

Shaping the Terms of Competition: Environmental Regulation and Corporate Strategies to Reduce Diesel Vehicle Emissions

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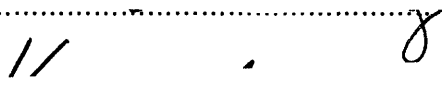
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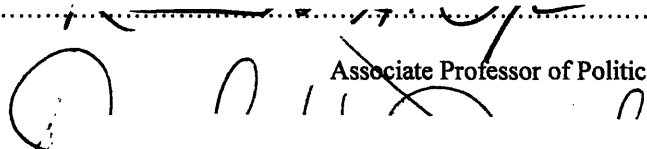
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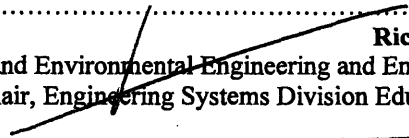
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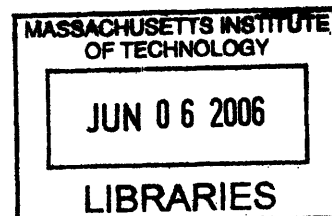
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ABSTRACT

Environmental regulations are typically portrayed as an outside force stimulating development of environmental technologies in regulated industries. In reality, firms influence regulation by communicating their technological progress, which helps form a basis for future standards. Because of differences in each firm's technological capability and environmental performance, regulations affect the competitive position of firms. Firms with advanced technologies stand to gain competitive benefit from more stringent environmental regulations, and may therefore choose to introduce a more costly but cleaner technology ahead of regulation. Such a competitive regulatory strategy has the potential to bring competitive benefits to the lead firm(s) and environmental benefits to the public.

This research explains the conditions under which competitive regulatory strategies are pursued in the diesel vehicle and fuel industry. Growing public concern about the health effects of diesel exhaust has led countries to implement several cycles of increasingly stringent emission and fuel regulations over the past two decades. Taking a comparative case study approach, this work studies multiple regulatory cycles for light-duty vehicles, heavy-duty engines, and diesel fuel sulfur in the European Union, Japan, and the United States. For each region's regulatory cycles, cases of corporate behavior, including early adoption, first-mover behavior, and noncompliance, are identified and analyzed for their context, motivation, influence on regulatory policy, and public and private effects. Source material consists of documentary sources, descriptive statistics, and semi-structured interviews with experts. This methodology generates multiple cases for comparison across countries, cycles, sectors, and firms.

While early- and first-mover behavior was observed in the regulatory cycles, firms do not aggressively pursue competitive regulatory strategies. They are guided by other motivations, such as fiscal incentives, diesel market share protection, and technology development/testing. A weak business case, risk aversion, industry pressure, and lack of supporting infrastructure pose strong disincentives. The final recommendations address issues pertinent to regulators, firms, and environmental groups: fiscal incentives as an effective means to encourage rapid technology adoption; environmental NGOs as a vehicle for communicating technological progress; use of technology demonstrations by lead firms to show regulatory readiness; and combination of short-term and long-term targets with mechanisms to encourage technology-based competition.

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CHAPTER 1 - Introduction

1.1 Research motivation

The environmental regulatory process is often characterized as a struggle between the regulators and the regulated. Regulatory stringency may offer greater health and environmental protection while imposing higher costs on industry. As a result, industry will often press for more lenient standards or extended compliance time. The international regulatory community and industry have searched for a more cooperative standard-setting process, where both sides can agree on mutually acceptable targets. Negotiations and cooperative agreements have become popular, but resulting standards have often been criticized as not challenging enough. Interaction between regulators and firms is plagued by information asymmetry, because firms have more information about their ability to meet regulations than regulators do. In an effort to reach a collective decision, such standards may also cater to the “lowest common denominator” in industry, which gives firms little incentive to innovate or invest in cleaner technologies and practices. Some business experts use anecdotal evidence to claim that companies should voluntarily pursue environmental performance to cut costs and improve efficiency. Some firms in a niche market do find customers willing to pay more for higher environmental quality, but widespread adoption is often necessary to gain meaningful environmental benefits. In many cases, regulations are very costly for the entire industry across the board, so without regulatory pressure or customer demand, firms lack incentive to invest in higher environmental performance.

This research focuses on an alternative way of looking at the interaction between regulators and regulated firms. It conceives of the regulatory process as inherently competitive, where one company or a group of companies might support greater regulatory stringency because it provides them with a competitive advantage or a larger market. This advantage may arise from superior technology, superior management, or lower compliance costs relative to competitors. The idea of firms supporting proposed regulations or meeting upcoming regulations ahead of the deadline is appealing from the standpoint of both public and private benefits. Cleaner technologies can be adopted earlier or spread more rapidly, resulting in greater

health and environmental benefits. Regulators have an easier time passing regulations if they have one or more industry supporters rather than solid opposition from the entire industry. Instead of designing regulations for “the least common denominator,” regulators may be more inclined to base their standard-setting on the leading-edge technology. The regulations may give the first movers an advantage over their competitors, or offer fiscal incentives to promote early compliance.

Companies’ support of regulation does not necessarily come in the form of political lobbying. Because technology assessments preface all regulatory decision-making, regulators have a keen interest in obtaining information about technological progress. Most research on environmental regulations still treat regulations as exogenously handed down from regulators, with companies as passive “regulation-takers.” In reality, firms provide substantial input into the regulatory process. Through their communication of technology development, they can influence regulatory stringency and shape the terms of competition.

This type of corporate strategy, called “competitive regulatory strategy,” can offer financial and reputation benefits to the lead firm. It is type of nonmarket strategy that deals with forces outside a company’s markets, such as governments, interest groups, and the public. An individual firm or subset of firms may advance environmental standards beyond the rest of the industry’s capabilities, or even beyond regulators’ expectations. This may lead to regulatory competition, where firms compete based on their ability to anticipate and/or influence regulations through technology development.

1.2 Problem statement and research questions

Extensive research has been done on corporate environmental strategies and industrial competition. However, few researchers have addressed how environmental regulations shape the competitive positioning of firms, and in turn, how firms shape regulations. This research seeks to enhance understanding of these forces, and their impact on regulatory competition. Before turning to the research questions, it is necessary to give further explanation of the corporate responses to regulation and competitive regulatory strategies, which are central to this research.

Companies respond to regulation in a variety of ways. Compliant firms are those whose products or processes meet regulations by the established deadline. This is true of the vast majority of firms, especially those whose products must be certified as compliant before they can be sold. Non-compliant firms, those that do not meet regulations, are usually only discovered through enforcement action taken by regulators. Then there are firms that go beyond existing requirements. A first mover is a firm that has a technology or product with environmental performance that surpasses any known existing or future regulations. This means that the firm has communicated its technology performance to the public or regulators in advance of final regulatory decisions. An early-mover is a firm that meets known future regulations ahead of the established deadline.

First-mover action goes beyond the early-mover behavior of meeting previously established regulations ahead of the deadline. Deriving benefit from first-mover behavior may get around the free-rider problem of firms waiting for one another to take the risk of being first with a new technology. If not for the expectation of private benefits, no firm would become a first mover and technologies would only develop after regulations were already established. If a first-mover firm's regulatory input does result in stricter regulations, its strategy places pressure on other firms to meet the stricter standards, thereby improving industry-wide environmental performance.

Early- or first-mover behavior may be indicative of a competitive regulatory strategy. A firm employing a competitive regulatory strategy is one that strategically initiates, accelerates, or supports more stringent regulation, motivated wholly or partly by the desire to gain competitive advantage from the regulation. "Strategy" implies that the firm's actions are deliberate, intentional, and pre-meditated. A firm may gain a competitive advantage once a new regulation is implemented, but if it did not anticipate and prepare for the opportunity ahead of the regulation, its outcome would not be considered an application of a competitive regulatory strategy. It is assumed that the firm does have an actual advantage, whether it is in technology, management, or cost-efficiency. The strategy may be weak or strong. An example of a weak strategy would be a firm which makes decisions (i.e. R&D investment, product introduction) to put itself in a position of competitive advantage in advance, but does not intentionally leverage its decisions during the regulatory process. A strong strategy would be a firm that is fully aware of its potential advantage and actively presses regulators to adopt more stringent regulations.

The research began with the main research questions:

Under what conditions do competitive regulatory strategies succeed in providing private benefits to first-mover firms and environmental benefits to the public? What motivates firms to engage in first-mover behavior?

Once the research was initiated, the questions were broadened to cover early-mover behavior as well, since acting ahead of known regulation may also provide competitive benefits. To answer the main questions, the research must also address the following:

- Why would a company introduce less polluting technology if not required by environmental regulations?
- What are the private and public benefits and costs?
- What factors foster or discourage early or first-mover behavior?

These questions will be answered in the context of regulations and corporate strategies for reducing diesel vehicle emissions. This environmental issue was selected because of its serious health and environmental impacts, increasingly stringent regulations, globally competitive industry, interdependent technology systems (i.e. vehicles, engines, fuels, aftertreatment equipment), and the variety of regulatory and market conditions observed in three key producer regions (the European Union, Japan, and the United States). The recent popularity of diesel vehicles for their fuel efficiency and low CO₂ emissions, combined with mounting concerns about diesel exhaust's health effects, makes this a timely opportunity to investigate competitive regulatory strategies in this setting. The diesel vehicle industry is competitive but concentrated, making it relatively small compared to other industries. This makes studying individual firm behavior and industry competition more manageable. The multiple regulatory cycles in each region – the periodic introduction of new, more stringent standards for light-duty vehicles, heavy-duty engines, and fuels – provides rich source material for comparative case studies.

1.3 Research contribution

This research uses a focused industry study to improve understanding of competitive regulatory strategies. In past studies, economists have explored regulation's effect on industrial competitiveness with large-scale quantitative studies, typically using aggregated data at the sector level. Game theorists have developed two-firm models to predict competitive behavior under different starting conditions. Meanwhile, management and social scientists have tried to get a better understanding of firm-level activity with anecdotal corporate case studies. This research seeks to combine the systematic analysis, theory generation, and case study methodology featured in these fields, and recast them as part of the study of socio-technical systems within the emerging engineering systems field. By embracing regulations as endogenous to technology development, this research demonstrates how global regulatory systems are commingled with the technological systems behind diesel vehicle emission reduction (i.e. vehicle system, fuel infrastructure). Studying technological systems in a regulated industry necessitates attention to regulatory systems.

The research design consists of studying multiple regulatory cycles and then analyzing behavior and outcomes at the organizational level. This two-tiered approach allows for a more comprehensive understanding of regulatory and corporate decision-making than studying a single set of regulations or one company. Reviewing entire regulatory cycles attempts to avoid the selection bias of only selecting prominent cases of early-mover or first-mover behavior. The methodology provides enough representative cases to observe meaningful patterns and to make comparisons between cycles, countries, and companies. Although this study is limited to a single innovation field – diesel vehicle emission reduction, it does span several major industries. Robust findings across these industries and countries make a case for the generalizability of this research to other industries.

1.4 Significant findings

The thesis research finds that regulatory and market conditions influence the opportunities for competitive advantage from regulations, but other factors, which are determined by regulatory action, public/NGO (nongovernmental organization) activity, and corporate attitudes, affect whether any early or first-mover behavior will actually occur. Applications of competitive regulatory strategies are seldom explicitly “strategic.” Regulated firms generally do not introduce technologies ahead of regulation and then push for more stringent regulation to disadvantage their rivals. Technology introductions are driven by other motivations, such as mitigating anti-diesel criticism. Nevertheless, the technologies do often generate regulatory demand in domestic and foreign markets, which can enhance the lead firms’ competitive position.

Industry associations and environmental groups serve as channels for communication flow about technology development, but their motivations are quite different. Industry associations are important to forging cooperative decisions, especially in Japan, and communicating overall technology progress to regulators. At the same time, in the interest of minimizing compliance costs and presenting a united front, they can also place pressure on lead firms to maintain the same position as the rest of the industry. Individual firms occasionally take a different position, but may face alienation and criticism from their industry association. Environmental groups or other public interest NGOs filter through industry claims and technological advances, and communicate their perspective on the information to regulators, media, and the general public. They can inspire consumer demand for cleaner products or convince regulators of the merits and feasibility of greater regulatory stringency. Companies could arguably do the same, but they risk negative publicity if they do not deliver on their technology promises. Lead firms are more likely to present their products’ performance publicly and then allow perceptive NGOs and regulators draw their own conclusions.

In several cases, first-mover countries that used regulations to encourage cleaner technologies did help the competitive position of their domestic firms. Those firms were well-prepared to market their products in other regions that later adopted similar standards. This supports the Porter hypothesis of lead countries improving national competitiveness with more

stringent regulations (Porter and van der Linde 1995). The cases further refine existing theory by articulating the differential effects of regulations on firms. However, not all situations behaved as strategic trade theory would predict. Regulators in first-mover countries do not always act strategically in favor of their domestic firms, especially if domestic firms lag foreign rivals in technological progress. Their interest in environmental protection outweighs concerns about national competitiveness.

1.5 Overview of chapters

This thesis consists of 11 chapters, which are arranged in three main sections. Chapters 1 to 4 are introductory background material about the research topic and methodology. Chapters 5 to 9 cover the regulatory cycles in emission and fuel standards. Chapters 10 and 11 discuss the findings and future work.

Chapter 2, a literature review, begins with a discussion of the evolution of business attitudes towards environmental regulation, from costly constraint to business opportunity to competitive tool. It explains the theoretical and empirical foundations for this research, which consists of business research on corporate environmental strategies, and political science and economics research on “raising rivals’ cost,” strategic trade policy, and information asymmetry between regulators and the regulated. Recent and ongoing empirical studies on the effect of environmental regulations on industry competition highlight the major conceptual and methodological issues important to this research project.

Chapter 3 explains this study’s two-tiered approach to the comparative case study method. The first tier, the review of regulatory cycles, establishes the boundaries for the second tier, an in-depth study of corporate and regulatory behavior at the organizational level. Cases of first-mover and early-mover behavior are identified through a systematic analysis of the regulatory cycles. The lack of any observed proactive behavior, or even non-compliance, is also investigated. A diverse set of documentary sources and quantitative data, complemented by personal interviews, form the basis of the case studies.

Chapter 4 provides an overview of the various industries and regulations involved in reducing diesel vehicle emissions. It explains the reasoning behind choosing the diesel vehicle

industry for a focused study and provides descriptive statistics about the industry. This chapter is particularly helpful to readers unfamiliar with recent diesel trends and differences in the industry and regulatory processes in the EU, Japan, and the US.

Chapters 5 through 9 cover the regulatory cycles, with two chapters on light-duty diesel vehicle standards, two on heavy-duty diesel engine standards, and one on diesel fuel sulfur standards. In explaining the regulatory cycles leading to the recently implemented 2004-05 standards, Chapter 5 explains how tax policy and more lenient NO_x emission standards in Europe have allowed for over 50% diesel penetration, whereas more challenging regulations for diesels in Japan and the US have made it difficult for diesels to compete with gasoline vehicles. Chapter 6 looks forward at the 2008-09 timeframe. Since Europe has been the main market for diesel cars, the chapter focuses on how technologies have shaped the Euro 5 standards, and discusses two first-mover companies with varying levels of success.

Chapter 7 differs from the other four regulatory cycle chapters in that it highlights incidents of non-compliance in the heavy-duty engine industry. In several cases, companies that delayed or circumvented emission control requirements actually improved their competitiveness. As a result, regulators revised testing and enforcement procedures to better monitor compliance. The divergent technology pathways taken by heavy-duty engine manufacturers for post-2005 regulations are discussed in Chapter 8. Increased global competition and the dependence on complementary technologies like fuels and additives have expanded government involvement. In the interest of boosting national competitiveness, governments have helped to establish supporting infrastructure and shape regulations at home and abroad to favor their domestic companies' technologies. Chapter 9 shows how first-mover countries have effectively used fiscal incentives to encourage the early adoption of ultra-low sulfur diesel fuel. In several European countries, tax differentiation has led to rapid diffusion of the fuel. Japan has used subsidies and negotiated agreements to accelerate adoption. Meanwhile, the US has faced slower and limited adoption because of the lack of fiscal incentives and a larger fuel distribution infrastructure.

Chapter 10 is the centerpiece of the research because it draws on the lessons learned from studying the regulatory cycles. It analyzes the regulatory and market contexts that shape whether firms engage in regulatory competition. The cases demonstrate that government-sponsored fiscal incentives are the major driver for early adoption, while market preservation and technology

development can motivate first-mover behavior. Even if companies appear to have a clear technological advantage over their competitors, they may be reluctant to act on it because of insufficient customer demand, risk aversion, industry pressure, or lack of supporting infrastructure. In the rare cases that a company did step forward ahead of regulation, the success of their technology introduction depended on their ability to shape regulations to their advantage. Generally this influence was not in the form of direct lobbying, but through technology demonstration or limited sales of the new product.

