federal EPA both sets the NAAQS and establishes and enforces emissions standards for new motor vehicles. It is then up to the states to find ways to bring the air within their borders to levels at or below federal ambient standards. States seek to do so by developing state implementation plans (SIPs) that detail how they will regulate new and existing stationary sources—that is, factories and other industrial plants.¹⁴⁵ The federal EPA must regularly review and approve SIPs, but the binding regulatory limits imposed on stationary sources emanate from state law, enacted in accordance with each SIP, not federal regulation.

Air sampling is used to determine if states' air quality meets the NAAQS. Those states that do not meet their NAAQS must implement various supplemental controls in future SIPs or they face the threat of sanctions, including the theoretical possibility of a federal takeover of stationary source regulation within their borders.

Emissions from mobile sources obviously factor into states' air quality, and yet ambient air sampling does not (and cannot) distinguish between emissions from mobile or stationary sources. Since the adequacy of any SIP's control of stationary sources can only be determined by air samples that include pollution from both stationary and mobile sources, the EPA uses information from its vehicle testing program to develop computer models that factor out the pollution that mobile sources contribute. As such, the accuracy of the EPA's testing protocol not only matters for determining whether classes of new vehicles or engines can be sold, but also holds direct implications for the EPA's conclusions about states' progress toward meeting their air quality goals. If the EPA's estimates of mobile source emissions are too high, states and the EPA will inaccurately infer that SIPs are more effective than they actually are in addressing stationary sources. Conversely, if the EPA's estimates for mobile sources are too low, the EPA will assume that states' efforts to control pollution from the sources over which they have jurisdiction are much less effective than they actually are.

143. Andrew Morrise and his co-authors helpfully connect the EPA's regulation of diesel emissions to the various features of the Clean Air Act discussed in this part. *See* Morrise et al., *supra* note 57, at 408-20.

144. For a discussion of the structure of air pollution regulation in the United States, see J. CLARENCE DAVIES & JAN MAZUREK, POLLUTION CONTROL IN THE UNITED STATES: EVALUATING THE SYSTEM (1998); and PAUL PORTNEY & ROBERT STAVINS, PUBLIC POLICIES FOR ENVIRONMENTAL PROTECTION (2000). As should now be clear, the relationship between ambient air quality standards and mobile source emissions standards is not one-to-one. The EPA does regulate carbon monoxide, NOx, and particulates emissions from mobile sources. But it does not directly regulate ozone emissions; instead, it regulates emissions of hydrocarbons, which, along with NOx, are precursors to ozone. It has not addressed sulfur dioxide or lead through mobile source emissions standards as much as through fuel content standards.

145. SIPs can include as well some measures aimed at reducing emissions from mobile sources, such as carpooling incentives or automobile inspection and maintenance programs.

When it comes to controlling NOx emissions, these various factors of the Clean Air Act made diesel NOx emissions an attractive target for enforcement scrutiny. Despite the progress the nation had made on many pollution problems, by the 1990s, many parts of the country continued to experience nonattainment with the EPA's ozone NAAQS. Many eastern states raised particular concerns about the contributions of the transboundary movement of air pollution to their nonattainment status. In 1995, the EPA entered into a collaborative process with a group of states and various industry and environmental organizations, known collectively as the Ozone Transport Assessment Group (OTAG). In July 1997, the OTAG process generated a series of recommendations to guide future EPA air policy, including one urging the EPA to consider ways to reduce NOx emissions from diesel engines.¹⁴⁶ In a separate action, at virtually the same time, the EPA issued more stringent NAAQS for ozone and particulate matter, increasing the number of areas that were in nonattainment status.¹⁴⁷

Since NOx is both a precursor to ozone and a key byproduct from diesel combustion, the EPA's revisions to its ambient ozone standard raised the stakes for states and regulated industrial operations to ensure that the EPA's law of the test for diesel emissions was robustly and accurately enforced.

The EPA had ample motivation to target diesel engine manufacturers. As a narrow, concentrated industry, the diesel engine manufacturers could be targeted without generating nearly the same kind of resistance that could be expected to accompany actions against other sectors. Moreover, for years, questions had swirled around the EPA's diesel engine testing protocol and whether it formed an accurate basis for estimating truck and bus contributions to overall NOx emissions (and thereby to the total ambient ozone problem).¹⁴⁸ If it could be shown that the EPA's testing protocol systematically underestimated the actual emissions coming from mobile sources, then fixing the error would mean that states could reap a near-instant "credit" toward the stationary sources they need to control in their SIPs. The burden on states to reduce air pollution from the sources over which they had authority would be reduced, and stationary sources would face fewer state regulatory demands to further lower their pollution of the ambient air.

B. EPA's Enforcement Action and Its Settlement

When crafting its NOx emissions standards in the 1980s and early 1990s, the EPA did not take into account a significant change in truck engine design that occurred in the 1990s: the advent of electronic engine controls.

146. See Letter from the Ozone Transport Assessment Group to Mary Nichols, Assistant Adm'r, U.S. Envtl. Prot. Agency (July 8, 1997), <https://archive.epa.gov/ttn/ozone/web/pdf/otagappb.pdf>; see also Larry Parker & John Blodgett, *Air Quality and the New Ozone NAAQS: The OTAG Process*, ENV'T & NAT. RESOURCE POL'Y DIVISION (July 30, 1998), <http://digital.library.unt.edu/govdocs/crs/permalink/meta-crs-522:1>.

147. See National Ambient Air Quality Standards for Ozone, 62 Fed. Reg. 38,856, 38,652 (July 18, 1997).

148. See Morris et al., *supra* note 57, at 415-17; Janet Yanowitz et al., *Prediction of In-Use Emissions of Heavy-Duty Diesel Vehicles from Engine Testing*, 36 ENVTL. SCI. & TECH. 270 (2002).

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With these controls, manufacturers were able to program their engines so they could sense when they were outside the conditions specified in the transient test. For example, the transient test replicates the speeds and torques of a truck operating on urban streets and highways in Los Angeles and New York. Using electronic engine controls, manufacturers programmed their engines to meet the EPA's emissions standard for those prescribed intervals. But after that time, the engines operated so as to maximize power and fuel economy, notwithstanding an increase in NOx emissions.

This change proved important for the ultimate customers of diesels—truckers and the owners of trucking companies—who have a particularly strong economic interest in fuel economy. A difference of just one-tenth of one mile per gallon can influence a trucker's engine purchasing choice.¹⁴⁹ Driven by the goal of increasing sales, diesel engine manufacturers responded by seeking to meet the transient test procedure in a way that maximized fuel economy. The EPA certified these engines as compliant because emissions were within the acceptable range when manufacturers tested them.

Exactly when and how the EPA learned that manufacturers were designing engines to maximize power and fuel economy outside the transient test cycle remains unclear. A March 2000 staff report prepared by the U.S. House of Representatives Committee on Commerce found that the EPA had knowledge of this strategy as early as 1991.¹⁵⁰ In a 1994 notice of proposed rulemaking, agency officials had indicated that they were aware that some manufacturers were using “transient sensing algorithms that ha[d] the effect of retarding the timing during transient engine operating conditions and advancing the timing during certain steady state operating conditions.”¹⁵¹ It was not until July 1998, however, that the EPA decided to bring enforcement actions against what were then the seven leading diesel engine manufacturers.

In filing its actions in court, the EPA argued that designing engines that produced excessive NOx outside the parameters of the transient test constituted a “defeat device,” which is prohibited under the Clean Air Act.¹⁵² The EPA estimated that, in 1998 alone, engines made by the targeted manufacturers produced 1.3 million tons of excess NOx emissions, a large portion of overall nationwide NOx emissions for that year.¹⁵³ Because truck engines can last for decades, the amount of excess emissions that these engines generated over their lifetimes was perhaps in the range of tens of millions of tons.