The recommendations in Chapter 10 are aimed toward regulators, NGOs, and companies, especially those who support encouraging the adoption of more effective emission reduction technology and rewarding technology leaders for higher environmental quality. First, governments should use tax incentives as a tool for spreading the adoption of leading-edge, commercially available technology. While cleaner technologies would be rewarded with lower taxes, it assumes that more polluting technologies would be penalized with higher taxes. Second, public interest groups, like environmental NGOs, should take advantage of their credibility with the public to communicate relevant scientific findings and technological progress. This can help create customer and regulatory demand for more advanced technologies, and encourage technology leaders to step forward with new products. Third, lead companies should use technology demonstrations that engage regulators and/or NGOs to express their technology readiness and to make a case for stronger regulations or incentives. As a way to institutionalize regulatory competition, the fourth recommendation proposes a combination of long-term and interim targets that offers increased regulatory certainty as well as accelerated emission benefits.

The final chapter, Chapter 11, briefly compares the results of this research with recent and ongoing empirical work on other industries. While several determinants of a company's ability to capture competitive advantage from regulation are comparable, this research offers new perspectives on the role of industry trade associations, regulatory compliance details, and technology demonstration as an alternative to political lobbying.

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CHAPTER 2 – Literature Review

2.1 Introduction

There has been growing recognition by the business community that environmental performance can act as a source of competitive advantage. In the past decade, articles in the business literature have offered case studies of companies whose environmental improvements have also benefited the bottom line (Hoffman 2000; Madu 1996; Porter 1991; Porter and van der Linde 1995; Preston 2001; Reinhardt 1999). Much of the focus has been on voluntary initiatives and resource efficiency measures that save on regulatory compliance costs. Pressure from customers, shareholders, and communities has also been shown to influence corporate environmental policy, but the strongest sources of pressure come from government regulations and customer demand (Henriques and Sadorsky 1996). According to an OECD review of eight surveys of firm managers conducted in various countries in the 1990s, traditional environmental regulations (i.e. direct regulations and market-based instruments) were ranked as the strongest driver of environmental performance (OECD 2001).

Technology-forcing environmental regulations in particular are intentionally designed to push industry beyond its current capabilities, such that companies innovate and develop new technologies to comply with upcoming regulations. The industry-government relationship can usually be described in one of two ways. Industry is most commonly portrayed as fiercely opposed to stricter environmental regulations because of the added cost and resource burdens they impose. On the other hand, regulators may rely on industry self-regulation, negotiated agreements, or voluntary compliance. These more cooperative approaches often require industry-wide consensus, so the resulting standards reflect the lowest common denominator in terms of environmental performance. The adversarial and cooperative relationship styles do work well in some situations, leading to technological innovation and improved environmental outcomes. This research explores alternatives to these adversarial and cooperative views of regulation – instances where the anticipation of future regulation would encourage competition among firms. By recognizing how technology development shapes regulatory stringency, some

firms may pursue technology and product introductions that put them ahead of regulatory requirements. Early-movers introduce new technologies that comply with future regulations ahead of schedule, whereas first movers introduce new technologies that surpass any known existing or proposed regulations.

This chapter examines how environmental regulation, technology development, and industry competition have been addressed in research literature. Much of the writing on this topic comes from scholarship in business, economics, and international relations. The first few sections of this chapter trace how business attitudes towards environmental policies have changed since the advent of pollution control regulations. It then follows with a description of competitive regulatory strategies, and more broadly, the means through which technology development and industry input influence regulatory decision-making.

2.2 Changing attitudes about environmental regulation

Prior to the 1960s, pollution control in industrialized countries was largely a local matter. However, with the rise in environmental awareness in the late 1960s and 1970s, countries began adopting national environmental protection laws. In the U.S., President Richard Nixon established the Environmental Protection Agency (EPA) in 1970 by executive order. Two years later, Japan established its Environment Agency under the Prime Minister's office. In 1972, Stockholm, Sweden, hosted the first global United Nations Conference on the Human Environment (Schreurs 2002). In 1973, the then nine-member European Community set out its environmental policy objectives in its "Programme of environmental action of the European Communities" (Hildebrand 2002). By 1974, Germany had also created a Federal Environmental Agency in its Interior Ministry (Schreurs 2002). With the rise in environmental regulatory activity, different perspectives on the effects of environment regulation on economic growth have emerged.

2.2.1 Environmental regulation as an economic constraint

The new pollution control measures of the 1970s restricted the pollution and waste generated by industry. At the same time, critics of the new policies warned that the costs of environmental compliance would limit innovation and economic growth. Encumbered with significant compliance costs, domestic firms would have difficulty competing in international markets (Jaffe, Peterson et al. 1995). In the U.S., the economic slowdown and productivity decline in the 1970s led some economists to speculate that environmental regulations were partially responsible (Gray 1987; Gray and Shadbegian 1995; Haveman and Christiansen 1981; Jaffe, Peterson et al. 1995; Levinson 1992; Norsworthy, Harper et al. 1979). Empirical studies of the manufacturing sector attribute 8 to 16% of the total factor productivity growth rate decline to environmental regulations. This is significant, but not large enough to blame regulation for the slowdown (Jaffe, Peterson et al. 1995). Jaffe et al. (1995) conduct an extensive review of empirical studies on the relationship between environmental regulation and economic performance in the US. They do not find enough evidence to support the argument that environmental regulation has a large adverse effect on national competitiveness.

In addition to the pollution control capital and operating costs expended by firms, there is also concern about the opportunity costs of regulation. By spending money and resources on pollution abatement and environmental R&D, companies may miss other investment opportunities (Stewart 1993). However, studies tend to focus on the cost and resource burden on regulated industries, even though regulations can create lucrative opportunities for new markets and industries.

2.2.2 Environmental regulation as a creator of markets

When faced with regulations, firms often turn to third parties – suppliers, contractors, and consultants – to help them comply with the standards. As a result, environmental regulations around the world have created a \$550 billion global market for environmental technologies and services (EC 2002). Because the environmental technology industry thrives on demand for better performance and lower costs, progressively more stringent regulations are a prerequisite

for further investment and innovation. If environmental standards stagnate at one level for too long, there is little incentive to change. Pollution prevention efforts have moved firms closer to the “efficient frontier,” but they have mostly involved picking “the low-hanging fruit.” In order to prevent stagnation and to keep the efficient frontier moving forward, industry needs to have continuous leadership by firms who keep innovating (Ashford 2000). Regulations may also be formulated or timed in such a way that firms do not have sufficient opportunity to adapt through true organizational learning. Instead, firms adopt “quick-fix” solutions, opting for costly “end-of-pipe” solutions instead of more creative but potentially less costly upstream changes. The more creative changes that lead to sustained innovation require major organizational change (Wallace 1995).

2.2.3 Environmental regulation as a business opportunity for regulated industries

In the debate over regulations’ effects on competitiveness, empirical researchers have focused largely on national competitiveness, and the aggregate effects of regulation on innovation and productivity. Most empirical studies employ time-series data at the aggregate industry level to measure the effect of regulation on R&D patenting, R&D expenditures, and productivity (Gray 1987; Jaffe and Palmer 1997; Jorgenson and Wilcoxon 1990). Firm-specific information is generally not available, and if it is, it usually lends itself to a qualitative case study rather than a quantitative study. One 1986 empirical study did try to measure the effect of environmental regulation on within-industry competitiveness. Farber and Martin (1986) found a positive relationship between pollution control effort and increased market concentration, after controlling for firm size, profitability, and pollution potential. However, this study was conducted for 1977 only, and did not account for the stringency of the regulation. Because census data was only available for manufacturing subsectors, and not individual firms, their study could not determine the differential effects of environmental regulation on individual firms.

Beginning in the 1990s, companies began to view environmental protection as commingled with economic competitiveness rather than as a “good” within itself (Hoffman 2000). Business thinkers challenged the empirical research that claimed regulations hurt competitiveness. Michael Porter (1991) presented his “revisionist” view, arguing that

environmental regulations could improve national competitiveness. The adoption of stringent environmental standards in one country would spur innovation among its domestic firms. With their technological advantage, they would be well prepared to dominate more markets once other countries adopt the higher standards. The Porter hypothesis assumes that the lead country has a large economic influence on the world economy; it must properly anticipate that other countries will eventually ratchet up their standards. Because of incomplete information and organizational problems, firms are not always profit-maximizing. Regulations offer an impetus for firms to discover more resource-efficient and cost-saving opportunities. In addition to lowering compliance costs, such “innovation offsets” could potentially give firms advantages over less regulated foreign firms and increase profits. In the end, environmental regulations produce “win-win” outcomes for the regulated firm and the environment (Porter 1991; Porter and van der Linde 1995).

The “win-win” theories of Porter and his supporters were heavily criticized by neoclassical economists, who argued that any cost-saving innovation offsets are eclipsed by the opportunity cost of R&D investment and management effort: “While it seems likely that environmental regulation will stimulate the innovation and diffusion of technologies that facilitate compliance, creation and adoption of new technology will typically require real resources, and have significant opportunity costs” (Jaffe, Newell et al. 2003). Empiricists criticized Porter and van der Linde’s (1995) case studies as “largely anecdotal” and more often the exception rather than the rule (Jaffe, Newell et al. 2003; Jaffe and Palmer 1997). Despite the disagreements between the “win-win” and the neoclassical economists, both sides agree that market incentive-based, rather than conventional command-and-control regulations, are more likely to promote innovation.

Even the economists that disagreed with the Porter hypothesis conceded that some regulated firms will benefit competitively from regulations at the expense of other firms. Regulations may provide advantages to early-mover firms by forcing them to introduce products with growing demand (Jaffe, Peterson et al. 1995). A 1996 study by Klassen and McLaughlin did try to quantitatively measure the impact of strong environmental management on financial performance. Using financial event methodology and archived news articles, they measured the impact of positive and negative environmental events on stock prices. They found significant positive returns from strong environmental management, measured in terms of environmental

awards, and significant negative returns from weak environmental management, measured in terms of environmental crises. Despite their findings, the study authors do note the discrepancy in past empirical studies, with some finding a positive correlation between social responsibility and financial performance, and others finding negative or no correlation (Klassen and McLaughlin 1996).

2.3 Corporate environmental strategies

While some empirical researchers like Klassen and McLaughlin have tried to measure the relationship between environmental and financial performance, researchers from the management sciences have documented corporate environmental strategies in case studies (Maxwell, Rothenberg et al. 1997). They find evidence of companies that have successfully turned environmental protection into opportunities for business growth (Hart 1997). Some of the most common strategies fall into the following broad categories of cost reduction, product differentiation, risk management, redefining business models, and competitive regulatory strategies. The following explains each category:

1. Cost reduction: Regulation increases the cost of pollution so companies have an incentive to reduce resource consumption in the first place. Energy conservation and waste minimization are common examples. Life-cycle assessment – quantifying a product or process’ environmental impacts and resource consumption at every stage of its life – has been used to identify “hot spots” for resource and fee savings (Nielsen and Wenzel 2002).
2. Product differentiation: Companies draw attention to the environmentally benign features of their products through labeling, advertising, or publicity. Depending on consumer demand for these “green” attributes, the products may command a substantial price premium. Patagonia, the California-based clothing maker, has retained a loyal customer base drawn to its commitment to environmental causes and therefore willing to pay more for its products (Reinhardt 1999).
3. Risk management: Though not required explicitly by any regulation, companies may adopt measures to reduce their exposure to liability risk. Some strategies include implementing

formal environmental management systems and substituting less toxic compounds in place of more harmful ones. Although not required by law, chemical companies routinely conduct short-term toxicity tests on new chemicals as a way of preventively dealing with unregulated hazards (Ashford 2000). The upfront testing costs are considerably less than the potential liability and reputational costs incurred if a chemical were found to be carcinogenic after widespread use.

4. Redefining business models: Efforts to move from product- to service-based business models increase consideration of life-cycle environmental impacts in business decisions. Placing the burden of maintenance, replacement, and disposal on the producer is often more efficient and convenient for the individual consumer, and enables the producer to extract higher fees in payment for the services. Xerox redefined its copier business model with its Asset Recycle Management program. By leasing copiers to its customers, it provided the latest product upgrades to customers and used its take-back system to remanufacture used parts into “new” machines. This program saved the company \$300 to \$400 million in 1995 alone and reduced the environmental impact of product end-of-life waste disposal (Hart 1997).
5. Competitive regulatory strategy: Companies may proactively seek or support regulation based on their ability to meet regulations at lower costs or with better technology than their competitors.

The literature on industrial ecology, green marketing, corporate social responsibility, and environmental management usually focuses on the first four categories. These strategies often involve saving costs in the present or the future, or assume that customers are willing to pay more for environmental features. Companies may claim that their decisions are based on a sense of altruistic concern for the environment and the local community. Competitive regulatory strategy, the fifth category and focus of this research, acknowledges companies’ strong profit motive and does not assume higher customer valuation for environmentally safer products.

Competitive regulatory strategies are a type of nonmarket strategy. Nonmarket strategy differs from market strategy in that the former deals with forces outside a company’s markets, such as governments, interest groups, activists, and the public. The nonmarket environmental consists of “social, political, and legal arrangements that structure interactions among companies and their public” (Baron 1995b). Lobbying legislators for favorable policies, pursuing

endorsement from consumer groups, or influencing regulation are examples of nonmarket strategies which can enhance a company's competitive position. According to David Baron (1995b), nonmarket forces "can foreclose entry into new markets, limit price increases, and raise the costs of competing. They can also unlock markets, reduce regulation, handicap rivals, and generate competitive advantage."

2.4 Competitive regulatory strategies

A proactive approach towards environmental innovation, well ahead of established regulations, can offer companies more time and flexibility to introduce a new technology and capture competitive advantage. By advancing technology beyond regulatory requirements, a company can offer input to regulators in the form of technical documents or R&D results, which may result in stricter standards and a higher return on their original investment (Vaitilingam 1993). The expectation is that companies will be able to strategically position environmentally responsible products to capture market share more aggressively (Preston 2001). In some cases, stricter environmental regulations may increase costs for the company, but it stands to benefit if the higher standards cost its competitors disproportionately more. Early- and first-mover companies place themselves in a better position to meet tighter standards in the future, and they even may establish an industry standard with their superior technology, effectively creating a barrier to entry (Klassen and McLaughlin 1996). Companies already compete aggressively on product attributes such as cost, quality, and technological performance. Since environmental protection is a public good that is undervalued by individual consumers, regulations are a means of giving it a value, by rewarding technology leaders and penalizing technology laggards.

The concept of regulated companies using regulations for competitive advantage has been discussed in the context of "raising rivals' cost," a concept popularized by economic theorists Steven Salop and David Scheffman. They propose a "raising rivals' cost" strategy as a better alternative to predatory pricing. A first-mover firm can raise its rival costs in a variety of ways – vertical integration, exclusive dealing arrangements, more efficient advertising, scale economies, and product regulation. Salop and Scheffman specifically point out that mandatory product standards or other government regulation can raise rivals' compliance costs, which will

lower their output or force them to exit the industry (Salop and Scheffman 1983). Then the first mover could raise prices and/or gain market share. Even if other companies tried to copy the first mover's technology, they would face costs and time delay not experienced by the first mover, whose investments would be considered sunk costs (Barrett 1991).

Other research has expanded on using *environmental* regulations specifically as a way of raising rivals' cost. It may be in the interest of an entire industry to impose stringent environmental regulations, which can be used as a barrier to entry. Incumbent firms may develop compliant technologies in advance of regulation, and then support regulation that uses the developed technology or imposes tougher requirements on new entrants (Dean and Brown 1995; Maloney and McCormick 1982). Dean and Brown (1995) find that in the late 1970s, US environmental regulations had a net negative effect on entry in manufacturing industries. Even if an industry uniformly opposes regulation because of compliance costs, some firms will ultimately profit because firms do not face uniform costs. Once firms are aware of regulations' capacity to redistribute wealth within the industry, the firms with lower costs or other advantages may work together with environmentalists to support regulation (Maloney and McCormick 1982). The motivation to raise rivals' cost can encourage innovation, even in the absence of a prior regulatory commitment for more stringent regulations (Puller 2005). Innes and Bial (2002) try to establish the types of regulatory policies that would encourage first-mover behavior while limiting their market power gains. They consider the incentives to raise rivals' cost to be too strong, and therefore propose a policy that would stagger regulatory implementation. Successful first-mover innovators would receive lower economic rents and laggards would not be punished as harshly (Innes and Bial 2002).