149. See *Success Story – Martin Transport*, MACK TRUCKS INC. (Oct. 7, 2010) (modified Jan. 27, 2011), <http://www.macklabornegotiations.com/assets/mack/css/images/5191.pdf> (quoting trucking company vice president as explaining that his company purchased new trucks during the recession because “a savings of one-tenth of one mile per gallon of diesel fuel equates to approximately \$300,000 per year.”).

150. See *Asleep at the Wheel*, *supra* note 10, at 6.

151. Approval and Promulgation of State and Federal Implementation Plans; California—Sacramento and Ventura Ozone; South Coast Ozone and Carbon Monoxide; Sacramento Ozone Area Reclassification, 59 Fed. Reg. 23,264, 23,418 (May 5, 1994).

152. 42 U.S.C. § 7522(a)(3)(B); see also 40 C.F.R. Part 86, Subpart A.

153. See DOJ, *EPA Announce One Billion Dollar Settlement with Diesel Engine Industry for Clean Air Violations*, U.S. ENVTL. PROTECTION AGENCY (Oct. 22, 1998), <http://yosemite.epa.gov/opa/admpress.nsf/b1ab9f485b098972852562e7004dc686/93e9e651adeed6b7852566a60069ad2e>.

The EPA had leverage over the engine manufacturers, as the agency had yet to issue final certificates of conformity for the manufacturers' engines for the upcoming year. With that kind of leverage against them, the manufacturers swiftly entered into a settlement with the agency in just a matter of months. However, the manufacturers never conceded that they had broken the law or created defeat devices. On the contrary, they claimed to have built engines that met the agency's own testing protocol, using methods of adjusting fuel injection that the agency had long accepted.¹⁵⁴ Nevertheless, with certificates of conformity hanging in the balance, they agreed to pay \$83 million, which amounted to the largest settlement of an enforcement action that the EPA had ever collected. In addition, manufacturers agreed to produce engines that achieved a NOx emission standard of 2.5 g/BHP-hr by October 2002, a 50% reduction over the preexisting federal standard.

Significantly, six of the seven manufacturers also agreed to submit their engines to supplemental emissions testing procedures beyond the existing transient test. These new testing procedures were designed to make up for limitations in the existing transient test that had allowed the excess emissions to go undetected for so long. The new testing procedure was called "not-to-exceed" because it emphasized an upper limit on the amount of emissions that could be released during the test, which restricted the variance around average emissions rather than measuring the average alone (as the other tests did). By October 2002, the EPA had certified that engines manufactured by each of the seven companies that signed a consent agreement had achieved required emissions reductions in accordance with the not-to-exceed testing procedure.

Through a process that legal scholar Andrew Morrise and his co-authors have termed "regulation by litigation,"¹⁵⁵ the EPA sought to require the seven targeted manufacturers to pull ahead of the rest of the industry by meeting more stringent pollution requirements. Since the manufacturers "voluntarily" accepted these more stringent standards in order to settle the agency's enforcement action, the EPA was able to circumvent the normal rulemaking process while binding the manufacturers to a much tighter time frame for compliance than it would otherwise have been permitted to impose if it had used the normal regulatory process.¹⁵⁶

C. The Testing Protocol Revisited

The EPA's lawsuit against the diesel manufacturers and the consent decrees it filed in 1998 made clear the limitations of the EPA's transient testing protocol that took effect in 1985. As noted, the manufacturers covered by the consent decree were required to adopt additional testing procedures, namely a supplemental steady-state

154. See Mike Osenga, *Diesel Industry Confronts the Emissions Settlement*, DIESEL PROGRESS 42 (Dec. 1998).

155. See Morrise et al., *supra* note 57. For a broader discussion of "regulation by litigation," see W. KIP VISCUSI, REGULATION THROUGH LITIGATION (2002).

156. For a critical account of this approach, see JAMES V. DELONG, OUT OF BOUNDS AND OUT OF CONTROL: REGULATORY ENFORCEMENT AT THE EPA (2002).

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test and the “not-to-exceed” protocol.¹⁵⁷ According to a new regulation the EPA adopted in 2000, all manufacturers would become subject to those same testing requirements starting in 2007.¹⁵⁸

Like the steady-state test the EPA relied on until 1984, the supplemental steady-state test the EPA required as part of the 1998 consent decree required manufacturers to test emissions at specified speeds and loads. The supplemental test would represent driving conditions not covered in the transient test—in particular, highway cruise speeds and loads.¹⁵⁹ The EPA’s test procedure detailed the speeds and loads it expected manufacturers to test. In addition, it reserved the opportunity to select three additional test points, which it would not disclose to manufacturers until immediately prior to the test. According to the EPA, those requirements would ensure “that emissions do not ‘peak’ outside of the 13-mode test points.”¹⁶⁰

The EPA further proposed the “not-to-exceed” test. Unlike the transient test, not-to-exceed does not specify a driving cycle. Instead, this test establishes an engine operating zone that approximates “any engine operation conditions that could reasonably be expected to be seen by that engine in normal vehicle operation and use.”¹⁶¹ Unlike the transient test, the not-to-exceed test is not limited to a particular length of time or to driving conditions similar to what would be found in New York or Los Angeles. It is meant to include all normal driving situations with the exception of very low speeds and low loads and very high speeds and low loads. Because not-to-exceed testing encompasses such a wide range of conditions, the EPA allowed manufacturers to meet a less stringent standard emissions standard when following this protocol. In a final rule adopted in October 2000, the EPA established that, under the not-to-exceed procedure, emissions could not exceed 1.25 times the applicable transient test standard.¹⁶²

In addition to these changes, in 2000, the EPA announced a major innovation on the horizon: in-use testing. The EPA finalized its in-use testing program in detail in 2005,¹⁶³ after in-use testing became possible with the development of “portable emissions measurement systems” (PEMSs). PEMSs are about the size of a large suitcase, mounted inside or outside the cab of a truck. The PEMSs available today measure gaseous pollutants: non-methane hydrocarbons, CO, NOx, and particulates.¹⁶⁴

On-board, in-use testing now makes it possible for the EPA to assess environmental performance over the course of a vehicle’s life. According to the program structure, the EPA selects a certain number of diesel engine

157. Notice of Filing of Consent Decree Under the Clean Air Act, 63 Fed. Reg. 59,330 (Nov. 3, 1998).

158. See Control of Emissions of Air Pollution from 2004 and Later Model Year Heavy-Duty Highway Engines and Vehicles; Revision of Light-Duty On-Board Diagnostics Requirements, 65 Fed. Reg. 59,896 (Oct. 6, 2000).

159. *See id.* at 59,915.

160. *Id.* at 59,916.

161. *Id.* at 59,911.

162. See Control of Emissions of Air Pollution from 2004 and Later Model Year Heavy-Duty Highway Engines and Vehicles; Revision of Light-Duty On-Board Diagnostics Requirements, 65 Fed. Reg. 59,896, 59,930 (Oct. 6, 2000).

163. See Control of Emissions of Air Pollution from New Motor Vehicles: In-Use Testing for Heavy-Duty Diesel Engines and Vehicles, 70 Fed. Reg. 34,594 (June 14, 2005) [hereinafter 70 Fed. Reg. 34,594].

164. *Id.* at 34,611.