In explaining concepts, most economists use a theoretical duopoly model, with a lower-cost firm/technology winner and a higher-cost/technology laggard (Gersbach 2002; Hackett 1995; Innes and Bial 2002; Puller 2005; Salop, Scheffman et al. 1984; Salop and Scheffman 1983). There is the built-in assumption that the lower-cost firm can successfully convince the regulator of the merits of its technology and that regulators can successfully implement the more stringent standards. Economics and business literature have relied on game theoretic models or analytical frameworks to explain competitive regulatory strategies, often citing a few empirical cases that illustrate their points. Frequently cited examples include Unocal's influence on California's reformulated gasoline specifications and Dupont's support of the Montreal

Protocol's CFC (chlorofluorocarbons) limits. Oil company Unocal gave substantial input into the California Air Resources Board's gasoline standard-setting process. Unbeknownst to CARB and other oil companies, Unocal was holding onto patents that overlapped with the standards. Once companies had been adhering to the standards for over a year, Unocal revealed that they had infringed on its patent. It was able to collect 5.75 cents per gallon in royalties from the other companies (Puller 2005). Dupont, a leading manufacturer of CFCs, faced low-cost competition from new entrants as well as an international agreement, the Montreal Protocol, to ban the ozone-depleting CFCs. Having invested in the development of expensive CFC substitutes, Dupont actually supported the Montreal Protocol and agreed to phase out CFCs a year early (Murphy 2002; Puller 2005).

Much of the literature focuses on success stories, while there may be many failed attempts to influence regulations or even recognize opportunities for competitive advantage. The simple two-firm models, while helpful in showing how the "raising rivals' cost" strategy might work, do not include the other factors that shape regulatory policy. Influence from other stakeholders, like customers, environmental groups, legislators, courts, and firms in complementary industries, can outweigh any influence that the low-cost firm/technology winner might have (Gerard and Lave 2003). One situation that may inhibit innovation and competition in oligopolies are research joint ventures. Companies may collude to reduce innovation, thereby slowing technological progress and delaying further regulation. This does not mean that there is no place for joint research; as long as independent research continues, there will be innovation in clean technologies (Hackett 1995; Puller 2005).

Although raising rivals' cost is a compelling reason to support more regulation, there are other reasons why a firm may pursue greater stringency. Large multinational firms have an interest in promoting stricter and harmonized product standards. Harmonization allows them to produce higher volumes of a single model for several markets. Incidentally, their greater financial and technical capacity also gives them an advantage over smaller domestic firms, which face higher costs and greater difficulty in meeting the standards (Foster 2001; Vogel 1995). Established firms also stand to take a larger share of regulatory benefits. According to a report on the US auto industry by the US Office of Technology Policy, "dominant, established firms in the concentrated markets are well positioned to shape regulatory environments to their advantage...They have greater resources to achieve their regulatory goals through lobbying,

funding, research, public relations, and differential absorption of regulatory costs” (Fine, Clair et al. 1996).

Companies in capital-intensive industries may pull ahead of current standards in anticipation of future standards since it may be more cost-effective to make one major investment than small incremental investments (Arora and Gangopadhyay 1995). Others may enhance environmental performance to preempt more stringent and costly regulations (Lyon and Maxwell 1999; Maxwell, Lyon et al. 2000). Over-complying with environmental standards may also improve a company’s reputation and work as a marketing tool to attract customers (Arora and Gangopadhyay 1995; Lyon and Maxwell 1999; Madu 1996). Green marketing by companies will contribute to environmental awareness, and further spur customer demand for their products and services (Preston 2001).

2.5 Technology development shapes regulatory policy

Competitive regulatory strategies are based on the premise that regulations are endogenous, i.e. companies can influence regulations. This contrasts from the normative view taken by most research in the 1970s and 1980s, which treat environmental regulations as exogenously determined by government and companies as mere “regulation-takers” (Gray 1987). The government identifies an environmental problem not internalized by the market, sets a standard or requirement to mitigate the problem, and expects industry to comply by a given deadline. Industry responses are analyzed as reactions to one-way directives. However, in reality, companies actively influence regulations, not only through political lobbying, but by their technological progress and firm strategy. In the past two decades, as economists have increasingly recognized the value in treating regulations as endogenous to innovation, more business literature has addressed influencing regulations as part of corporate strategy. Most of this work consists of theoretical arguments, with illustrative cases (Barrett 1992; Hackett 1995; Maloney and McCormick 1982; Maxwell, Lyon et al. 2000; Rugman and Verbeke 1998).

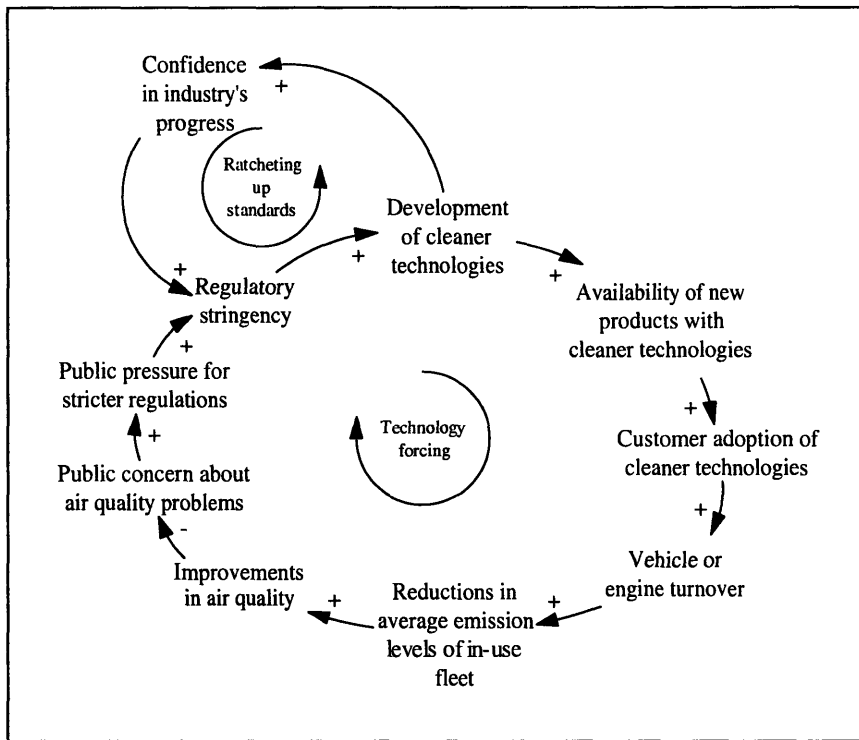
For example, Barrett (1992) claims that companies have moved beyond the standard theory of environmental regulation, where companies passively respond to regulation. He uses game theory to explain how a firm can strategically influence environmental regulation and

increase profitability. Based on a duopoly model of one firm knowing about a new cleaner technology that the other firm does not, Barrett finds that the rational option would be to install the technology and then tell the government. This assumes that the government would adopt policies that would reward the first-mover firm for its strategic behavior (Barrett 1992). Rugman and Verbeke (2000) build on Michael Porter's basic "five forces" model, arguing that government regulation is a "sixth force" directly affecting a firm's strategy.¹ At the same time, they acknowledge that the shift in firm strategy could alter the effects of government intervention. Viewing regulations as endogenously determined is consistent with political economy literature, which views regulations as a product of bargaining between industry, government, and other stakeholders (Cadot and Sinclair-Desgagne 1995).

As an illustration, Figure 2-1 shows the simplified technology-forcing causal loop for vehicle emission regulations; the ratcheting up of standards follows from the development of cleaner technologies. Treating regulations as exogenous to corporate strategy misses the reinforcing loop of "ratcheting up standards," which works alongside the public demand for emission reduction.

¹ Michael Porter's basic "five forces" model is a popular tool for strategic management. For details, see Michael Porter, *Competitive Strategy*, New York: Macmillan, Inc., 1980. The five forces which influence firm strategy are competitors, buyers, suppliers, potential entrants, and substitutes. Previously, government intervention was treated as acting indirectly through some or all of the five forces, but Rugman and Verbeke claim it should be recognized as a direct force in its own right.

Figure 2-1: Simplified Model of Technology-Forcing Regulation for Vehicles



Note: Generated using Vensim software by Ventana Systems.

2.5.1 Information asymmetry between regulators and the regulated

Environmental regulatory agencies rely heavily on assessments of companies' technological progress to set standards. Companies' technical expertise – distinct from political lobbying – gives them significant leverage over policy decisions. Regulators would like to get as much information as possible about technologies, costs, and health impacts to inform their decision. At the same time, the regulated industries have an incentive to downplay their technological progress to avoid high expectations and more stringent regulation. Regulators' ability to observe regulatory performance over time and adapt regulations based on new information may invite strategic behavior by firms (Baron 1995a). In general, companies offer very cautious and conservative assessments, but in the worst case, they may intentionally conceal or delay progress on environmental R&D (Gersbach 2002; Nannerup 1998; Yao 1988). If no

company can meet the proposed standards, regulators will weaken or postpone standards. This constitutes a serious information asymmetry problem. Even if regulators can approximate the probability distribution of possible marginal costs, the regulated company has better information about its technology's performance and marginal cost (Baron 1995a; Barrett 1991). Depending on a regulation's effect on its business, companies will be prone to some predictable bias during these information exchanges. Third-party technology vendors, such as emission control manufacturers, are eager to supply information about the ability of their technology to meet regulatory standards. They are more likely to be optimistic about technological progress because regulations will give them a market for their products. Meanwhile, companies responsible for purchasing and integrating the new technologies into their products will express less confidence about their capabilities.

In response to regulatory proposals, industry associations collect information from member companies about expected compliance costs and technological progress. They usually present aggregated data to regulators to protect the individual company's competitive position. Even though reporting is anonymous, companies may cautiously understate their progress and overstate costs because of the uncertainty surrounding new technologies. Situations may arise where a company has a particularly unique technology approach that it is unwilling to disclose, even anonymously, to its trade association. Confidential one-on-one meetings between regulators and company representatives may encourage the company to be more open and frank about its progress than it would be in a public forum or to its trade association (Ng 2003). After meeting with a variety of companies, regulators are able to compare private claims against each other, which is something that companies and trade associations usually cannot do.

Some regulatory agencies are equipped with their own research and testing capabilities, which provides a check on industry data. The US EPA has its National Vehicle and Fuel Emissions Laboratory in Ann Arbor, Michigan. Its ability to test emission control technology, vehicles, engines, and fuels allows for independent evaluation of manufacturers' claims (NVFEL 2000). Research conducted by universities and by independent or government-affiliated labs can also be a source of information. While these organizations can be helpful in indicating long-term R&D trajectories, regulators are often interested in technology that already exists or is near commercialization. For the near-term planning, the regulated industries are often the best source for information because they are actively doing research on commercializable technologies.

While a regulator may have incomplete information about a company's R&D activity and compliance costs before a regulation is established, it can observe the actual technologies and costs of the firm *ex post*. It can then use this updated information to anticipate the hidden information for future rounds of regulatory standard-setting (Baron 1995a). The perceived trustworthiness of an information source can also be verified over time if regulations are updated in multiple periods and open to reassessment. This type of adaptive regulatory approach holds much promise for improving the responsiveness and efficiency of environmental regulations (Foster 1999).

2.5.2 Strategic use of information channels

Companies directly communicate their position on regulatory policy through established regulatory channels, such as written comments in response to proposed regulations or in private meetings with regulators. This process of initiating regulatory action and providing information is known as signaling (Arora and Gangopadhyay 1995; Baron 1995a; Porter and van der Linde 1995). Technological claims made in the process of regulators' information gathering often run concurrently with political action and lobbying. A regulatory change resulting in adverse distributive consequences for one party and rent-seeking opportunities for another is likely to provoke political action (Baron 1995a). While it is expected that technology vendors will support market-creating regulation, it is not as common for a regulated firm to support more costly regulation. However, superior technology, superior management, lower compliance costs, or favorable publicity may prompt a firm to support a regulation despite opposition from the rest of the industry. The private, confidential meetings are especially important in such circumstances because a firm may feel uncomfortable formally differing from their industry or industry association's official position.

2.5.3 Avoiding rent-seeking

Although some environmental regulations simultaneously confer competitive advantage onto some firms and offer substantial public benefits, others may be a result of rent-seeking with

little or no benefit to the environment or human health. Regulatory capture occurs when parties successfully lobby for a self-serving regulation that has questionable public benefits. This can come in the form of subsidies, limits on competition, control of substitute and complementary goods, or price fixing (Stigler 1971). Stigler (1971) focuses on parties that are able to obtain regulation in exchange for votes or resources (e.g. campaign contributions), but there is another reason why regulatory capture may occur. Environmental regulatory agencies have an inherent proclivity toward optimistic technology claims because of their interest in achieving environmental progress. The openness of technology vendors, and perhaps to a lesser extent, the first-mover firms, boosts a regulator's confidence in the attainability of stricter regulations. Given the large uncertainties in technology development and environmental consequences, regulators are undoubtedly attracted to strong evidence that supports its case for a regulation. It is important for a regulator to distinguish from genuine claims of effectiveness and public benefit, and veiled attempts at rent-seeking.

A company seeking to increase demand for its product or technology through regulation would need to credibly convince government regulators that any environmental standards proposed actually do improve public welfare (Aplin and Hegarty 1980; Reinhardt 1999; Winter and May 2002). Because of concerns about unemployment and market concentration, the company may also have to show the regulation does not have significant distributional effects.

Companies may align themselves with well-known environmental NGOs or citizen groups to convince the public, and perhaps more importantly, regulators, that their strategy is genuinely environmentally beneficial. NGOs prefer cooperation over protest and opposition, while companies seek to strengthen their reputation and credibility, so this "strategic bridging" can help achieve environmental, social, and business goals (Stafford, Polonsky et al. 2000). However, there is still risk in these alliances. Ultimately, NGOs are answerable to their members and supporters, not to their corporate partners. Working together with a company on a specific issue also does not necessarily constitute broad endorsement of the company's business practices. NGOs may again adopt adversarial strategies to boost their profile and maintain credibility with their base of supporters (Stafford, Polonsky et al. 2000).

Competitive regulatory strategies often give advantages to large, well-established firms at the expense of small firms. Firms may seek environmental regulations as a barrier to entry or to protect their existing market share from competing technologies or new entrants. Because of the

high compliance costs, only the large firms tend to have the resources to invest in the necessary R&D and capital expenses (Baron 1995a; Porter 1980). To protect against market concentration and job loss, regulators frequently make special allowances for smaller-sized businesses or particular geographic regions. Competitive regulatory strategies presume that the environmental leaders reap benefits while environmental laggards perform poorly. Increased market power for the lead firms may have environmental benefits but lead to higher prices for consumers (Barrett 1992). The government's desire to spread compliance costs evenly across the industry may be a hindrance to first-mover companies seeking to gain an edge over their competitors through regulation.

2.6 First-mover countries

Previous sections have discussed firms' strategically using environmental regulations to their competitive advantage. National governments can also use environmental regulations to improve the competitive position of their domestic firms in international markets. This section discusses the emergence of environmental regulations as part of strategic trade policy.

International trade economists began analyzing strategic trade policy in the early 1980s. According to Brander (1995), strategic trade policy is "trade policy that conditions or alters a strategic relationship between [oligopolistic] firms." The well-known Brander-Spencer model considers duopolists in two countries exporting homogeneous products to a common third-party market. A government can give competitive advantage to its domestic firm by subsidizing its domestic firm's production through export or R&D subsidies (Brander and Spencer 1985). The cost of subsidization is perceived to be outweighed by the economic benefits accrued by helping a domestic firm or industry gain a foothold in the international market. In a modification of the Brander-Spencer "third-market" model, Krugman (1986) uses an international duopoly model consisting of one domestic firm and one foreign firm selling a product to the domestic market. The government may offer subsidies and tax incentives to its domestic firm to increase customer demand and encourage large scale production. By accelerating the pace at which the firm moves down the learning curve and lowers marginal costs, the government gives its domestic firm a head start before opening the market to foreign competition (Krugman 1986). Another variant

model is the “reciprocal markets” model, where two countries have firms competing in each other’s markets (Brander 1995). Both countries’ may have governments actively trying to secure competitive advantage for their own firms. In his book Trade Warriors, Marc Busch describes several cases in high technology industries, where countries engaged in costly trade wars in order to promote their national champions (Busch 1999)

Strategic trade literature eventually began to view environmental regulations as a form of government intervention. Barrett (1994) found that depending on market structure and competition, it may be optimal for governments to adopt “strong” environmental standards, where the marginal cost of abatement exceeds the marginal environmental damage. The standards can improve the competitiveness of domestic firms, in the same vein as R&D or export subsidies (Barrett 1994). If a first-mover country adopts more stringent and costly product regulations, it can protect its domestic industry from international competition by restricting the sale of noncompliant imports. As the global market for the “greener” product grows, the nation(s) with the more stringent standards will enjoy scale economies and competitive advantage from having the early incentives to develop the technologies. This contrasts with previous thinking that more stringent environmental regulations, which raise compliance costs, would disadvantage firms in international product competition. However, if the other nations do not adopt the more stringent standards, the first-mover country’s industry may find itself at a cost disadvantage in foreign countries (Stewart 1993). Instead, the domestic firms may lobby their government to delay new standards, arguing that the compliance costs place them at a disadvantage relative to their foreign competitors.

Regulatory heterogeneity is unsustainable in the long-term because export-oriented multinational firms have an interest in supporting harmonized regulations. Through organized lobbying efforts, multinational companies may be able to persuade their home governments to push for uniform standards in other countries. Countries have an interest in harmonizing product regulations because it reduces transaction costs and other trade barriers, while encouraging specialization, scale economies and competition. Process standards are not as easily harmonized as product standards. A country with more stringent product standards can limit import competition, so foreign governments have an incentive to harmonize with the import country’s higher standard. Restricting imports from nations with weaker process standards is usually

illegal under international trade law; moreover, there are no restrictions on businesses moving operations to countries with weaker process standards (Stewart 1993).

In addition to competitiveness considerations, first-mover states or nations may be more receptive to greater stringency because of their high levels of investment and/or their preference for more environmentally protective measures. Multinational firms may find allies among environmental and consumer organizations, who are eager to see more protective environmental and health measures adopted internationally (Vogel 1995). A first-mover country also helps to foster its domestic environmental industry, which can ultimately market its products and services to other national markets. The presence of an environmental industry can propel a country to national leadership on environmental regulations because the industry's profits improve social welfare² (Feess and Muehlheusser 2002).

In Trading Up, David Vogel (1995) describes cases where strict environmental, health, and safety (EHS) regulations represent a source of competitive advantage for domestic companies because it is easier for them to meet the requirements than their foreign competitors. Some argue that stricter EHS regulations constitute thinly veiled non-tariff trade barriers rather than genuine efforts to protect health and environment. Several conflicts over regulatory diversity have reached the World Trade Organization's dispute settlement board, which has heavily relied on evaluating parties' use of scientific evidence and risk assessment. The large degree of scientific uncertainty in many EHS cases offers opportunities for a precautionary approach but also substantial leeway for rent-seeking by domestic firms (Oye and Bernauer 2004). Domestic firms may be able to defend the scientific basis of more protective standards even if the underlying motivation is a protectionist one.

Information asymmetry complicates a national government's attempts to use environmental standards as a strategic instrument. Compared to a scenario with full information, incomplete information reduces the distortionary effects caused by a government's strategic behavior (Nannerup 1998). Although environmental standards may be inferior to direct subsidies or tariffs as a means to improve competitiveness, they are more likely to avoid allegations of illegal free trade restrictions.

² If the environmental industry's profits are not taken into account and the government is maximizing social welfare, the emission tax will always be below marginal damage. However, when the environmental industry is included in the model, the tax may even exceed marginal damage, especially if there are gains from learning by a nascent industry.

Regulators do not necessarily automatically side with their domestic industries. They may use the superior performance of foreign firms as leverage for domestic firms to improve technology. Gerard and Lave (2003) give the example of the US EPA playing foreign automakers against domestic automakers. Successful innovation by foreign automakers could undermine claims by domestic automakers that standards are unattainable. While regulators' decisions might credibly endanger domestic firms' market share, the resulting standards would not be so stringent that domestic firms would go out of business (Gerard and Lave 2003). Governments may use regulatory uncertainty – the threat of future regulation – as a way to induce domestic firms to develop new technology that would be compatible with international standards. If industry's progress is unsatisfactory, regulators would take punitive action by implementing stiffer standards (Cadot and Sinclair-Desgagne 1995).

Fiscal incentives, often used by national governments to spur technology adoption, may also serve to encourage domestic firms to keep up with foreign competition. For example, in the mid-1980s, the German auto industry was vehemently opposed to the introduction of the catalytic converter, even though it was already used in the US and Japan. However, when the German government proposed fiscal incentives for catalytic converters, BMW and Mercedes became less opposed to the technology (Wurzel 2002).

2.7 Recent and ongoing empirical studies

Very recently, researchers have begun to perform in-depth case studies and focused industry studies on competitive regulatory strategies, going beyond theoretical models and anecdotal evidence. These studies take on diverse regulatory instruments, corporate responses, national settings, and outcomes, providing a basis for comparisons. In particular, they give emphasis to industry structure and country-specific factors, which had been lacking in previous research. Recent findings by fellow collaborators and other researchers with similar interests help provide guidance to this research project.

2.7.1 AGS CARE project

A multi-university research project, entitled “Competitive Advantage, Regulation, and the Environment” (CARE) has been occupied with assessing the effects of market and regulatory conditions on company-level environmental strategies, the effects of the strategies on company and plant-level innovation, environmental performance, and competitiveness, and the feedback effects of the company-level environmental strategies on market and regulatory conditions (Adler, Bernauer et al. 2004). The project, sponsored by the Alliance for Global Sustainability, includes research teams at the Massachusetts Institute of Technology, Swiss Federal Institute of Technology (ETH) at Zurich, and Cambridge University. The project covers multiple industry sectors – chemicals, pharmaceuticals, motor vehicles, refining and fuel, food processing and distribution, pulp and paper, and consumer electronics. While large-scale quantitative data collection, surveys, and interviews are still underway, early work on qualitative case studies on companies and industries have already offered some interesting insights (Adler, Bernauer et al. 2004).

CARE collaborators have found that the actual outcomes of regulatory competition in environmental and consumer policy do not match the two dominant schools of thought. One school expects competition in laxity, or a “race to the bottom,” would occur in liberalized markets because governments do not want to lose their firms to locations with less regulatory burden. The opposing perspective views regulation as driven by regulatory capture, such that well-organized industry groups are more likely to have influence on policy than large and diffuse public groups. Instead, empirical evidence shows that competition in laxity rarely occurs; in fact, regulatory stringency in most industrialized countries has increased (Bernauer and Caduff 2004). The rent-seeking theory must be qualified because firms are seeking ways to limit competition through more stringent environmental and consumer risk regulations. Interests of producer groups and NGOs may align when individual or groups of firms within a specific industry lobby for more stringent regulation: “Public concerns and NGO campaigns can act as facilitators for rent-seeking by producers” (Bernauer and Caduff 2004).

Case studies on growth hormones, electronic waste, and food safety by Bernauer and Caduff show that firm size and sectoral characteristics play a key role in firms’ ability to influence regulations to gain competitive advantage. In the electronic waste and food safety

cases, they find that the larger firms are more likely to have a competitive advantage because they have greater financial and technological capacity to meet stringent regulations. Implementation costs are also lower for larger firms, especially those in more concentrated industries.

Environmental regulations may lead to disagreements between domestic and foreign firms. First-mover countries may face opposition from other countries who view additional regulations as a trade barrier. In the electronic waste case, US producers were opposed to the EU's new Extended Producer Responsibility law, claiming that it would disadvantage American firms and create a significant barrier to entry into European markets. However, some EU firms, like Sweden's Electrolux, have already invested in environmentally friendlier designs and would benefit from more stringent electronic waste laws. Similarly, in the growth hormone case, US and Canadian meat producers accused the EU of using their ban on imported hormone-treated meat to protect domestic producers. They even took the dispute to the WTO's dispute settlement board, contending that the hormone ban was not based on sufficient scientific evidence (Bernauer and Caduff 2004).

Over-compliance or voluntarily adopting standards may be an effort to preempt more stringent government standards. In the food safety case, there is some indication that companies push for higher standards to "buy political legitimacy and public good-will," and to give themselves more regulatory certainty and uniformity (Bernauer and Caduff 2004). In all three cases, the erosion of public trust in companies and government has raised the prominence and credibility of NGOs as the public's main source of information.

Another team of researchers studied the relationship between regulation and environmental innovation in the pulp and paper industry in Sweden, Finland, Germany, and the US (Foster, Hilden et al. 2006). Its most significant environmental impacts are during product manufacturing rather than during use, so process regulations, not product regulations, are the focus. Like in the electronic waste and food safety industries, large pulp and paper firms do have a competitive advantage because of their ability to fund R&D and finance investments. However, the new, efficient plants are not as flexible to adapt to different regulatory standards or to produce different types of products. More stringent regulations alone are not enough to induce process innovations, especially as the pulp and paper industry in Germany and US falls further

behind the global “technology frontier.” They argue that public incentives for R&D are necessary.

The different regulatory environments and corresponding industry responses in each country show the importance of country-specific preferences on innovation. The pulp and paper industry has more political clout in Sweden and Finland than in the Germany and the US. As a result, the Nordic governments are more likely to listen to the industry’s concerns, such as requests for more public spending on related R&D. The Swedish and Finnish companies’ investment in environmentally-friendly and efficient technologies is motivated by the greater environmental awareness of their home constituents (Foster, Hilden et al. 2006).

2.7.2 Other empirical work

In a discussion paper for the Centre for European Economic Research (ZEV), researchers Beise and Rennings use case studies in high-efficiency diesel cars and wind energy to address whether environmental regulation can create lead markets. They conceive of a lead country adopting the innovation first, other countries following suit, and then the lead market becoming a major exporter. Their work ties into the earlier discussion of first-mover countries. They categorize advantages of a lead market into price, demand, transfer, export, and strict regulation advantages. In their analysis of fuel-efficient cars, they try to explain the discrepancy between the success of high-efficiency diesel cars in Europe and their failure to become popular in the US. They claim that the high fuel prices in Europe are not sufficient to explain why diesel cars did not take off in the US. Even US fuel economy standards failed to stem fuel consumption. Customer demand played a more important role. Small, fuel-efficient cars were compatible with the European and Japanese market, but not the US one, where customers desired more luxurious, larger, and more powerful vehicles like trucks and SUVs. While Beise and Rennings make valid comments about the importance of customer demand, they also do not address the role of environmental regulation in shaping market choices, which may be another valid explanation for a lower rate of diesel penetration in the US. They also do not offer an explanation for the lower diesel car adoption in Japan, despite the country’s high fuel prices and preference for smaller cars.

The second case on wind energy more readily exhibits the advantages of strict regulation, which the authors dub the “Porter effect.” A lead market’s strict regulation diffuses internationally and in turn, offers first-mover advantages in the export market to its domestic firms. Denmark has been the lead market for wind energy. Its producers started industrial production of wind turbines five years ahead of the competition, thanks to the Danish government’s Renewable Energy Feed Tariffs (REFITs). REFITs are cross-subsidies that require fossil fuel energy producers to pay renewable energy producers (Beise and Rennings 2005). While their categorization of lead market advantages is a useful one, Beise and Rennings select illustrative case studies that fit certain categories, which might indicate selection bias.

A recent report by the World Resources Institute focused specifically on the automotive industry. In an investor-oriented report “Changing Drivers,” the authors explore how emerging carbon constraints to mitigate climate change could affect the competitiveness of the 10 leading automotive manufacturers. It sees regulation as both an opportunity and constraint, which varies depending on the position of the individual firm. Even if carbon constraints impose costs across the whole industry, some manufacturers will face smaller cost increases than their competitors, partly because of their existing product portfolio. Those specializing in smaller, less carbon-intensive cars will have an inherent advantage over those with a sales mix consisting largely of trucks and SUVs. The authors see opportunities for companies to innovate and capture competitive advantage by being early-movers with lower-carbon technologies. It takes a balanced approach of looking at all the major companies in the industry and several promising technologies - advanced gasoline, diesels, hybrids, and fuel cells (Austin, Rosinski et al. 2003).

The recent studies discussed in this section help to highlight major conceptual and methodological issues that will be important to this research project. They underscore some possible factors that may contribute to companies’ ability to gain competitive advantage from regulatory stringency. Those include size advantages, country-specific preferences, proactive governments, aligned NGO interests, and regulatory incentives for innovation. The research that considers an entire industry, like the Foster et al. pulp and paper study and the “Changing Drivers” report, are particularly useful because they offer an industry baseline with which to compare the leading companies. Multiple-country comparisons also help to separate the idiosyncrasies of a specific industry from the effects of different regulatory systems. However, the qualitative case study-based nature of the studies leads to some doubt about the

generalizability and selection bias of the findings. While the cases enhance understanding of how competitive regulatory strategies might work, further research will require a more systematic analysis of the selected industry.

2.8 Summary

This chapter explored how economics and business literature has addressed the idea that some companies might gain competitive advantage from the environmental performance of their products. First-mover companies and first-mover countries may have an incentive to support more stringent environmental standards to limit competition and increase market share. Many of the concepts are discussed in the context of game-theoretic models, aggregated panel data studies, or company-specific case studies. There is a need to study the impact of technological progress on the stringency of environmental regulations within a focused industry-wide case study (Jaffe and Palmer 1997). Such a study would canvas a wide variety of corporate and regulatory responses – not just the success stories about first-mover firms or countries that are disproportionately represented in case studies.

In order to address some of the criticisms about the anecdotal nature of most case studies, this study takes a broader methodological approach than most case study-based research. Like many previous empirical studies, it selects a specific environmental innovation field – in this case, diesel vehicle emission reduction. Instead of developing a simplifying framework or model, the research investigates the complexities of actual organizational behavior to better understand the interaction between technology development and environmental regulations. It studies multiple companies and countries, with a focus on seeking explanations for different behavior and outcomes. There have been several rounds of increasingly stringent emission and fuel standards in the past two decades, so this study takes advantage of the series of recurring regulatory processes. Studying the response of different industries to the same innovation field of diesel emission reduction allows for inter-industry comparison, without the complication of introducing a different issue. The use of multiple countries, companies, time periods, and industries results in a larger dataset and allows for meaningful controlled comparisons.

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CHAPTER 3 – Research Methods

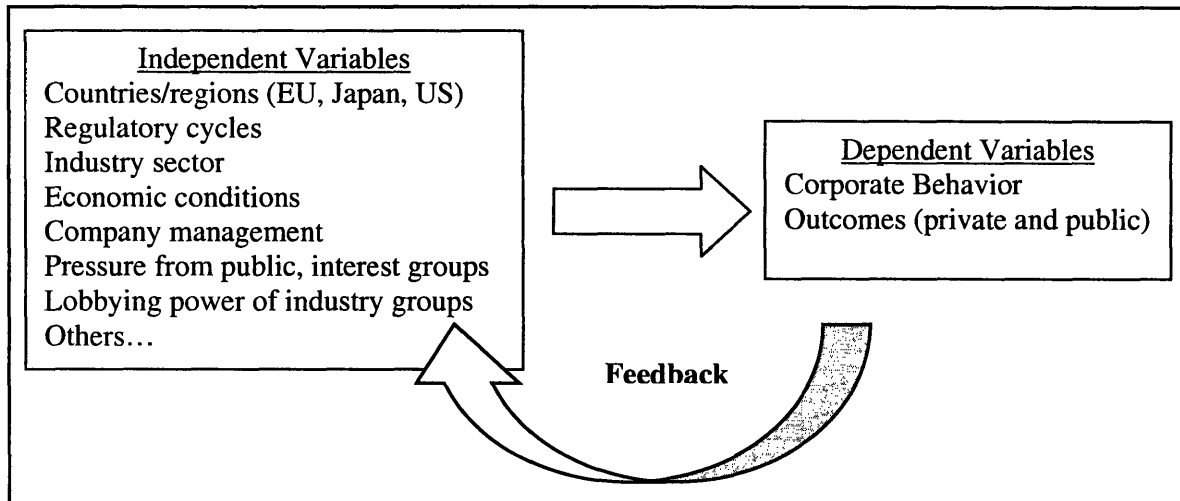
3.1 Introduction

The research seeks to understand the conditions under which companies in the diesel vehicle industry introduce cleaner technology ahead of regulations, and the factors that influence the public and private outcomes. The goal is to understand the causal mechanisms behind corporate behavior, while acknowledging that causation is not unidirectional. Environmental policy and technology development influence each other, and the many other factors potentially motivating corporate decisions (e.g. public pressure, customer demand, economic incentives) may also be shaped by corporate actions.

Because theory is still forming in this area, theory will be generated by collecting and analyzing research data. This research approach is commonly known as “grounded theory,” where the purpose is theory generation, not theory verification. Instead of starting with hypotheses expected from existing theory, this approach lends itself to generating plausible explanations or propositions from real-life observations that may be tested through further study. Theory-building research should ideally start with a “clean theoretical slate,” where there is no thinking about relationships between variables and theories at the outset of the research. However, formulating the research problem and identifying potentially important variables are essential first steps (Eisenhardt 1989).