“families” to be tested, which comprise about 25% of a manufacturer’s fleet in any given year.¹⁶⁵ These tests are not conducted on new engines or vehicles, but vehicles in operation. The engine manufacturers must find truck drivers who are willing to volunteer to participate in the on-board testing program. Each vehicle is then equipped with a PEMS. Its regular operator drives the truck on a regular route hauling a regular load. Manufacturers must then report test results to the EPA, including all emissions data, engine operating parameters, test conditions, test equipment specifications, and vehicle and engine information generated during the test.¹⁶⁶

Manufacturers are required to test 5 to 10 vehicles from each engine type or “family.”¹⁶⁷ If at least 5 out of 6 vehicles in a family achieve “a specified vehicle pass criteria,” no further testing is required for that family.¹⁶⁸ If more than one vehicle fails, the manufacturer must test all 10 vehicles and achieve a pass rate of 8 out of 10. If that rate is not achieved, the EPA may require additional testing.¹⁶⁹

The results obtained from in-use tests are not fully equivalent to results from laboratory tests. Because a portable emissions measurement system is not as finely calibrated as a laboratory measurement device, error rates can differ between the two methods of measurement. The PEMSs fold up into a suitcase and can cost about \$100,000 to \$180,000, while the analytical instrumentation for a laboratory measurement system can fill a trailer and reportedly cost in the range of \$300,000 to \$500,000—a price difference reflecting the laboratory equipment’s greater precision.¹⁷⁰ As part of a settlement of a legal challenge to an earlier rule, the engine manufacturers, the EPA, and the California Air Resources Board (CARB) agreed to a “measurement allowance” of .45 g/BHP-hr for PEMSs, meaning that, when the EPA determines compliance, it must subtract that amount from the emissions results obtained from PEMSs.¹⁷¹

Tenting Standards After Litigation

In 2000, the EPA initiated a rulemaking that would make major changes to its emissions standards for heavy-duty diesel engines. The agency estimated that, by 2007, emissions from diesel trucks would account for nearly 30% of NOx emissions and 14% of particulate emissions from all transportation sources.¹⁷² By this time,

165. See *id.* at 34,598.

166. See *id.* at 34,607 (June 14, 2005); see also Off. of Transp. & Air Quality, *In-Use Testing Program for Heavy-Duty Diesel Engines and Vehicles, Technical Support Document*, U.S. ENVTL. PROTECTION AGENCY (June 2005), <https://www3.epa.gov/otaq/highway-diesel/regs/420r05006.pdf>.

167. See 70 Fed. Reg. 34,594, *supra* note 163, at 34,601.

168. *Id.*

169. *Id.*

170. See Off. of Transp. & Air Quality, *supra* note 166, at 2. This estimate comes from a phone interview we conducted with an official from U.S. EPA Office of Transportation and Air Quality Assessment and Standards Division.

171. See Control of Emissions of Air Pollution from New Motor Vehicles; Emission Measurement Accuracy Margins for Portable Emission Measurement Systems and Program Revisions, 73 Fed. Reg. 13,441 (Mar. 13, 2008); *Test Plan To Determine PEMS Measurement Allowance for the PM Emissions Regulated Under the Manufacturer-Run Heavy-Duty Diesel Engine In-Use Testing Program*, U.S. ENVTL. PROTECTION AGENCY (2010), <http://www3.epa.gov/otaq/regs/hd-hwy/inuse/420b10901.pdf>.

172. See Control of Air Pollution from New Motor Vehicles: Proposed Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, 65 Fed. Reg. 35,434 (June 2, 2000) [hereinafter 65 Fed. Reg. 35,434].

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the health risks and environmental consequences associated with both of these pollutants had become much better established.¹⁷³ The EPA also noted the growing popularity of diesels, calling these engines “a vital workhorse in the United States, moving much of the nation’s freight, and carrying out much of its farm, construction, and other labor.”¹⁷⁴ The agency estimated that about one million new diesel engines were being brought into service each year.¹⁷⁵ The harmful nature of diesel emissions, combined with the rapidly growing use of diesels, motivated the EPA to take further action.

The EPA finalized its more stringent emissions standards in 2001: a particulate standard of 0.01 g/BHP-hr, an NOx standard of 0.2 g/BHP-hr, and a non-methane hydrocarbon standard of 0.14 g/BHP-hr, each taking effect beginning in 2007.¹⁷⁶ For NOx, the proposed standard represented roughly a 90% emissions reduction compared to the previous standards that took effect in 2004. Figure 2 summarizes the progression of federal standards for NOx and particulates during the period from 1990 to 2007.

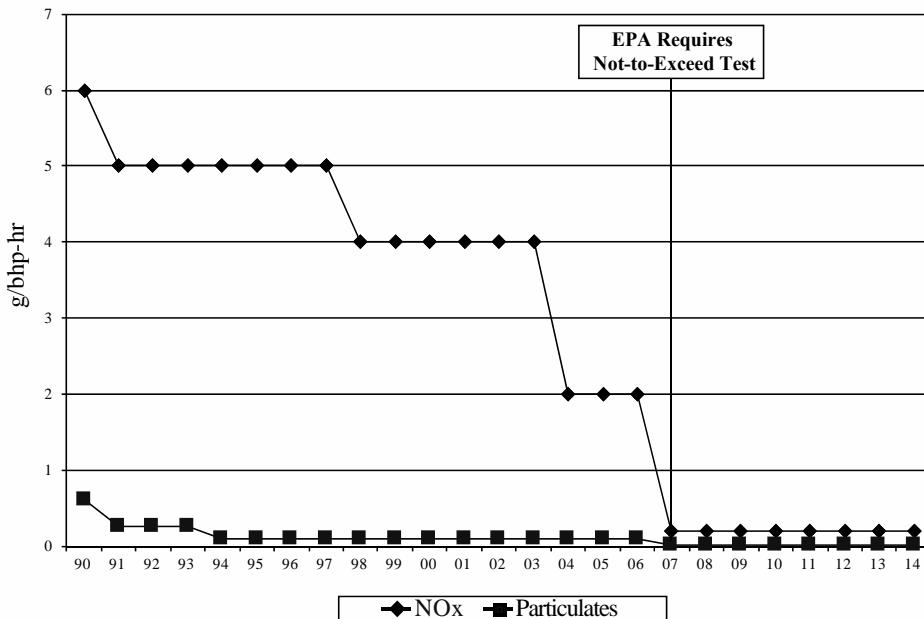
173. See *supra* Part II.

174. See 65 Fed. Reg. 35,434, *supra* note 172, at 35,436.

175. See *id.*

176. See Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, 66 Fed. Reg. 5005 (Jan. 18, 2001).

Figure 2: U.S. EPA Standards for NOx and Particulates from Heavy Duty Diesel Engines, 1990-2007



The EPA anticipated that manufacturers would need to use “after-treatment devices” to meet these new standards. Until this point, manufacturers had reduced emissions mainly by changing engine operating characteristics. The new NOx standards would likely require manufacturers to install NOx adsorbers that would capture NOx after combustion but before being released into exhaust.¹⁷⁷ Unfortunately, sulfur in diesel fuel can “poison” NOx adsorbers, so in conjunction with tightening emissions limits, the EPA also limited the sulfur content in diesel fuel sold to consumers to 15 parts per million beginning in 2007, a 97% reduction.¹⁷⁸

As the EPA set its more stringent emissions standards and established more demanding testing protocols, another factor entered the picture that served to undercut the actual impact of the EPA’s performance standards: consumers. According to Standard & Poor’s estimates, trucks with engines meeting the EPA’s 2007 emissions requirements cost 5% more to buy and turned out to be 2% less fuel efficient.¹⁷⁹ Customers were also uncertain about the reliability of the new engines, a crucial consideration given that many truck operators work under tight

177. See Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, 66 Fed. Reg. 5002, 5048-52 (Jan. 18, 2001).

178. See *id.*

179. See Fiore, *supra* note 87.

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time schedules, with tight profit margins and limited fleet sizes. Trucks powered by engines that are substantially different from those that operators have worked with in the past represented a significant risk of business interruption and failure to meet shipping deadlines.¹⁸⁰ As a result, customers were skittish and reluctant to wait to buy new trucks after 2007. Industry sales figures indicate that consumers “pre-bought” trucks in order to take advantage of lower-cost, more fuel-efficient, tried-and-true models, despite their poorer emissions performance. Demand for trucks equipped with heavy-duty diesel engines increased by 25% in 2005 and 12% in 2006, and sales in 2006 reached an all-time high of 410,000.¹⁸¹ Standard & Poor’s reported that sales of heavy-duty trucks “declined sharply”—by 66%—for the two years following the effective date of the EPA’s new testing protocols.¹⁸²

Given that the useful life of a heavy-duty diesel engine is over 400,000 miles,¹⁸³ trucks that were pre-bought before 2007 have stayed on the road—and some may even continue to stay on the road—for quite a number of years, delaying the benefits of the EPA’s new rules.¹⁸⁴ Furthermore, as trucks age, they are used less for long-haul highway driving and more for short-haul urban driving. Rural areas were probably the first to experience the benefits of the EPA’s new heavy-duty diesel engine emission rules, while urban areas (which have the more serious air pollution problems) may have experienced dirtier air for a longer time due to how many pre-2007 trucks remained in use.¹⁸⁵

E. Volkswagen in the Blind Spot

We can now fast-forward to the scandal involving Volkswagen’s diesel cars, which unfolded in a manner strikingly similar to the saga of heavy-duty truck engines. Although the Volkswagen story is still unfolding—with the company embroiled in litigation and under investigation by regulatory authorities in the U.S. and Europe—it is clear that the government’s performance tests were not up to the task of ensuring that actual emissions matched those reflected in the law of the test. Despite the EPA’s experience with the heavy-duty diesel engine industry, the agency had never established an in-use testing protocol for diesel *automobiles*.¹⁸⁶ As a

180. See *id.*

181. See *id.*

182. See Jim Corridore, *Industry Surveys: Heavy Equipment and Trucks*, S&P CAPITAL IQ (Jan. 2015), <https://gskkr.files.wordpress.com/2015/01/heavy-equipment-and-trucks.pdf>. The sales drop-off was not permanent. Starting in 2010, however, sales started to rebound, largely “to replace aging equipment.” *Id.*

183. See Off. of Transp. & Air Quality, *Development of Heavy-Duty On-Highway Engine Regulations in the U.S.*, U.S. ENVTL PROTECTION AGENCY (June 9, 2014), http://www.theicct.org/sites/default/files/5.%20Development.%20of%20HDOH%20Engine%20Regulations%20in%20US%20_Orehowsky.pdf; see also 61 Fed. Reg. 33,421, *supra* note 85.

184. See Morris et al., *supra* note 57.

185. See *id.*

186. See Jack Ewing, *Researchers Who Exposed VW Gain Little Reward from Success*, N.Y. TIMES (July 24, 2016), <http://www.nytimes.com/2016/07/25/business/vw-wvu-diesel-volkswagen-west-virginia.html> (discussing the “significant engineering challenge” associated with testing emissions from automobiles on the road).

result, Volkswagen cars passed the regulators' laboratory emissions tests but then emitted substantially higher levels of NOx on the road.

It only took a few researchers at West Virginia University, working under contract for the International Council on Clean Transportation (ICCT) to uncover the Volkswagen scandal. ICCT, a nonpartisan, nonprofit organization headquartered in the United States, works to promote environmental improvement in the transportation sector by conducting independent research. In 2012, ICCT submitted a proposal to the European Commission asking the Commission to fund a study of the in-use emissions performance of diesel-powered cars, with the aim not of uncovering deception but rather to find out if automobile manufacturers could meet more stringent regulatory targets.¹⁸⁷ After its proposal was denied,¹⁸⁸ the organization decided to fund a smaller version of the project out of its own organizational budget—which is, incidentally, less than one-tenth of one percent the size of the EPA's budget.¹⁸⁹

ICCT selected West Virginia University's Center for Alternative Fuels, Engines and Emissions (CAFE) to conduct in-use tests on three vehicles.¹⁹⁰ In 2013, CAFE's researchers rented two diesel cars and borrowed a third: two Volkswagen models (Jetta and Passat) and one BMW (X5).¹⁹¹ All three were certified as meeting EPA and California emissions standards; all had relatively low mileage; and all checked out satisfactorily, with no signs of any malfunctioning engine or after-treatment parts.¹⁹² The three cars were then equipped with a PEMS and driven through five established test routes in Southern California, with each route representing different driving conditions (e.g., city traffic, highways, and hills).¹⁹³ The Volkswagen Passat was also driven from Southern California to Seattle and back.¹⁹⁴

CAFE found that the two Volkswagen models emitted NOx emissions higher than the levels reflected in the regulatory standards: the Jetta emitted 15 to 35 times the applicable EPA standard, while the Passat emitted 5 to 20 times the standard.¹⁹⁵ The BMW model, by contrast, kept emissions to levels below the standard on all but the steepest of the routes.¹⁹⁶ When the researchers took the two Volkswagen models to CARB's emissions

187. See *FAQ: In-Use NOx Emissions from Diesel Passenger Cars*, INT'L COUNCIL ON CLEAN TRANSP. (Sept. 25, 2015) [hereinafter INT'L COUNCIL ON CLEAN TRANSP.], <http://www.theicct.org/news/faq-use-nox-emissions-diesel-passenger-cars>; Ewing, *supra* note 186.

188. See INT'L COUNCIL ON CLEAN TRANSP., *supra* note 187.

189. See *Audited Consolidated Financial Statements (2013)*, INT'L COUNCIL ON CLEAN TRANSP., http://www.theicct.org/sites/default/files/2013_ICCT_AFS.pdf; see also *EPA's Budget and Spending*, U.S. ENVTL PROTECTION AGENCY (last visited Nov. 8, 2016), <https://www.epa.gov/planandbudget/budget>.

190. See INT'L COUNCIL ON CLEAN TRANSP., *supra* note 187; see also Ewing, *supra* note 186.

191. See INT'L COUNCIL ON CLEAN TRANSP., *supra* note 187; see also Ewing, *supra* note 186.

192. See Gregory J. Thompson et al., *In-Use Emissions Testing of Light-Duty Diesel Vehicles in the United States*, CTR. ALTERNATIVE FUELS, ENGINES & EMISSIONS, W. VA. U. (May 15, 2014), http://www.theicct.org/sites/default/files/publications/WVU_LDDV_in-use_ICCT_Report_Final_may2014.pdf.

193. See *id.*

194. See *id.*; INT'L COUNCIL ON CLEAN TRANSP., *supra* note 187.

195. See Thompson et al., *supra* note 192, at 62-63; INT'L COUNCIL ON CLEAN TRANSP., *supra* note 187.

196. See Thompson et al., *supra* note 192, at 63; INT'L COUNCIL ON CLEAN TRANSP., *supra* note 187.

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testing laboratory and had the regulatory tests run on the two cars, their NOx emissions were below the mandatory limit.¹⁹⁷

Following the release of the CAFE study in May 2014, regulators at CARB and the EPA began their own investigation. During that time, Volkswagen representatives allegedly “continued to assert to CARB and the EPA that the increased emissions from these vehicles could be attributed to various technical issues and unexpected in-use conditions.”¹⁹⁸ The company issued a voluntary recall in December 2014, but subsequent testing by CARB failed to convince the regulators that the issue had been solved.¹⁹⁹ CARB and the EPA threatened to hold up certification of Volkswagen’s 2016 model year cars. According to the EPA, “[o]nly then did VW admit it had designed and installed a defeat device in these vehicles in the form of a sophisticated algorithm that detected when a vehicle was undergoing emissions testing.”²⁰⁰ Volkswagen had installed some kind of a digital system on its vehicles that automatically detected when the vehicle was in normal use and when it was connected to a testing machine, and then alternated the calibration of the engine accordingly. Apparently, the system was so accurately designed that, when connected to laboratory testing equipment, it automatically switched to the “normal,” non-testing mode precisely one second after the time period called for in the EPA’s testing protocol.²⁰¹