In creating a basis for investigating the research questions, the main causal relationship can be articulated as a set of independent variables affecting the dependent variables – corporate behavior and outcomes – which in turn also affect the independent variables.

Figure 3-1: Main Causal Relationship



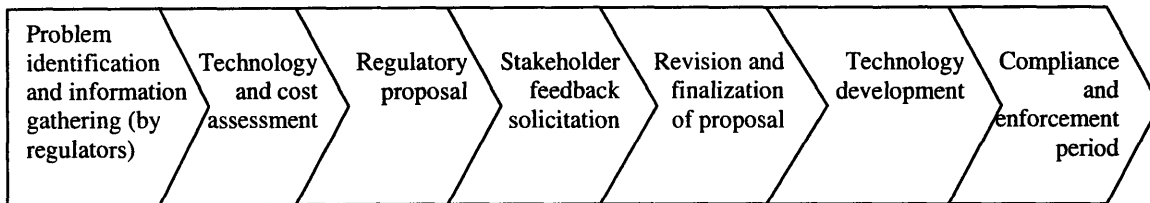
This multiple-causes and multiple-effects relationship, where some of the causes are not known a priori, lends itself to a deductive approach. Findings from the research will generate propositions that plausibly explain the outcomes.

3.2 Comparative case method

A typical case study approach would be to use a company as the main unit of analysis. This might involve selecting several companies that chose to introduce advanced pollution reduction technologies ahead of regulatory requirements, and some that did not. However, taking the company as the unit of analysis overlooks larger contextual reasons for corporate behavior. Sampling a subset of companies for case studies may limit the breadth of comparison possible. Selection bias would be a problem because it would be tempting to choose the most prominent examples of unusual corporate behavior. To mitigate some of these problems, this research uses a two-tiered approach, first evaluating motivations and outcomes in different regulatory cycles, and then investigating behavior at the organizational level.

Since the research focus is on companies' interaction with environmental regulations, the cycles of regulatory change can be used to form the boundaries of the case studies. A "regulatory cycle," as used in this thesis, is a set of emission or fuel regulations in a country or region that must be met by a certain date or timeframe. Studying a regulatory cycle includes reviewing several phases of its accompanying regulatory process:

Figure 3-2: Regulatory Process



In some situations, this process may be iterative, with revised proposals and rounds of technology assessments and stakeholder feedback; in other situations, the process may be simplified if government regulators and industry can come to a mutually acceptable agreement without entering a formal decision-making process.

The countries and regions investigated in this study – the EU, Japan, and the US – do not have simultaneously timed regulatory cycles for emission and fuel standards. Yet there is enough overlap that they can be grouped to study collectively. Since many companies in the auto, truck, engine, fuel, and emission control industries sell their products globally, they must cater to each market's regulatory cycles, leading to a natural comparison among overlapping cycles.

In Table 3-1, the groups of regulatory cycles highlighted in gray were selected for this research. They cover light-duty vehicles, heavy-duty engines, and diesel fuel, with at least two groups of regulatory cycles within each category for comparison. Because of their recent occurrence, the accompanying regulatory processes are well documented in the public record. Implementation and outcomes are observable from the earlier cycles, while the later cycles, with some regulations yet to take effect, allow for consideration of strategic firm behavior and future regulations.

Table 3-1: Recent Regulatory Cycles for On-road Diesel Vehicles and Fuels

	2000-2004	2004-2007	2008+
Light-duty vehicles	Euro 3 2000 JP LD 2002 US Tier 1 1997-2003 CA LEVI 1994-2003	Euro 4 2005 JP LD 2005 US Tier 2 2004-07 CA LEVII 2004-10	Euro 5 2008 JP LD 2009
Heavy-duty engines	Euro 3 2000 JP HD 2003 US HD 2002/04	Euro 4 2005 JP HD 2005 US HD 2007-10	Euro 5 2008 JP HD 2009
On-road fuel sulfur	Euro 4 2000, 350ppm JP 2003-05, 50ppm	Euro 4 2005, 50/10ppm JP 2005-07, 10ppm US 2006, 15ppm	Euro 5 2009, 10ppm
Off-road vehicles	EU Stage 2 2001-04 JP MOT Stage 1 2003 & MOC Stage 2 2003 US Tier 2 2001-06	EU Stage 3 2006-13 JP MOT Stage 2 2006-08 US Tier 3 2006-8	EU Stage 4 2014 US Tier 4 2008-15
Off-road fuel sulfur	EU 1994, 2000ppm JP 2003-05, 50ppm US pre-1993, 5000ppm	JP 2005-07, 10ppm US 2007, 500ppm	EU 2008, 1000ppm EU 2009, 10 ppm US 2010, 15ppm

Regulatory cycles from the off-road sector were not selected because most regulatory developments are still very recent and in progress during the time of this research study. Based on preliminary research, some of the most contentious debate about regulatory standards has focused on the highway vehicles and fuels. Although the technology required for off-road emission reduction is costly and challenging, it lags the development of light-duty and heavy-duty highway vehicles by several years, so many of the policies and technology solutions may be passed down from the automobile and truck sectors.

Within each selected group of regulatory cycles, individual companies and industries are closely examined for their behavior, comprising the second tier of analysis. The regulatory cycle provides a convenient and natural framework to understand their actions. Companies and industry groups often announce their positions on regulations and offer information about their technology progress at different phases of the regulatory process. In addition to comparing company behavior, the variations in government, NGO, and public responses in the EU, Japan, and the US provide the opportunity for comparative study. The two-tiered comparative case

study approach is more comprehensive, starting off broadly with the regulatory cycles and then focusing in-depth at the organizational level. This deeper level of analysis allows the “cases” to be reconfigured in a variety of ways – as a single regulatory cycle in a country, an entire industry’s interaction with a set of regulations, or one company’s response to the regulatory process. Grouping the cases in various ways can lead to important patterns of within-group similarities and inter-group differences. Pairing seemingly similar cases for comparison may reveal important variables responsible for differences (Eisenhardt 1989).

By taking this approach, this study avoids the biased selection of cases that occurs in most qualitative studies. The cases are not selected for their ability to fit the definition of an early or first mover. Instead, reviewing each regulatory cycle will generate cases of corporate behavior, which could range from non-compliance to first-mover behavior. Although this process is by no means exhaustive, it does capture representative behavior that is documented by the media, industry, or regulatory agencies.

The need for an open-ended approach to identifying causal mechanisms is fulfilled through process tracing. Process tracing is an approach in which the researcher examines the decision process by which the initial conditions are translated into outcomes. It studies the steps of the decision-making process, often down to the level of the motivations and perceptions of the individual actor. Process tracing is especially useful in cases where there are a limited number of observations because it yields many observations within each sequence of events or organization (George and McKeown 1985; King, Keohane et al. 1994). For this research, the process tracing approach was used to investigate organizational positions and decisions at various stages of each regulatory cycle, and to assess the attitudes of decision makers over time and on different issues. Looking beyond the final outcomes offers opportunities to improve understanding of intermediate decisions. It also leaves the door open for more than one causal mechanism to explain the phenomena. While this does make it difficult to generate one clear explanation for behavior, it sacrifices clear determinacy for comprehensiveness. However, with multiple regulatory cycles suitable for comparative study, patterns may emerge to strengthen confidence in the explanations.

In approaching each regulatory cycle, the following questions served as a guide for gathering information.

- What was the regulatory process?
- How and when did the regulatory levels first get proposed and then finalized?
- Who were the early movers, first movers, or supporters, if any? Opponents? What were their motivations?
- What technologies were available to meet the standards?
- What influence did companies and their technologies have on regulations – from design to implementation?
- What were the private financial and reputational benefits and costs to the individual companies and to the industry?
- What were the public environmental, health, or economic benefits and costs to the customers and the greater public?

The data sources used to answer these questions are described in the next section.

3.3 Data sources

A combination of documentary sources, quantitative data, and personal interviews are used as a source of data. Documentary sources include industry databases, professional/trade journals, research project summaries, patent databases, company reports, and regulatory documents. Descriptive statistics about individual companies, industries, and countries are available from company financial reports, industry associations, and government agencies. Phone or live interviews were conducted with individuals in industry, government, NGOs, and academia/research who have been involved with at least one of the regulatory cycles.

3.3.1 Documentary sources

Primary documents are a rich source of information about public and private behavior and decisions. Most documentary resources were obtained through public channels, such as government agencies, company websites, or public-private research projects. Some were subscription-only electronic databases and journals, which require Virtual Electronic Resource

Access (VERA) from the MIT Libraries. Table 3-2 summarizes the types of documents used and the information they provide.

Table 3-2: Types of Documentary Research

Type	Purpose	Example of Sources
Research papers and reports	These show the status of existing technology and promising developments. They provide technical information about the effectiveness of specific technologies. Organizations often use these publicly available reports to communicate their results with academia, industry, and regulators.	Society of Automotive Engineers Technical Paper Series
Patents	The volume of patents in a certain area can reflect the amount of interest in pursuing a particular technology. However, patents are not perfect indicators of innovation because heavy patenting is not a direct measure of innovativeness. Within a given company, the timing of patents may show chronological trends.	JAPIO (Japan Patent Information Organization), US Patent and Trademark Office, esp@cenet (European Patent Office)
Regulatory documents	Technical regulatory documents often show the technical rationale behind regulatory decisions. Industry submissions or comments reveal individual company or shared industry positions.	US Environmental Protection Agency, European Commission, Japan Ministry of the Environment
Corporate press releases and annual reports	Companies may announce their technology developments, product introductions, or positions on regulatory issues through press releases.	Company websites, LexisNexis Academic database (MIT subscription)
Government press releases	Regulatory agencies may give advance notice of rulemaking procedures.	Government agency websites
Investment analyst reports	Based on financial data and market trends, analyst reports provide analysis about the current and projected performance of a company or industry.	Gale Group databases such as Investext (MIT subscription)
NGO press releases and issue reports	NGOs draw attention to their initiatives and campaigns through public statements, often highlighting their key health and environmental concerns. They also draw attention to specific company behavior deserving criticism or praise.	NGO websites
Joint research projects	Public-private research projects may demonstrate the type of research that interests and/or influences government policymakers.	Japan Clean Air Program, European and US Auto-Oil Programs
News articles	Newspaper and magazines offer a real-time snapshot of events and attitudes. Popular press also indicates whether regulatory issues have received attention from interest groups and the mainstream media.	New York Times, Associated Press, Asahi Shimbun, Financial Times (via LexisNexis database)
Trade articles	Industry-specific media sources offer in-depth information about company activities, and reflect the concerns and biases of that particular industry.	Diesel Fuel News, Heavy Duty Trucking, Automotive News Europe (via LexisNexis database)

Because of the proliferation of electronic publishing, there is wide variation in the reputability of sources obtained from the Internet. Concerted effort was made to only use sources from well-known organizations or with published print equivalents. Multiple sources were used to verify information obtained from lesser known sources.

3.3.2 Quantitative data

Quantitative data can also be seen as another form of documentary source, but they are distinct in that they are the result of collected numerical data that must be processed further for genuine usefulness. Quantitative data, such as financial data, demographic data, and air quality measurements, are helpful in understanding corporate financial performance, market conditions, and public and private outcomes. Statistics may come in a tabular format, requiring calculations and graphical display to reveal meaningful trends.

Table 3-3: Types of Quantitative Data

Type	Purpose	Example of sources
Financial data	Financial reports contain information about profits, returns, sales, expenditures, etc., which indicate the financial performance of the company and/or industry.	Company annual reports, SEC filings, analyst reports (Investext), Ward's Auto World
Certification data	Data from regulatory agencies on vehicle and certification test results give information about the margins with which companies can meet regulatory standards.	Regulatory databases
Industry data	Statistics, such as total sales and market share can demonstrate the industry's overall health, competitiveness, and trends.	Industry associations, business databases, government census reports
Country/ regional demographics	Demographic figures about a geographic area may explain the reasons for differences in its industries or special challenges faced by its companies.	Transport agencies, government census reports
Air quality measurements	Air quality trends show the seriousness of air quality problems and progress in reductions.	Environmental agencies

3.4 Interviews

The purpose of the personal interviews is to build upon the information gathered from documentary sources and quantitative data, and to explore organizational and individual perceptions of technology and regulatory decisions. Interviews uncover motivations and concerns that are not revealed or even contradictory from the other sources. The selection of potential interviewees was based on their depth of involvement in a given regulatory cycle or cycles and their organizational affiliation. The types of interviewees are summarized below:

Table 3-4: Interviewee Affiliations and Roles

Organizational affiliation of interviewees	Organizational roles
Industry	Government/regulatory affairs officers Environmental affairs officers R&D managers
Environmental/health NGOs	Transport or air quality issue leaders
Professional or trade organizations	Regulatory or environmental specialists
Government (state, national, regional)	Regulatory officials Technical staff
Academic/research	Emissions, fuel, and health effects experts with strong connections to industry and government

Various sources were used to identify appropriate participants for interviews. Documentary resources such as trade journals, government reports, industry publications, press statements identified spokespeople on diesel-related issues. Organizational websites for regulatory agencies and companies listed the individuals responsible for environmental regulatory policy on diesels. International meetings and conferences on diesel regulatory issues listed speakers and participants. Reviewing the publicly available presentations and biographies in advance helped to determine the relevance of the speakers' experience to this research. Attendance at several conferences and workshops relevant to diesel emissions helped to establish relationships with potential interviewees and individuals who facilitated introductions to other diesel experts. Based on a wide search of potential interviewees and close attention to diversity of affiliations and organizational roles, a contact list was created. Personal contacts and initial interviews also led to additional contacts. This "snowball" strategy allowed for a more informed selection of interviewees once interviewing was underway. Reassessment of areas requiring

more investigation influenced the types of organizations and individuals contacted for additional interviews.

The MIT Committee on the Use of Humans as Experimental Subjects (COUHES) reviewed and approved the interview procedures that are part of this research (COUHES 2003). Using the COUHES guidelines, procedures for protecting confidentiality were developed. They were explained to the interviewees through the initial contact letter and at the beginning of the interview. The following are the confidentiality procedures for the interview process:

Table 3-5: Interview Procedures for Protecting Confidentiality

<p>Participation is voluntary.</p> <p>The interviewee may decline to answer any questions.</p> <p>The interviewee may decline further participation at any time without prejudice.</p> <p>The interviewee may designate any comment as “off the record,” and will be given the opportunity to stipulate this designation for any earlier comments at the end of the interview.</p> <p>Any notes from the interview will be for personal use and not publicly distributed.</p> <p>Comments will not be attributed to the interviewee unless consent is granted.</p> <p>When comments remain anonymous, the information collected will be reported in such a way that the identity of the individual is protected.</p> <p>Proper measures will be taken to safeguard the collected information. Written notes will be kept in a private, locked space, while electronic notes will be kept on a password-protected computer.</p>
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Each potential interviewee was contacted by a mailed or emailed letter requesting his or her participation. The letter described the purpose and scope of the research project and interview. It discussed the interview procedures for protecting confidentiality listed in Table 3-5. Once a potential interviewee agreed to participate, a follow-up email exchange or phone conversation arranged a convenient time and date. In a few cases where an in-person meeting was feasible, the interview was conducted at the interviewee’s office or meeting room.

The interview question format was semi-structured, meaning that there was a set list of questions created for each interview, but also flexibility to depart from the list to pursue further discussion in certain areas. Although some questions were common across many interviewees, other questions were specific to each interviewee, based on institutional affiliation and experience. Most interviews were conducted by phone. If time and resources allowed, the interviews were conducted in person. The average interview duration was 45 to 60 minutes.

Each interview began with a brief review of the research motivation and confidentiality protection. Because the interviewee usually received the questions in advance by email, the order and pacing of the questions were flexible, allowing for a more natural flow of conversation. In select cases, a second interview or follow-up phone call was conducted to continue the interview or to clarify a response. References to information obtained from documentary sources or insights from other interviews (with the source disguised) were incorporated into interviews as a method of triangulation to test a claim with multiple respondents. None of the interviewees were tape recorded; only notes were taken.

Once the interviews had been conducted, there had to be a systematic way of reviewing and organizing the interview notes. Interview “coding” organizes the interview responses into coherent topics or themes for further analysis. The interview responses were manually coded based on pre-defined broad categories, which are underlined in Table 3-6. Based on the content of the responses, subcategories were also created.