In September 2015, CARB and the EPA released formal notices of violation, asserting that Volkswagen had installed defeat devices in hundreds of thousands of its vehicles, across seven models from 2009 to 2015.²⁰² Researchers at MIT and Harvard estimated that the excess emissions from this initial set of 482,000 identified vehicles could contribute to 60 to 130 premature fatalities nationwide.²⁰³ CARB and the EPA also announced they would conduct additional testing of other vehicles. By November 2015, following further testing, the two regulatory agencies issued another notice of violation covering seven more Volkswagen models from 2014 to 2016.²⁰⁴ In January 2016, the U.S. Department of Justice filed a civil action in federal district court on behalf of the EPA against Volkswagen, seeking what could have amounted to up to nearly \$50 billion in statutory penalties.²⁰⁵ The government charged Volkswagen with installing defeat devices in approximately 580,000 vehicles and accused the company of concealing information and making “affirmative misrepresentations” to

197. See Thompson et al., *supra* note 192, at 64; INT’L COUNCIL ON CLEAN TRANSP., *supra* note 187.

198. U.S. Envtl. Prot. Agency, Notice of Violation to Volkswagen (Sept. 18, 2015), <http://www.epa.gov/sites/production/files/2015-10/documents/vw-nov-caa-09-18-15.pdf>.

199. See *id.*

200. *Id.* at 4.

201. See U.S. Envtl. Prot. Agency, Notice of Violation to Volkswagen 4 (Nov. 2, 2015), <http://www.epa.gov/sites/production/files/2015-11/documents/vw-nov-2015-11-02.pdf>

202. See *id.* Included among the models was the Audi A3. Audi is owned by Volkswagen.

203. Steven R.H. Barrett et al., *Impact of the Volkswagen Emissions Control Defeat Device on US Public Health*, 10 ENVT’L RES. LETTERS (2015).

204. See U.S. Envtl. Prot. Agency, *supra* note 201. The notice of violation was also sent to Porsche, which is owned by Volkswagen.

205. The complaint was filed against Volkswagen AG, Audi AG, Volkswagen Group of America, Volkswagen Group of America Chattanooga Operations, Porsche AG, and Porsche Cars North America, which are collectively referred to in this paragraph’s discussion of the complaint as “Volkswagen.” Complaint, United States v. Volkswagen, 2016 U.S. Dist. (D. Mich. 2016) (No. 2:16cv10006).

government regulators.²⁰⁶ In June 2016, the automaker agreed to a partial settlement of this suit for approximately \$15 billion.²⁰⁷

The swift, responsive regulatory action that the EPA and CARB have taken following the ICCT study's release has been laudable. Yet the Volkswagen scandal is revelatory about what might have been done differently, perhaps even seven years earlier. Not only did it cost ICCT only \$70,000 to identify the disparity in on-road emissions in the first place, but the speed at which CARB and the EPA subsequently identified the broader problems suggests the relative ease of detecting the scandal.²⁰⁸ Granted, CARB and the EPA have a sweeping set of other responsibilities and finite resources, but having encountered similar methods with heavy-duty diesel *truck* engine manufacturers in the 1990s, it should have hardly come as any surprise that diesel *car* manufacturers might want to approach the inherent tradeoffs in diesel technology in similar ways. Indeed, it should come as no surprise because performance standards facilitate, if not encourage, regulated firms to proceed in such fashion: namely, to meet the law of the test, but to do so in ways that yield private advantages, even at the expense of societal welfare.

IV. Lessons for Performance-Based Regulation

Although commentators have sometimes suggested that a performance-based environmental regulation would be difficult to effectuate because it would require government officials "to do hard things that they have never been willing to do before,"²⁰⁹ the history of the EPA's regulation of heavy-duty diesel engine emissions clearly shows that government has actually been quite willing to rely on performance standards for many decades, at least in the automobile emissions context. The EPA established goals for engine manufacturers to meet—specifying a designated test with emissions levels below the stated standards, but not mandating that manufacturers use any particular means to meet that goal. The EPA's accumulated experience with performance standards in this area could offer useful insights for decision makers at the EPA and elsewhere who find themselves facing choices about whether to use a performance-based approach.

What lessons can be drawn from the EPA's regulatory history with diesel engine emissions? In this part, we conclude by adding to the larger literature on regulatory instrument choice a series of what should by now be evident limitations of performance standards. The heavy-duty diesel engine emissions saga helps clarify what is

206. *Id.* Worldwide, Volkswagen has acknowledged that as many as 11 million of its vehicles have had their emissions outputs managed by these same kinds of defeat devices. See William Boston & Sarah Sloat, *Volkswagen Emissions Scandal Related to 11 Million Cars*, WALL ST. J. (Sept. 22, 2015), <http://www.wsj.com/articles/volkswagen-emissions-scandal-relates-to-11-million-cars-1442916906>.

207. See U.S. DEP'T JUST., *supra* note 7. The settlement covers 2.0-liter engine model cars, but still outstanding are civil charges concerning 3.0-liter models. The Justice Department has also made clear that criminal charges have not yet been ruled out. *Id.*

208. Reportedly it cost the West Virginia University researchers up to an additional \$20,000 or \$30,000, funded by other sources, to conduct the study. See Ewing, *supra* note 186.

209. OLIVER A. HOUCK, THE CLEAN WATER ACT TMDL PROGRAM: LAW, POLICY, AND IMPLEMENTATION 147 (1999) (discussing the challenges states faced in implementing a performance-based approach to water quality).

realistic to expect from a move to a more fully performance-based approach to regulation in the realm of environmental policy or other policy areas. Obviously, appropriate caution is always in order when generalizing from a single case study. We do not claim that performance standards will always operate as they have here. Indeed, as we have discussed in other work, not all performance standards are the same. How they are designed—the degree of specificity that they provide about the desired outcome, the closeness between the outcome specified in the standard and the outcome of ultimate concern to the regulator (and to society), the way that performance is measured, and the basis for the standard (e.g., risk versus feasibility)—can affect how they will operate in practice.²¹⁰

Still, this case study offers a meaningful advance in our understanding of performance standards, especially because, as we have previously noted, there exists an “absence of empirical studies . . . showing when, where, and how well performance standards work.”²¹¹ This absence has been all the more striking given the widespread acceptance of the superiority of performance standards, which we discussed in Part I. Unlike one-size-fits-all means standards, performance standards bring with them greater compliance flexibility, offering the theoretical possibility of greater cost-effectiveness. In the absence of retrospective research on performance standards, the conventional wisdom’s unbridled enthusiasm for these standards has rested almost exclusively on theory and intuition. A single case study, then, can help either to corroborate the conventional wisdom or to caution against accepting it unconditionally. The latter is what we conclude from this case study of diesel emissions control. If nothing else, this case study reveals how the theoretical case usually advanced in favor of performance standards must be tempered with an understanding of how these standards actually operate in practice and what challenges they present to regulators for their effective implementation.

A. *Limits to Performance Standards*

Performance is integral to any regulatory system, as any given regulatory strategy will always need to be assessed in terms of its performance in achieving the regulators’ desired outcomes and any other relevant criteria, such as costs. Notwithstanding the widespread acclaim for performance standards noted in Part I, their ultimate success, like that of any other approach to regulation, depends on the quality and quantity of the performance that they achieve.

The experience with performance standards for heavy-duty diesel emissions brings to the fore several key limitations and challenges to performance standards that have been too seldom recognized in the literature on regulatory instruments. These limitations raise the question of whether it makes sense to treat performance standards as “generally superior” to means standards.²¹² The full recognition of the limitations and challenges

210. See also Coglianese et al., *supra* note 24, at 709-11.

211. *Id.* at 714.

212. OIRA, *supra* note 19, at 8.

illustrated with the EPA’s experience regulating diesel emissions should lead policymakers to be more cautious before accepting overly broad, unqualified, and glowingly positive generalizations about performance-based regulation.²¹³ In contrast with the prevailing enthusiasm in the literature, the EPA’s experience with diesel emissions regulation offers seven counterbalancing lessons about a performance-based approach to environmental regulation.²¹⁴

1. *Performance standards can sometimes generate problematic “teaching-to-the-test” responses.* The behavior of diesel engine manufacturers in the face of regulatory demands reveals an obvious but insufficiently acknowledged problem with performance standards: gaming the system. In the field of education, gaming like this is referred to as “teaching to the test.”²¹⁵ This phenomenon need not be at all malicious or ill intentioned. Teachers acting in good faith may teach their students techniques needed to score high on tests, but those students may nevertheless fail to internalize fully the underlying knowledge and cognitive skills that the tests seek to measure. Just as with students taking tests in the classroom, businesses in a regulated sector may satisfy the regulators’ tests but fail to satisfy completely the regulators’ underlying purpose. Performance standards not only are vulnerable to this problem, but they even seem to invite it. After all, the chief advantage cited in defense of these standards lies in their flexibility. Firms are permitted, if not entirely encouraged, to find ways to meet a designated outcome that will align better with their own self-interests. Indeed, sometimes the methods that firms use to meet mandated outcomes may not align as well with the public interests that the regulation is supposed to serve. As with teachers who teach to the test, the behavior of firms need not be blameworthy; after all, they are just seeking to do what the law requires—pass the test—while also achieving other lawful objectives, such as minimizing costs or satisfying consumers’ preferences.

Some might argue that what the diesel engine manufacturers did amounted to cheating. That would have clearly been the case had the manufacturers tried to pass their emissions tests by doctoring records or bribing engineers running the test so they would fudge the test results. This would be just as if teachers gave students the answers to tests, or if, after administering exams, teachers erased incorrect answers and filled them in with correct ones—behavior that has been shown to have occurred with high-stakes educational testing.²¹⁶ Nothing of this sort appears to have occurred when it came to passing the diesel engine emissions tests, and that kind of cheating is not at all what we mean by “teaching to the test.” We mean behavior that aims for passing a required test, and does legitimately pass it, but that nevertheless fails to fulfill the larger purpose behind that test.

213. As economist Kip Viscusi has noted, it would be “an oversimplification to claim that [performance standards] are always preferable.” W. KIP VISCUSI, RISK BY CHOICE: REGULATING HEALTH AND SAFETY IN THE WORKPLACE 129 (1983).

214. A similar list upon which this section of the article draws, but which also uses some other examples, can be found at Coglianese, *supra* note 31.

215. See, e.g., Jennifer L. Jennings & Jonathan Marc Bearak, “Teaching to the Test” in the NCLB Era: How Test Predictability Affects Our Understanding of Student Performance, 43 EDUC. RESEARCHER 381 (2014).

216. See Alan Blinder, Atlanta Educators Convicted in School Cheating Scandal, N.Y. TIMES (Apr. 1, 2015), <http://www.nytimes.com/2015/04/02/us/verdict-reached-in-atlanta-school-testing-trial.html>.

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With the EPA's regulation of heavy-duty diesel engine emissions, the agency established a test and required that engine manufacturers pass it. The manufacturers did just that. No one ever disputed that the manufacturers built engines that satisfied the EPA's tests. The government's claim in its lawsuit was instead that the manufacturers had "complied" in a way that skirted the overarching regulatory goal of reducing actual NOx emissions from trucks on the roads, that the onboard programming constituted a prohibited "defeat device."²¹⁷ Yet viewed from another perspective, what the diesel engine manufacturers did was simply satisfy the NOx test while still meeting other market demands facing the firms. Presumably, this is just what these same manufacturers are doing now, even after the consent decree. At least, that is what scholars and policy leaders have trumpeted as the theoretical advantage of performance standards.²¹⁸

For the manufacturers of heavy-duty diesel engines, the only difference today is that they are facing a new testing protocol. This testing protocol is surely not perfect, and neither government officials nor the public should be surprised if some manufacturers find a way to meet the new testing protocol in a way that delivers value to their private interests (and those of their customers) at some sacrifice to the broader public interest in environmental protection. This possibility of a kind of shirking or gaming behavior is inherent in the discretion afforded by performance standards. Recognizing this reality is not, of course, to say that performance standards should never be used. It is to say, though, that regulators must be ever vigilant when relying on performance standards, making sure they are monitoring not only *if* firms are complying but also *how*.

2. Performance standards can sometimes increase, rather than decrease, the cumbersomeness and complexity of environmental regulation. Regulators face constant criticism for imposing burdensome, complex rules that span volume after volume of the *Code of Federal Regulations*. The regulatory history of diesel engine regulation reveals that performance standards are not necessarily any panacea for seemingly out-of-control red tape. True, the EPA's performance-based limit gave heavy-duty diesel engine manufacturers the theoretical flexibility to choose how to reduce NOx emissions. But the agency has also added requirement after requirement to its testing regimen over the years, resulting in a highly prescriptive protocol for how manufacturers must conduct required emissions testing. That protocol now demands that teams of automotive engineers in each company work to understand and then apply these prescriptive tests. Furthermore, as the diesel emission

217. Some in the industry have claimed that they did meet the EPA's original goal, but that the EPA expanded its goals in the wake of numerous states facing nonattainment status for ozone after 1997. Since the original transient test mainly simulated urban driving patterns, the manufacturers might well be excused from thinking that the EPA's goal was to reduce NOx emissions in cities—where ozone is most pronounced. That the engine's operating parameters shifted under highway conditions—when presumably the trucks and buses would be out of urban areas—arguably did not conflict at all with the goal of protecting urban air quality. In this regard, it is interesting to note that starting in 1974, when the EPA first adopted motor vehicle emission regulations that prohibited defeat devices, the agency's own definition of such a device applied to one that "[r]educes the effectiveness of the emission control system under conditions which may reasonably be expected to be encountered in normal *urban* vehicle operation and use." Motor Vehicle Certification Procedures, 39 Fed. Reg. 7545, 7549 (Feb. 27, 1974). It was not until 1992 when the agency eliminated the word "urban" from its definition of a defeat device in its motor vehicle emissions regulations. *See Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines*, 57 Fed. Reg. 31,888, 31,894 (July 17, 1992) (defining defeat device as one that "reduces the effectiveness of the emission control system under conditions which may reasonably be expected to be encountered in normal vehicle operation and use").

218. *See supra* notes 14-20 and accompanying text.

experience indicates, even when manufacturers apparently think they have satisfied the government's tests to the letter, the EPA still has the ability to threaten to deny a certificate of conformity and file an enforcement action when it concludes that the letter or even perhaps the spirit of the law has been violated. This result seems far from the rose-colored regulatory simplicity that performance standards are supposed to deliver.

Not only did the EPA's standards' impose burdensome costs and complexities on industry, but also the EPA itself has hardly found them easy to design. The EPA took decades to refine its testing protocols, and presumably the tests will be refined still further for automobile emissions following the Volkswagen scandal. These kinds of refinements inevitably depend on agency experience observing how regulated firms comply with the law of the test. With diesel emissions regulation, the EPA arguably acted more swiftly than it otherwise would have been able to do. Its "regulation by litigation" approach in the 1990s, taken in response to the actions of the heavy-duty diesel engine manufacturers, presumably short-circuited some of the time it would have taken to impose its current standards and extensive testing protocols, as under the Clean Air Act it would have needed to provide manufacturers with longer lead times to develop new engines.²¹⁹

3. Despite their promise of flexibility, performance standards can still sometimes constrain industry choice and opportunities for innovation. Performance standards' theoretical advantage stems from the discretion they can provide to regulated firms. But in practice, the amount of discretion that a performance standard provides will vary significantly, depending on the meaningful options the standard allows regulated firms to consider. Sometimes, the only way to meet a performance standard is to adopt a single available means, making the real effects of performance standards indistinguishable from a means standard.