Table 3-6: Categories Used in Interview Coding

<p><u>Motivations for Early/First-Mover Behavior</u></p> <ul style="list-style-type: none">First-mover or receptive countries/regionsFiscal/tax incentivesTop managementR&D staff innovationCustomer demandOpportunity for technology spillover to other companies or marketsProtect existing market shareGain competitive advantage through regulationsAnticipation of future regulationsImprove reputationMedia influenceNGO influence
<p><u>Disincentives for Early/First-Mover Behavior</u></p> <ul style="list-style-type: none">Lack of business caseFear of more regulationTechnological uncertaintyFear of upsetting customersLack of infrastructureIndustry/trade association pressure
<p><u>Contextual Factors</u></p> <ul style="list-style-type: none">Country/culture-specific differencesConcern about national competitiveness and employmentRegional leadersRelationship with regulatorsRelationship with NGOs
<p><u>Outcomes</u></p> <ul style="list-style-type: none">Private benefitsPublic benefitsEarly- or first-mover examples cited by interviewees
<p><u>Tools</u></p> <ul style="list-style-type: none">Credibility of technology assessments and cost estimatesCultural differences make “best practices” hard to transfer from one country to anotherUse of third-parties and demonstration projects to enhance credibilityEarly action on presently unregulated pollutants

3.5 Accessibility of data sources

There were limitations to data accessibility for this research project. Documentary sources consisted of publicly available sources or subscription-based sources through MIT's library subscriptions. In some cases, public agencies were contacted to obtain publicly accessible documents. However, some third-party reports and datasets were not reviewed because they required a substantial purchase or subscription fee. Although some private companies did provide some specific sales data not readily available through their published literature and website, they could not provide detailed financial or marketing information for confidentiality reasons. Some government agencies collect and produce more extensive documentation and datasets than others. Compared to the EU and Japan, the US provides the most extensive data about its government decision-making and regulatory processes. For example, the US EPA provides all the supporting documentation for its emission and fuel standard proposals on its website or by written request. Most major European and Japanese regulatory and technical documents already had English translations because they are intended for sharing with other regulators and company representatives worldwide. On rare occasions, documents not in English were available only in German or Japanese, posing a significant language barrier, even with use of free online translation software. However, the variety of other sources available did not make these limitations a serious liability for this research project.

3.6 Summary

The documentary sources, quantitative data, and interviews described in this chapter form the basis for the comparative case studies. The two-tiered methodological approach is based on the comparative case study method. However, it is much broader than the company-level case studies typical for research on corporate environmental strategies. Studying the regulatory cycles first helps set the market and regulatory context for corporate and regulatory decision-making. Analyzing behavior and outcomes at the organizational level then generates representative cases to observe meaningful patterns and to make comparisons between cycles, countries, and companies.

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CHAPTER 4 – Diesel Vehicle Industry

4.1 Introduction

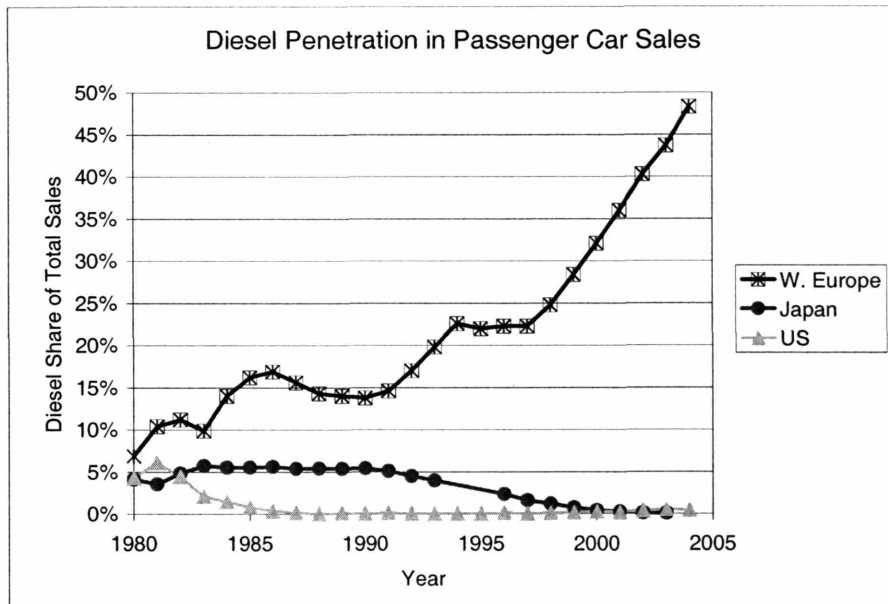
Empirical researchers have suggested the greater need for focused industry studies to understand company responses to regulation: “Studies could focus on firms in heavily regulated industries...and could include a more detailed analysis of the impacts of particular classes of regulation, say, by media, on innovative effort. Ideally an in-depth study of one or two companies in a particular industry, such as chemicals, could be used to develop an understanding about how regulated firms respond to new regulations and some related hypotheses which could then be tested using data from other firms in the industry” (Jaffe and Palmer 1997).

For this research study, the diesel vehicle industry is chosen for a focused industry study, which will generate propositions about how competitive regulatory strategies might work. It will also shed light on the types of regulatory policies that encourage firms to act as early or first movers on technology or product introductions. Since diesel vehicles are actually a system of technologies, the “diesel vehicle industry” incorporates several industries – automobile, truck, engine, petroleum, and emission control companies. While the vehicle, engine, and petroleum industries face environmental regulation on their processes and products, this research focuses on product regulations, such as performance standards or specifications. The increasingly stringent emission and fuel regulations, the subsequent high levels of regulation-driven R&D and capital investment, and the oligopolistic industrial structure make competition based on environmental performance relevant to business practice. Because environmental performance and regulatory compliance are so central to their technology development, the companies are more likely to include environmental concerns as part of their overall corporate planning and strategy.

The recent interest in diesel vehicles as a partial solution to fuel consumption and carbon dioxide (CO₂) concerns makes the selection of this industry especially timely. In Europe, fuel taxes are very high, making fuel prices equivalent to \$5-6 per gallon. Diesel vehicles are an attractive choice because they have up to 30% higher fuel economy than gasoline vehicles. Diesels also produce lower CO₂ emissions, which is an appealing feature to government officials

and customers increasingly concerned about anthropogenic CO₂'s impact on climate change. Differential fuel taxes and lower vehicle fees for low CO₂-emitting vehicles in many European countries have also given diesel an extra edge over gasoline. Diesel penetration in Western Europe's light-duty fleet has risen since the 1980s, and has now reached approximately 50%, as shown in Figure 4-1. Major technology developments by the European automotive industry have aided this diesel boom. Turbocharged diesel engines (1979 - Peugeot), electronic direct injection (1989 - Audi), and common-rail injections systems (1997 - Bosch) have greatly enhanced the power, fuel economy, and driveability of diesels.

Figure 4-1: Diesel Penetration



Source: Ward's Automotive Yearbook (2005)

Although higher oil prices from the oil crises in the 1970s did increase diesel cars sales in the US and Japan during the 1980s, diesel demand eventually died out, and now passenger cars in Japan and the US have a diesel penetration of less than 1%. Stringent PM standards proposed by US and Japanese regulators in the 1970s constituted a virtual ban on diesel cars. In Europe, relatively lenient PM standards were finally introduced in the late 1980s. The German government wanted to adopt more stringent diesel standards, but German automakers Mercedes

and Volkswagen lobbied the European Commission for greater leniency. Furthermore, fiscal incentives intended for catalytic converter-equipped gasoline cars were expanded to include diesel cars compliant with the PM standard (Wurzel 2002).

In the US and Japan, diesel power is reserved mainly for medium to heavy-duty highway and off-road vehicles, where its greater power, higher fuel economy, and lower operating costs are especially valued. Poor performance by diesel cars introduced in the US in the 1980s left American consumers with a negative image of diesels. Relatively low fuel prices also did not justify diesel cars' higher purchase cost. Japanese auto manufacturers have held a negative perception of diesel as a dirty and outmoded technology. For example, Honda founder Soichiro Honda vowed that the company would never make a diesel engine. However, after Honda missed out on the diesel boom in Europe, Honda went against the founder's words in 2003 by offering a new diesel engine for some of their European Accords (Griffiths 2003; Honda 2004). Growing concerns about high oil prices and oil security, as well as improvements in diesel emission control and Europe's diesel boom, have prompted the US and Japan to reconsider diesels for an expanded role in personal transportation.

Despite the technological advances in emission control, diesel exhaust still poses a major air pollution problem because of its particulate matter (PM) and nitrogen oxide (NO_x) emissions. Diesel exhaust consists mostly of PM by weight and contains a variety of air toxics, many of which are not yet fully understood or regulated. In a growing number of scientific studies, diesel exhaust has been linked to respiratory diseases, heart disease, cancer, and premature deaths. NO_x contributes to the formation of ground-level ozone, which causes asthma and other respiratory problems. NO_x also leads to acid rain and ecosystem damage (EPA 2002c; Health Effects Institute 2003). Since diesel exhaust comes primarily from vehicle transportation, especially large commercial vehicles, governments in the EU, Japan, and the US have been setting emission limits on vehicles and engines since the 1980s. They have also regulated fuel quality, with particular attention to lowering fuel sulfur levels, which helps emission control equipment function effectively.

Studying the diesel vehicle industry provides plenty of built-in variation. While the EU, Japan, and the US, have the most the most stringent emission and fuel standards, they have very different economic conditions, environmental priorities, and regulatory contexts. They also are home to very strong and influential automobile, truck, and oil industries.

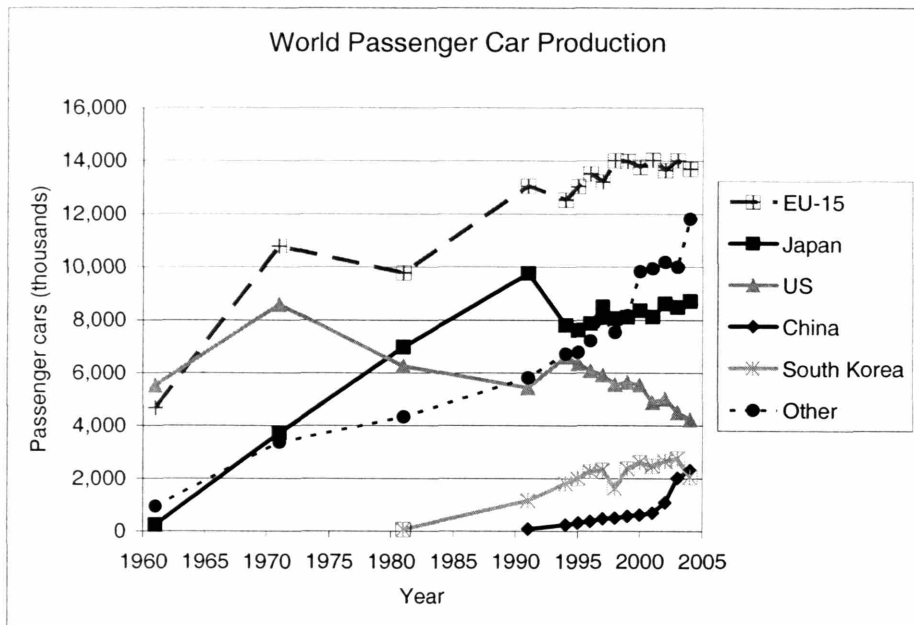
Increasingly stringent standards on diesel vehicles, engines, and fuels have spurred development of cleaner vehicle and engine technologies. Because compliance with tighter standards usually imposes additional R&D and production costs on the regulated industries, proposed standards have often met with stiff resistance from individual companies and industry-wide trade associations. Emission standards may be technology-forcing, which means they require the development of technologies that are not yet currently available. Technologies capable of compliance are expected to reach a commercializable stage when the regulation deadline arrives. Companies face uncertainties about technological progress and future discoveries about diesel exhaust's health effects, which can affect the stringency of future regulation. Nevertheless, they must continue producing products, so they still have to make investment, R&D, and production decisions. Companies that are better equipped to handle stringent environmental regulations have an advantage over their competitors.

The next two sections give an overview of the motor vehicle industry and road infrastructure in the EU, Japan, and the US, which can help explain some of the trends in each region. The popularity of diesel vehicles parallels mounting concern about the health risks associated with diesel exhaust. This chapter ends with a discussion of the different regulatory processes in the three regions.

4.2 Motor vehicle industry

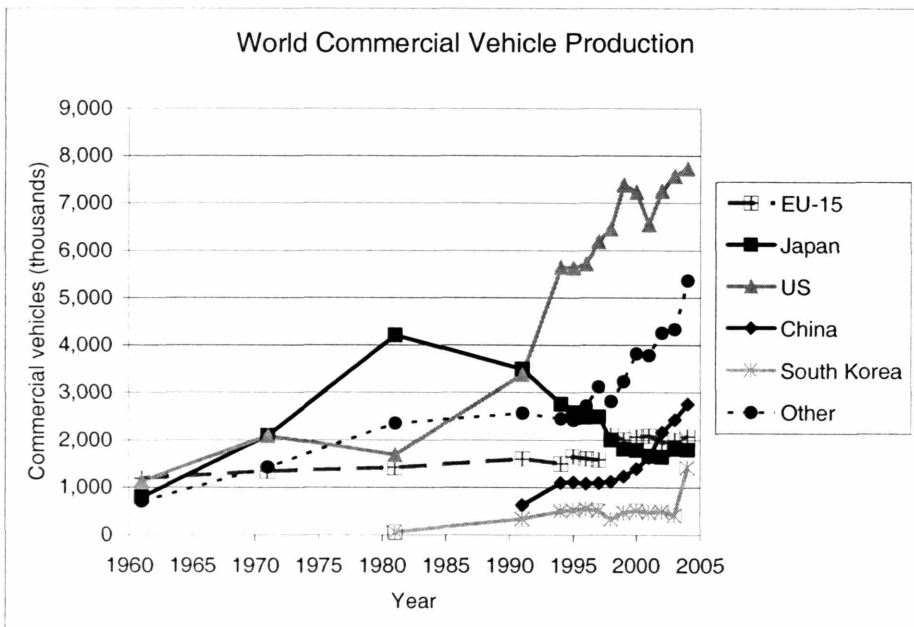
As of 2004, 62% of the world's passenger cars and commercial vehicles (trucks, buses, etc.) were made in the EU-15, Japan, or the US. This is significantly less than their collective share of 80-90% in the 1970s and 1980s, a result of the decline in the US auto industry and the dramatic growth of automobile industries in South Korea, Brazil, and China (US Bureau of Transportation Statistics 2005a). Figure 4-2 shows the passenger car production trends from 1960.

Figure 4-2: World Passenger Car Production



Source: US Bureau of Transportation Statistics (2005a)

Figure 4-3: World Commercial Vehicle Production



Source: US Bureau of Transportation Statistics (2005a)

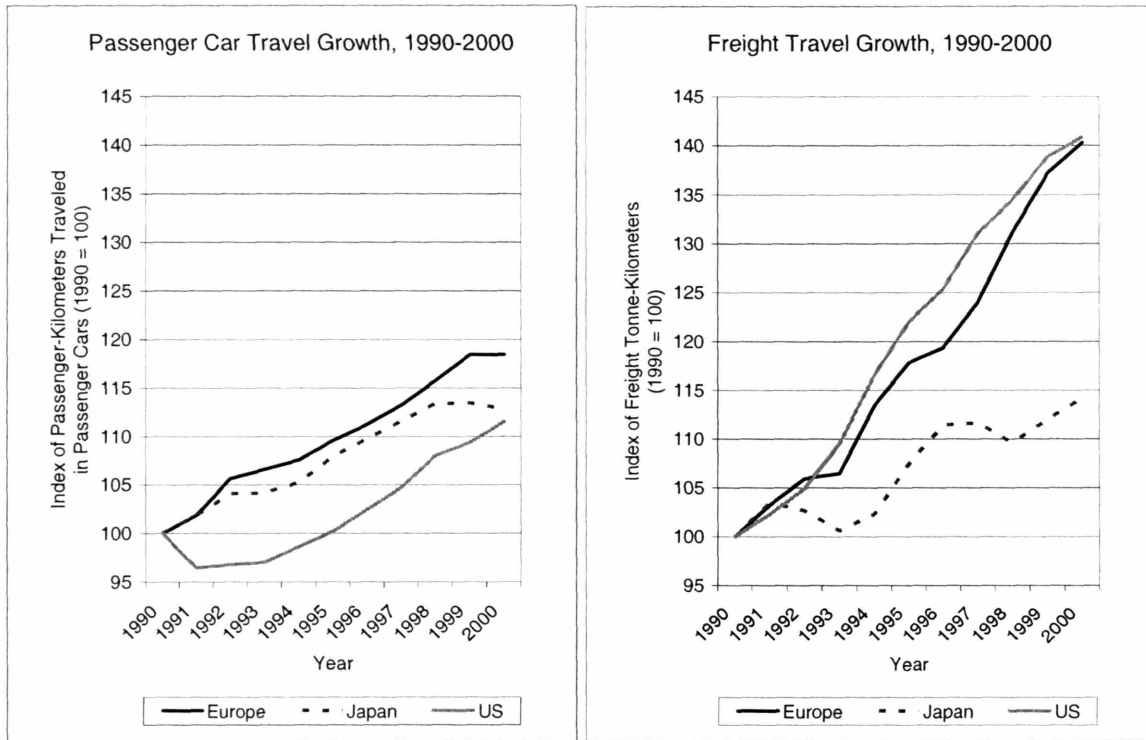
The US is still the dominant player in manufacturing trucks and buses, while the EU-15 and Japan have significantly lower commercial vehicle production (see Figure 4-3). China has already surpassed them in vehicle units, and South Korea looks to overtake them within a few years. The demand growth for commercial vehicles worldwide is even greater than that for passenger cars. From 1991 to 2004, global passenger car production increased by a mere 21% compared to 76% for commercial vehicles. Much of this growth in demand is coming from developing countries with rapidly growing economies, like China and India. Although established multinational companies have tried to take advantage of this growth by producing vehicles in local plants, the booming market has opened the door for more competitors, especially those from developing countries.