In general, the more closely a performance standard's obligation mirrors the policy objective the standard is supposed to serve, the more options a regulated firm can consider.²²⁰ For example, the ultimate outcome most environmental regulation seeks to serve is the protection of human health. Consider how many options a regulated diesel engine manufacturer would have if a hypothetical regulation sought to reduce the adverse health effects from exposure to ground level ozone by imposing an obligation on firms to keep from increasing by some specified amount the health risks from human exposure to ambient levels of ozone. Under such an imaginary regulation, the legal obligation would mirror the ultimate outcome, and manufacturers could consider any number of options that might advance the policy objective. For example, they could warn citizens to remain inside more on days with elevated levels of smog; they could seek to reduce emissions from their factories; or they could reduce emissions from their automobiles.

219. See Morris et al., *supra* note 57.

220. See Cary Coglianese & Lori Bennear, *Flexible Environmental Regulation*, in OXFORD HANDBOOK OF U.S. ENVIRONMENTAL POLICY 582 (Sheldon Kamieniecki & Michael E. Kraft eds., 2012).

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Furthermore, each of these major options would presumably contain additional subsidiary options. Take the option of targeting automobile emissions as an example. Emissions could be reduced by focusing either on emissions of volatile organic compounds that evaporate from the engine or on emissions of HC or NOx from the tailpipe. Within the option of tailpipe emissions control, there are additional options, as discussed in Section II.B, of adjusting the engine timing and fuel injection, installing after-treatment control devices, or making changes to the content of the fuel. Now, compare the full set of these options available in response to a hypothetical regulation that set the mandatory objective equal to the ultimate outcome with the options available to a manufacturer subject to a tailpipe performance-based emissions limit. Even though the tailpipe limit is performance-based, it clearly affords the manufacturer a narrower range of options than a performance standard that mirrors the ultimate outcome.

The point is that not all performance standards result in equal degrees of flexibility. Even among the same type of performance standards—say, a tailpipe emissions limit—there can be different degrees of flexibility. In fact, as the EPA’s experience with regulating heavy-duty diesel engine emissions testifies, a performance standard sometimes can be virtually indistinguishable from a technology standard when a firm has only one option available to it for meeting the performance mandate. After the EPA lowered its NOx limits by about 90% in 2007, engine manufacturers were effectively compelled to adopt after-treatment as their only feasible option for complying.

4. Basing a performance standard on a single goal can sometimes lead to undesired outcomes with respect to other goals. As explained in Section II.B, the chemistry of NOx and particulate formation in diesel engines presents government regulators and engine manufacturers with an important tradeoff when it comes to reducing the public health effects of diesel emissions: increasing combustion temperatures to decrease particulate emissions serves to increase NOx generation.

Tradeoffs like these are nothing if not a staple of policymaking, but their implications for performance standards have yet to be adequately recognized in the field of regulation. The paucity of attention to tradeoffs in the literature on performance standards is surprising, and particularly worrisome. If government adopts a standard for one goal but ignores other goals, the latter objectives may eventually suffer as industry adapts by securing the mandatory goal at the expense of other goals.

Fortunately, EPA officials recognized the bigger picture with respect to air pollutants from diesel engines. If the EPA had only set a stringent performance standard for NOx, industry’s response would likely have been to lower the temperature of combustion to reduce NOx generation, which would have increased the amount of unburned fuel released as particulates. For this reason, the EPA appropriately issued *both* particulates and NOx emissions standards and consciously considered the implications of each standard for the other. But this has not

always been the case with performance standards.²²¹ Scholars and policy advisors would do well to follow the EPA's example in this respect and pay attention to the need to identify and address tradeoffs when considering the use of performance standards.

5. *Performance standards eliminate neither conflict nor litigation over environmental policy.* Although some observers have suggested that performance-based regulation will reduce conflict and make environmental policy more collaborative,²²² the experience with the EPA's diesel emissions regulations does not provide much reason to expect any substantial reduction in adversarialism. Environmental groups, industry, and the EPA have repeatedly resorted to litigation over diesel emissions regulation.²²³ Environmental groups sued the EPA in 1984 seeking to compel the agency to issue NOx standards for diesels. Industry then sued the EPA in 1989 in an effort to delay the imposition of any new standards. Eventually, in 1998, the EPA sued the heavy-duty diesel engine manufacturers for failing to comply faithfully with the emissions control regime. Although the EPA's enforcement suit against the manufacturers was eventually settled, the agency still later found that one of the companies violated the settlement agreement and, in still another subsequent court action, a court upheld a \$72 million penalty against the recalcitrant firm.²²⁴ When the EPA engaged in rulemaking some years later to strengthen penalties for noncompliance with its revised diesel emissions standards, industry successfully sued the agency twice.²²⁵ Nearly twenty years after first taking an enforcement action against manufacturers of diesel truck engines, the EPA again pursued litigation over diesel engine emissions, this time against Volkswagen, Audi, and Porsche for similar alleged violations of the diesel emissions standards for light-duty vehicles.²²⁶ As should be clear, performance-based regulation neither harmonizes the different entities' stakes in the regulatory regime nor diminishes individuals' desire to advance their interests. It clearly does not eliminate conflict or litigation.

6. *Without effective testing and monitoring, performance standards are destined to fail.* All regulation depends on effective oversight. But since performance standards invite firms to make their own choices, effective testing and monitoring assumes a special significance for this form of regulation. Throughout the course of the EPA's history regulating diesel emissions, the agency appropriately recognized not only the need

221. Federal regulation of child-resistant packaging and automobile airbags provide two examples where tradeoffs were initially not reflected in applicable performance standards, with unfortunate consequences. In the child-resistant packaging case, regulators initially required only that packages be hard for children to open; only years later, after children had been poisoned due to packages left opened by adult caregivers, did the standard come also to include the competing goal of ensuring that packages could readily be opened by adults. Airbags initially were designed to protect individuals the size of an average adult male, leading to serious injuries and fatalities to children and smaller adults caused by the airbag deployment. Both of these examples are discussed in greater detail in Coglianese, *supra* note 17.

222. See FIORINO, *supra* note 16, at 21.

223. Of course, the mere fact that litigation occurs does not necessarily mean that beneficial forms of policy cooperation have broken down, especially since the litigation process over environmental regulations is much less combative than it can be in other contexts. See Cary Coglianese, *Litigating Within Relationships: Disputes and Disturbance in the Regulatory Process*, 30 LAW & SOC'Y REV. 735 (1996).

224. See United States v. Volvo Powertrain Corp., 854 F. Supp. 2d 60 (D.D.C. 2012).

225. See Mack Trucks, Inc. v. EPA, 682 F.3d 87 (D.C. Cir. 2012); Daimler Trucks N. Am. LLC v. EPA, 737 F.3d 95 (D.C. Cir. 2013).

226. See *United States Files Complaint Against Volkswagen, Audi, and Porsche for Alleged Clean Air Act Violations*, U.S. ENVTL.

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to revise emissions standards, but also to keep working to refine testing protocols. Initially, the EPA’s protocol called for just steady-state conditions, but over time, the testing regimen grew in complexity as the agency adopted different versions of transient tests (and has even incorporated some limited in-use testing). As agency officials gained experience with how industry responded to their law of the test, they learned that each preceding version of the agency’s testing protocol did not deliver enough confidence that regulatory objectives were being satisfactorily measured and ultimately achieved in practice.