Although the EU, Japan, and US are not as dominant as they were in the 1960s-1980s, their domestic motor vehicle industries and reliance on automobile use have led to global leadership on motor vehicle standards. In order to ensure greater uniformity on emission standards, other countries are expected to adopt standards and test protocols already developed by the EU, Japanese, or US government. Even as other countries grow their own domestic auto industries, they seek to ultimately sell to the world market, which is converging towards more stringent regulations. Concerns about air quality, urban congestion, and fuel consumption are increasingly shared by developed and emerging markets alike.

4.3 Road infrastructure

Trends in road transportation influence each national and regional government's approach towards regulating mobile sources. Pollutants are regulated on a per-vehicle and per-distance basis, so a growing vehicle fleet and increased travel distances can cut into progress on emission reduction. Europe, Japan, and the US have all experienced significant growth in both passenger car travel and freight travel. Passenger car travel has increased by over 10% in each region. The greatest growth has occurred in freight travel by road in Europe and the US, which experienced a 40% increase in tonne-kilometers traveled between 1990 and 2000. This reaffirms the need to place greater attention to regulating emissions from heavy-duty diesel vehicles.

Figure 4-4: Passenger Car and Freight Travel Growth, 1990-2000



Sources: Japan Ministry of Land, Infrastructure, and Transport (2005), US Bureau of Transportation Statistics (2005a), Eurostat (2006)

Although distance traveled has increased, vehicle ownership rates in the Europe, Japan, and the US appear to have reached a plateau. The US has the highest ownership rate in the world: 775 private cars per 1000 Americans. Many factors are behind the high ownership rate: low fuel taxes, large geographic area, overall low population density, a well-developed road network, and a weak public transportation network. The EU and Japan have stabilized their ownership rates around 500 cars per 1000 inhabitants (IFP 2005).

Because the US has such a large geographic area, its road transportation network is far more extensive than those in Japan and the EU. As seen in Table 4-1, the total length of US roads, railways, and oil pipelines far surpass EU and Japan figures. The greatest discrepancy among the three regions is the length of oil pipelines, where the total US pipeline length is almost an order of magnitude larger than even the EU-25 and 3 orders of magnitude larger than Japan's. Because of its enormous scale, the operation and maintenance of the transportation

infrastructure in the US, and to a lesser extent, the EU, is much more costly than in Japan. This means that any environmental policy changes involving the infrastructure will likely be more challenging to implement in the US and the EU.

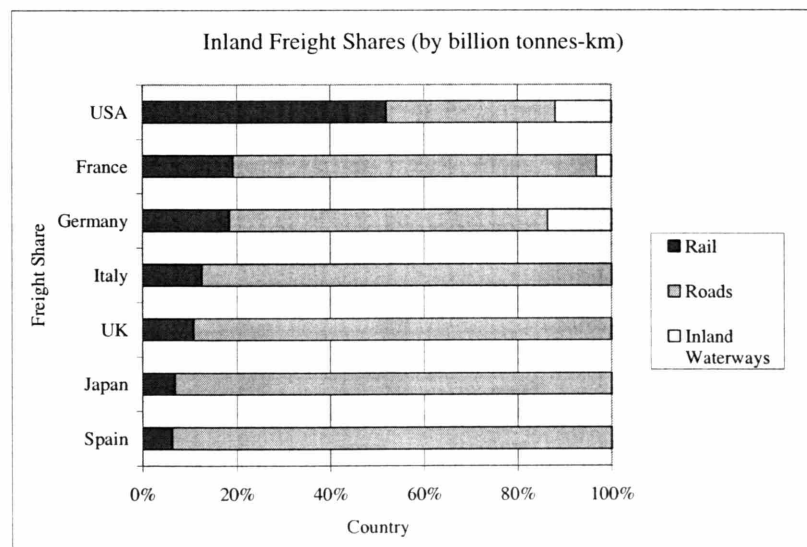
Table 4-1: Passenger and Freight Infrastructure, 2001 Figures

(in 1000 km)	EU-25	US	Japan
Road network	4,800	7,173	1,172
Railway network	199.7	315.3	23.7
Oil pipelines	27.5	255.2	0.2

Source: EC Directorate-General for Energy and Transport (2004)

Although the US has more roads than Japan and the EU, more of its inland freight (on a weight basis) moves by railway than by truck (Figure 4-5). The EU and Japan rely predominately on roads for freight transport within their borders. The US share of road use is only 40%. As a result of this discrepancy, it would be expected that the freight transportation lobby would be stronger in the EU and Japan than in the US. This seems to be true in European countries, where pressure from the trucking industry, which predominately uses diesel-powered vehicles, has kept duties on diesel fuel low relative to gasoline.

Figure 4-5: Inland Freight Shares, 2003



Source: OECD (2005b); Note: Figure excludes pipelines.

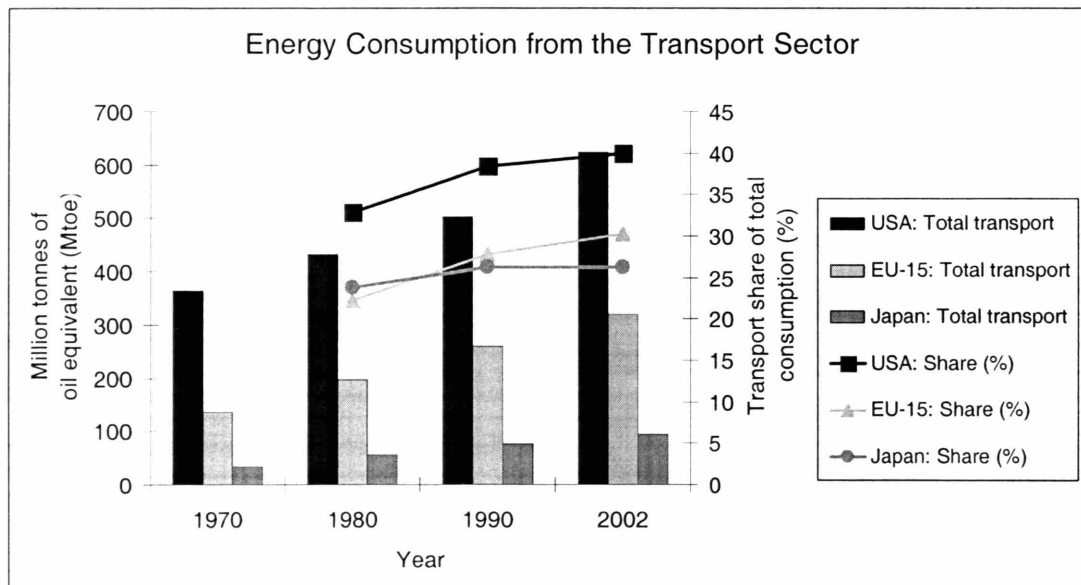
4.4 Factors driving the growing interest in diesels

The strongest factors explaining the growth in diesel popularity have been high oil prices and concerns about the contribution of anthropogenic CO₂ emissions to climate change. Fuel tax and vehicle registration policies in the EU have encouraged customers to purchase more fuel-efficient and low CO₂-emitting vehicles, many of them diesels.

4.4.1 Energy consumption

In the three regions, the transportation sector's consumption of energy has grown in both absolute terms and in its share of total energy consumption.

Figure 4-6: Transportation's Contribution to Energy Consumption



Source: OECD (2005a)

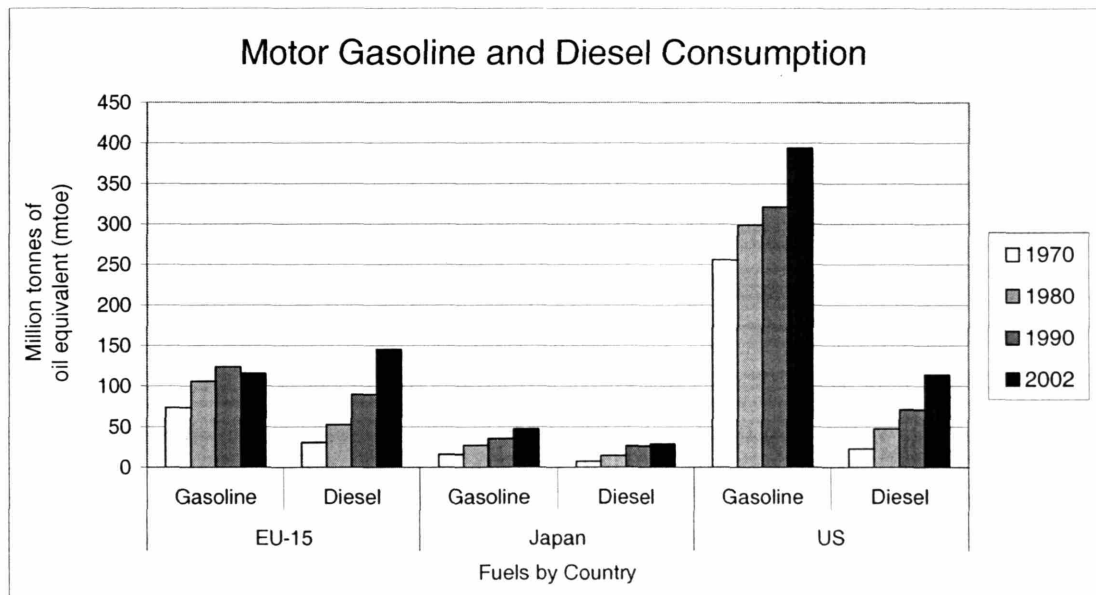
The amount of energy consumed by transportation in the U.S. is particularly striking. By 2002, U.S. transportation energy needs already comprised 40% of the country's total energy

consumption, while it was 26% and 30% in Japan and the EU-15. Road transport is by far the most energy-consuming of transportation types. It makes up over 80% of the total energy used by transportation in the three regions. The rise in consumption comes from an increase in both vehicles on the road and vehicle distance traveled (OECD 2005a).

Over 98% of all energy for transportation comes in the form of liquid petroleum-based fuels, either gasoline or diesel fuel. Figure 4-7 shows the trend of gasoline and diesel consumption. Europe’s rapid adoption of diesel cars in the 1990s is reflected in its rise in diesel fuel consumption from 1990 to 2002, and the accompanying decrease in gasoline consumption. By 2002, its diesel consumption had surpassed its gasoline consumption, whereas in Japan and the US, gasoline is still the dominant transportation fuel.

Passenger car owners who have above-average annual driving distances are more inclined to choose diesel over gasoline cars. The money saved from lower fuel costs and higher efficiency makes up for the more expensive upfront cost of the vehicle. In 2001, when France already had a diesel penetration approaching 60%, the annual mileage of a diesel car was 19,700 km, compared to 11,400 for a gasoline car (Orfeuill 2001).

Figure 4-7: Motor Gasoline and Diesel Consumption in 1970, 1980, 1990, and 2002



Source: OECD (2005a)

The freight transportation industry is even more sensitive to fuel prices than individual passenger car customers. The large vehicle size and weight, and the longer annual distances traveled translate to greater fuel consumption. For example, a large tractor-trailer truck (e.g. Class 7 or 8 truck in the US) can typically travel 5-7 miles per gallon (2-3 km/liter). In the US, such a vehicle travels an average of 63,000 miles (101,000 km) per year, compared to the 12,000 miles (19,300 km) traveled by typical passenger car or light truck (US Census Bureau 2004). In Europe, a typical light-duty vehicle travels 6,000-9,000 miles (10,000-15,000 km) annually, while a heavy-duty diesel vehicle travels 37,000 miles (60,000 km) per year (European Environment Agency 2005).

Table 4-2: Average Annual Distances Traveled by Light-duty and Heavy-duty Vehicles

Annual distance	EU-15	Japan	US
Light-duty	9,300 miles (15,000 km)	5,800 miles (9,300 km)	12,000 miles (19,300 km)
Heavy-duty (freight)	37,000 miles (60,000 km)	n/a	63,000 miles (101,000 km)

Sources: European Environment Agency (2005), US Census Bureau (2004), FIA Foundation (2003)

4.4.2 CO₂ emission reduction

Awareness about climate change as a serious global environmental problem has increased in recent decades. Although some controversy persists about the extent of the human contribution to the problem, most scientists agree that higher levels of greenhouse gases, like CO₂, and methane, will lead to higher average global temperatures and sea level rise. Governments around the world have been seeking ways to reduce CO₂ emissions from industrial activity. The EU and Japan are both parties to the Kyoto Protocol, an international and legally binding agreement to reduce CO₂ emissions by at least 5% below 1990 levels by the 2008-2012 commitment period. The EU has agreed to an 8% reduction and Japan has agreed to a 6% reduction (UN Framework Convention on Climate Change 2006). Even though the US did not

ratify the agreement, US firms with markets overseas have begun to turn their attention to CO₂ reduction as well.

Transportation is a leading contributor to CO₂ emissions, second only to electricity and heating. CO₂ emissions roughly correspond to the quantity of energy consumed, so the US leads with almost one-third of its CO₂ emissions coming from transportation.

Table 4-3: CO₂ Emissions from Transportation

	EU-15	Japan	US
CO ₂ emissions from transportation (billion tonnes/yr)	843.4	250.1	1,794.0
Transportation as a percentage of total	25.4%	20.8%	31.3%
Per capita CO ₂ emissions from transportation (million tonnes/yr)	2.20	0.85	14.05

Source: OECD (2005b; 2005c)

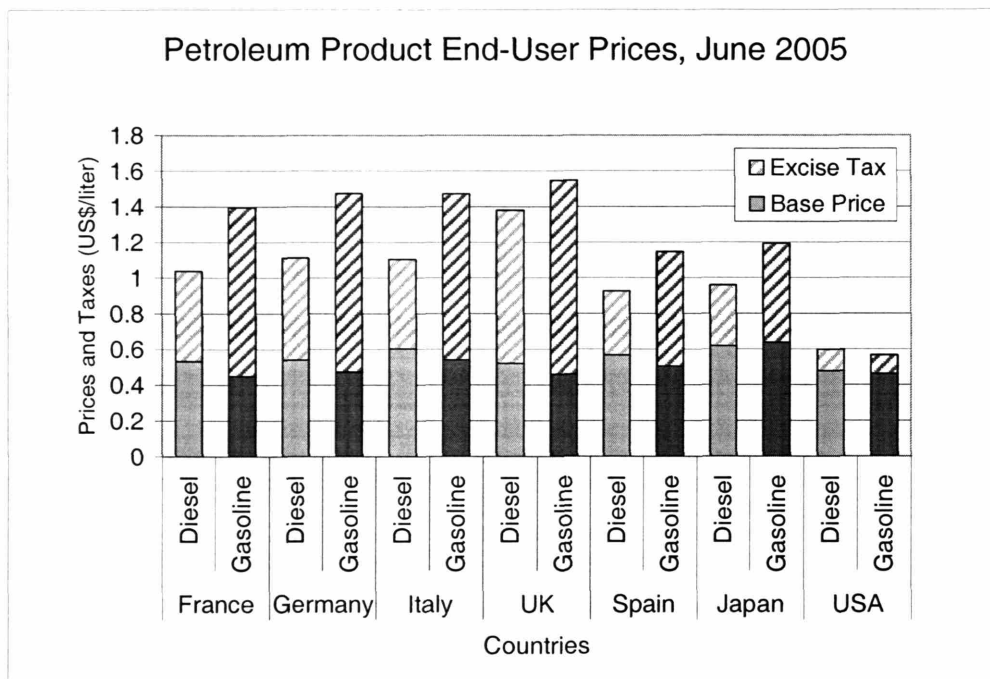
Because transportation, and specifically road transportation, is a leading contributor to energy consumption and CO₂ emissions, there is a major incentive to reduce vehicle fuel consumption. Some technological approaches have been to add energy-efficient features to vehicles, reduce vehicle weight, or to adopt alternative powertrains, like battery-electric or hybrid gasoline-electric engines. Although not a new technology, diesel powertrains have advanced with the development of electronic control and common-rail fuel injection, making diesels a highly popular option for passenger cars in Europe. As noted earlier, diesel vehicles consume energy and emit CO₂ at a level 30% lower than their gasoline equivalents. Many national governments in Europe tax diesel fuel at a lower rate than gasoline, further encouraging diesel penetration in the passenger car fleet.