Although it may seem rather obvious that performance standards depend inherently on the ability of regulators to measure and monitor firms’ performance,²²⁷ this case study of diesel engine emissions regulation shows all too well how difficult, if not nearly impossible, it can be for regulators to obtain accurate, relevant information on regulated firms’ performance. The EPA’s tragic failure to detect Volkswagen’s noncompliance twenty years after its experience with diesel truck engine manufacturers only drives this point home. Regulators must remain cognizant that performance on the test very well may not equate to performance in action, especially when regulators test performance in artificial settings, such as a laboratory.

7. Even when performance standards are implemented fully, and even when firms faithfully comply with them, policy success may still remain elusive. Performance standards are usually based on an output or outcome that is thought to be a precursor to, or perhaps a proxy for, the ultimate outcome of concern underlying the standards. For that reason, these standards can fail, even when firms fully comply with their letter and spirit, if the link between the outcome specified in a standard and the ultimate outcome of concern prove to be faulty, outdated, or incomplete. Other factors—natural or human—may well contribute to the underlying problem, and these factors may remain completely unchanged by the regulation. The regulation’s design may either fail to target the root cause of the problem or may fail to foreclose other causal pathways that lead to that problem.

The EPA’s experience with the control of heavy-duty diesel engine emissions helps illustrate this possibility. As noted in Section III.D, one consequence of the EPA’s more stringent emissions standards was to expand the market for older engines. When the new standards were announced, orders for current models increased. Customers, whose behavior the EPA did not regulate, were concerned not only about the increased cost of engines that would meet the new standards, but also about the engines’ performance and reliability. The market for used vehicles also expanded, and fleet owners maintained older vehicles longer. At least in the short term, the EPA’s new standards and testing protocol may very well have increased NOx emissions somewhat, rather than have decreased them.²²⁸

227. See Coglianese & Lazer, *supra* note 32, at 704.

228. See Morris et al., *supra* note 57, at 502 (“If enough engines were added through pre-buys or older engines were continued past their useful lives in the absence of the consent decrees, the net effect on air pollution might be an increase rather than a decrease for a period of time.”).

Even if the EPA’s more stringent standard ultimately decreases levels of NOx over time, it is still possible that the standard may fail to achieve the reductions in ground-level ozone that the EPA intends it to reach. NOx is a precursor to ozone, which is formed through a photochemical reaction, but it is well-known that ozone “does not necessarily respond in a proportional manner to reductions in the precursor emissions.”²²⁹ The relationship between NOx and ozone is not a linear one; it depends on other factors such as the level of volatile organic compounds in the atmosphere. Some observers have speculated that reducing NOx without making comparable reductions in volatile organic compounds can actually blunt the rate of reduction in ozone, perhaps “even making ozone worse in some cities.”²³⁰ The mere possibility of such an outcome, however speculative, suggests that performance standards, like any regulation, can fail to work as anticipated, suffering flaws in design even when achieving full compliance.

B. Comparing to Means Standards

Even though we have just presented a litany of limitations to performance standards, we do not intend to claim that performance standards are distinctively problematic or should never be used. On the contrary, some of the same challenges that performance standards present, like those the EPA encountered in implementing its diesel emissions rules, can also arise with means standards. Means standards, for example, can and do generate conflict and litigation; they can and do produce red tape; and obviously they can and do inhibit flexibility and innovation. Means standards can also run afoul of tradeoffs, side effects, and unintended consequences. If the EPA had mandated a certain type of combustion control technology to reduce just NOx emissions, for example, it would have still run the risk of increasing particulates.

But it is also possible that means standards can reduce or even avoid some of the problems encountered with performance standards. Had the EPA eschewed a performance-based approach and instead imposed technology requirements, such as by requiring a specific kind of after-treatment, it might have made faster, more certain progress, without the setbacks and delays that resulted from industry’s efforts to take advantage of the flexibility afforded by a law-of-the-test approach. Furthermore, it seems reasonable to surmise that when agencies mandate that firms adopt a technology based on experience demonstrating that it works, the process of discovering what technology to require and validating that it does truly work (especially if that validation involves in-use testing) will likely reveal potential problems that might otherwise not have occurred to the regulator. Of course, if any mandated technology itself is tested or validated only in a limited or narrow manner,

229. BARBARA J. FINLAYSON-PITTS & JAMES N. PITTS, *CHEMISTRY OF THE UPPER AND LOWER ATMOSPHERE: THEORY, EXPERIMENTS, AND APPLICATIONS* 871 (2000).

230. Joel Schwartz, *EPA Rule Is Making Ozone Smog Worse: ‘Weekend Effect’ Makes Costly Measures Backfire*, ENV’T & CLIMATE NEWS 12 (May 2006).

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the risk of overlooking tradeoffs or other problems could be the same under either a performance-based or means-based approach. Yet it is certainly hard to imagine the EPA ever mandating engine controllers that met the desired NOx levels only during the period of laboratory testing but that subsequently adjusted automatically to maximize fuel economy and performance instead of NOx control. Means standards inherently reduce the possibility of dynamic adaptation by industry, virtually eliminating problems like teaching to the test.

Conclusion

Performance standards are clearly not a cure-all. Their success ultimately depends on a regulator's ability to specify performance and then to measure and monitor it accurately, conditions that will not always be met. Obviously, as with any kind of regulation, when performance standards are poorly designed or used under unsuitable conditions, they can prove ineffectual or even counterproductive. Moreover, the flexibility built into performance standards can create its own special kinds of worries, like the teaching-to-the-test phenomenon.

In the end, the choice about whether and how to use performance standards will depend on the underlying circumstances, as well as how performance standards stack up against alternative regulatory approaches in those circumstances. Although performance standards are sometimes assumed to be “generally superior” to other approaches, the reality is more complex than previously acknowledged. For any given problem, regulators must determine whether the limitations for performance standards are more severe than the limitations for other types of standards.

Our explication of problems associated with the EPA’s diesel emissions performance standards, and our acknowledgement of possible relative virtues of means standards, is not intended to imply that government should never issue performance standards. To the contrary, there remain sound reasons for preferring performance standards in certain instances. The targets of regulation—in particular, large industrial firms—usually have better information than government about their operations and about how to correct the complex public problems created by their market activity.²³¹ Consequently, the flexibility that performance standards afford can sometimes make sense. These standards can be socially beneficial if they afford businesses the opportunity to innovate and find less costly means of achieving desired social objectives. The persistent challenge for government, though, is to make sure that any innovation does not compromise the public welfare goals underlying the standards. When diesel engine manufacturers developed electronic injection control techniques that would meet the EPA’s tests while also better meeting consumer demand, that innovation occurred principally to satisfy consumer preferences, not to advance the regulator’s larger public goal of

231. See Cary Coglianese, *Business Interests and Information in Environmental Rulemaking*, in BUSINESS AND ENVIRONMENTAL POLICY 185 (Michael Kraft & Sheldon Kamieniecki eds., 2007).

pollution reduction. In a market economy, such behavior is to be expected and perhaps even applauded. However, when performance standards are imposed on private actors to achieve legitimate social goals, the very predictability of private adaptive behavior, combined with performance standards' flexibility, provides a special reason for ongoing governmental vigilance.

In short, when the law amounts to a test, that test must be both well proctored and subject to ongoing review and modification in the face of changing conditions, including adaptive industry behavior. Success is not preordained merely because of performance standards' widely extolled theoretical advantages. Rather, success depends on regulatory officials' analytic capacity to map the often complex and dynamic causal pathways that lead to a regulatory problem. It also depends on the regulator's ongoing monitoring of firms' adaptive behavior and how that behavior might affect different pathways leading to the underlying problem. In its demand for accurate information and sound analysis, then, performance-based regulation is neither generally superior nor generally inferior to any other form of regulation.²³² Successfully designing and implementing performance-based regulation can be just as challenging as it is for any kind of regulation. Under some circumstances, it might be more challenging still.

232. See Cary Coglianese et al., *supra* note 25.