4.4.3 Government tax policy

High tax rates in Europe and Japan have generally led to smaller vehicle sizes, whereas in the US, where the fuel tax is relatively low, light trucks, SUVs, and vans have grown in popularity. In Europe, the fuel excise tax is often more than 50% of the final end-user price, as

shown in Figure 4-8. Several European countries, such as the UK, the Netherlands, Sweden, Iceland, Finland, Norway, and Switzerland, have some of the highest end-user fuel prices in the world (GTZ 2005).

Figure 4-8: Petroleum Product End-User Prices

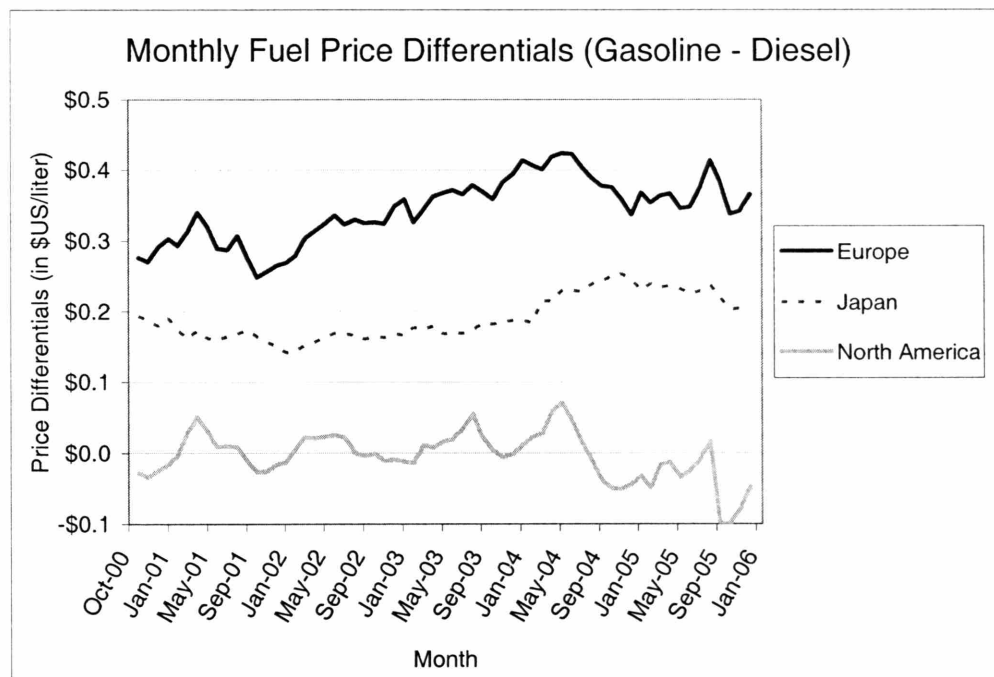


Source: International Energy Agency (2006)

Although diesel fuel usually has a slightly higher base price than gasoline, its significantly lower tax rate in Europe makes diesel less expensive overall. Europe has historically taxed gasoline more heavily than diesel to encourage drivers to switch to the more energy-efficient diesel cars. This was partially driven by the oil crises in the 1970s, when fuel was scarce; the tax differentiation policy has persisted ever since. Also, the trucking lobby is an influential force in keeping the diesel tax rates lower than gasoline. The diesel-gasoline price differential is not as pronounced in Japan, but diesels still have a tax advantage. In the US, the price differential between diesel and gasoline is usually negligible. Figure 4-9 shows the difference between gasoline and diesel in Europe (France, Germany, Italy, Spain and the UK only), Japan, and North America (US and Canada only). It shows the discrepancy in fuel price

differentials in Europe, where gasoline has averaged US\$0.34 per liter (\$1.30 per gallon) more than diesel, or 40% more. Such a strong difference gives an incentive to European customers to purchase diesel cars, even though diesel cars cost more.

Figure 4-9: Monthly Gasoline-Diesel Price Differentials, October 2000 to January 2006



Source: International Energy Agency (2006)

4.5 Health and environmental concerns

4.5.1 Diesel vehicles' contribution to pollutant emissions

For diesel vehicles, the key pollutants of concern are NO_x and PM, especially fine particulates, which are especially damaging to human health because of their long-term impacts on premature mortality. This section offers an overview of the contribution of diesel vehicles' to total air pollutant emissions. It would have been preferable to directly compare the situations in the EU, Japan, and US, but different measurement and data collection methods require that each region be discussed separately.

United States

The US Environmental Protection Agency (EPA) documents annual emission trends data, taking input from state and local air agencies, tribes, and industry. The National Emissions Inventory is used for modeling, regional strategy development, regulation setting, risk assessment, and trend tracking (EPA 2002d).

Table 4-4 summarizes on-highway diesel vehicles' share of major air pollutants, with NO_x and PM highlighted in gray. Even though total NO_x emissions have decreased, diesels have been contributing to an increasing share of NO_x emissions. Their contribution to PM₁₀ and PM_{2.5} appear relatively small, but unlike the other pollutants, which have specific chemical compositions and sizes, PM is a complex mix of hundreds of constituents. Not all particulates are equal in their risk to human health. For example, wind-blown fugitive dust (i.e. uncontaminated soil) is not a critical source of particles responsible for health effects, while particles from internal combustion engines, coal combustion, and wood burning have serious adverse effects (WHO 2003).

Table 4-4: Highway Diesel Vehicles' Contribution to US Air Pollutant Emissions

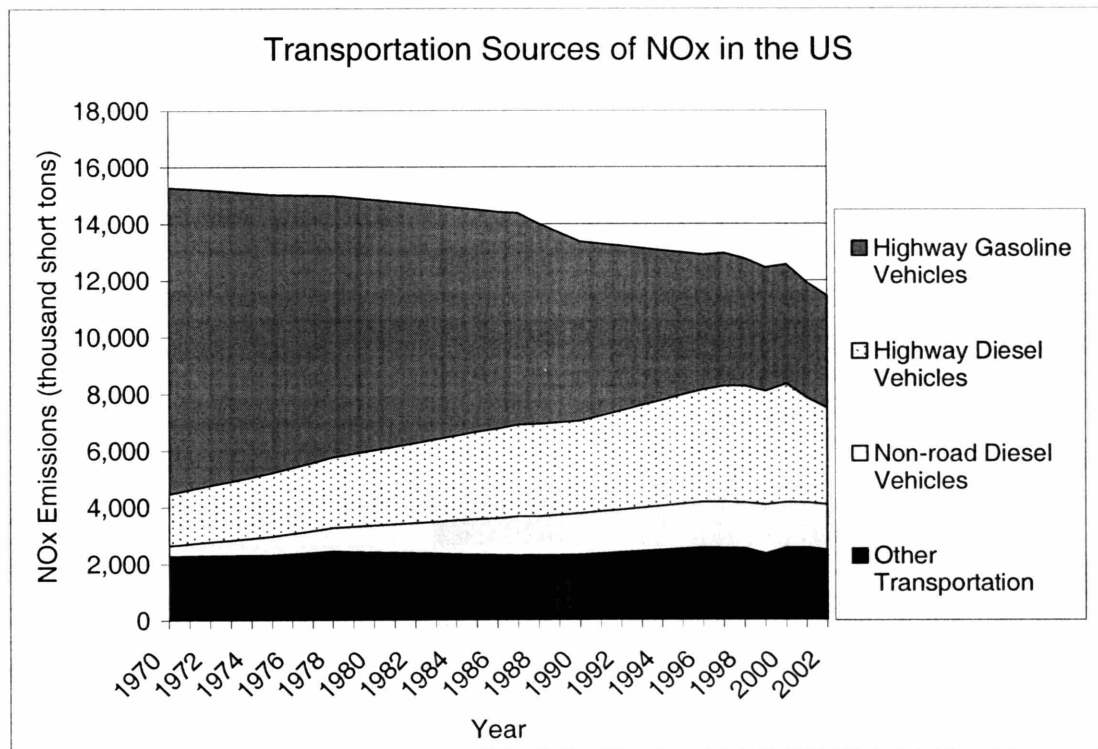
Criteria pollutants	1970	1980	1990	2000
CO (carbon monoxide)	0.3%	0.8%	1.2%	1.1%
NH ₃ (ammonia)	n/a	n/a	0.1%	0.1%
NO _x (nitrogen oxides)	6.8%	9.8%	12.8%	18.6%
PM ₁₀ * (particles below 10 micron in diameter)	0.9%	3.0%	1.0%	0.6%
PM _{2.5} (particles below 2.5 micron in diameter)	n/a	n/a	3.4%	1.7%
SO ₂ (sulfur dioxide)	0.3%	0.9%	1.4%	0.5%
VOC (volatile organic compounds)	1.3%	1.6%	1.9%	1.4%

* Figures for 1970 and 1980 may not be accurate because EPA was reporting missing emission data during that time period.

Source: EPA National Emissions Inventory (2002d)

Approximately 55% of US NOx emissions come from transportation. Stationary source fuel combustion is responsible for another 40%. Despite increases in vehicle distance traveled, the US has made substantial progress since the 1970s in reducing NOx emissions from gasoline vehicles (see Figure 4-10). However, progress in reducing NOx from diesel vehicles has been slower. Freight travel with diesel vehicles has increased, and heavy-duty diesel engines were not regulated for NOx until 1984 and for PM until 1988, much later than light-duty vehicle regulations. As a result of increased freight travel and later adoption of emission standards, NOx emissions from highway and non-road diesel vehicles increased up until the late 1990s.

Figure 4-10: NOx Trends in the US

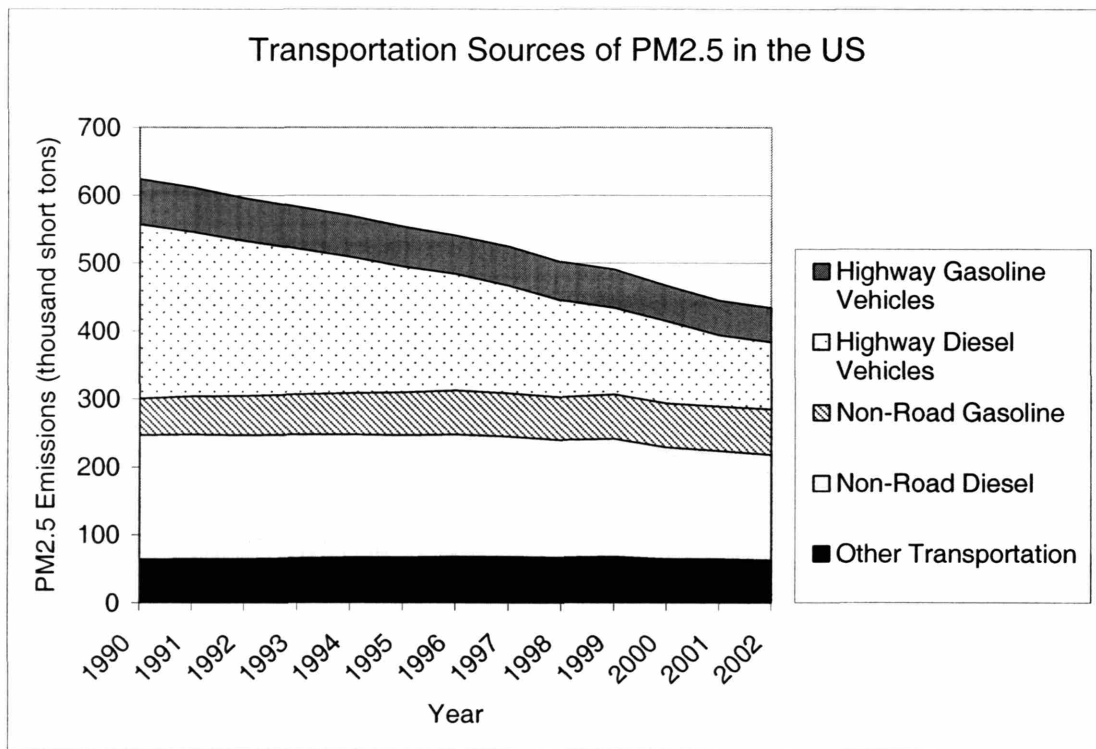


Source: EPA National Emission Inventory (2002d)

At 8%, transportation's contribution to PM appears very small compared to the over 60% of particulates coming from agriculture, forestry, fugitive dust, and fires. Despite vehicles' relatively small contribution to particulates, the particulates emitted during fuel combustion are

more harmful to human health than natural sources, like fugitive dust. Agricultural sources and forest fires usually occur sporadically in remote locations, whereas the highest levels of vehicle pollution routinely occur in densely populated urban centers. Of all transportation sources, highway diesel vehicles emit 23% and non-road diesel vehicles emit 36% (EPA 2002d). Highway diesel vehicles used to make up a larger proportion of transportation-generated PM2.5 emissions, but more stringent PM standards have brought those emissions down. Non-road vehicles are now the largest emitter among transportation sources.

Figure 4-11: PM2.5 Trends in the US



Source: EPA National Emission Inventory (EPA 2002d)

Europe

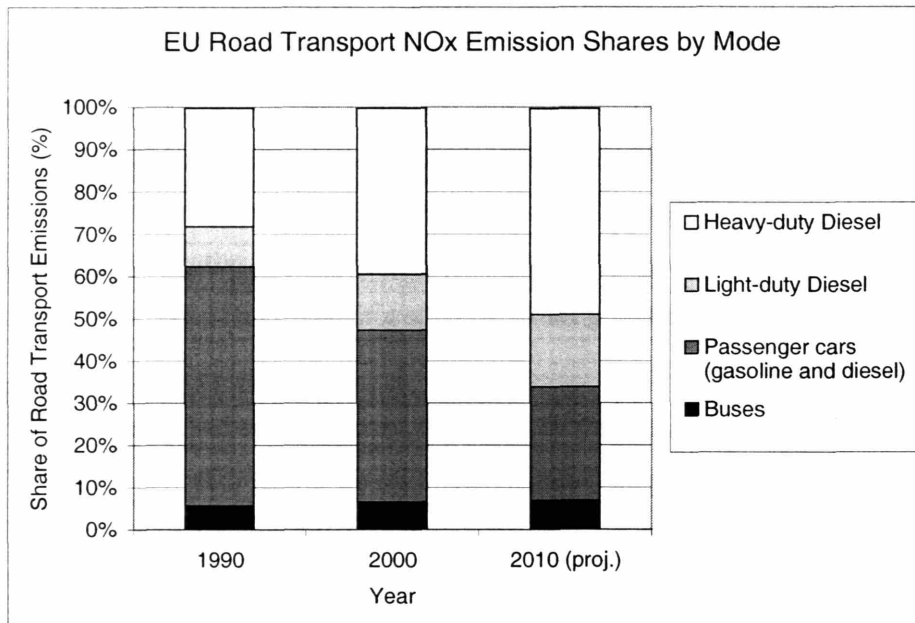
EU member states have made significant progress in reducing air pollutant emissions from road transport. From 1990 to 2000, the EU reduced road transport's NO_x emissions by 25% and PM₁₀ emissions by 26%. The introduction of catalytic converters in the late 1980s to early 1990s and increasing diesel penetration led to significant NO_x reduction in passenger cars.³ Catalytic converters and fuel switching aided the PM reduction (European Environment Agency 2003). Measures to reduce transport emissions continue into the future. Road transport remains the dominant source of NO_x emissions, accounting for 47% of the total across all sectors. It is responsible for 28% of total PM emissions.

Unlike the US data on transportation sources of pollutants, data from the European Environment Agency do not distinguish between diesel and gasoline passenger cars. However, each diesel car emits more NO_x than a modern gasoline car with a catalytic converter. Since the 1996 Euro 2 standards, European NO_x limits have been more lenient for diesel cars than gasoline cars. The impact of increasing dieselization is seen in the light-duty and heavy-duty diesel categories. As seen in Figure 4-12, light-duty and heavy-duty diesel vehicles have grown in their contributions to road transport's NO_x emissions. Even though increased diesel penetration in Europe's vehicle fleet may have ultimately had adverse effects on PM and NO_x emissions, it was actually a key factor in the 47% and 51% reductions in CO and NMVOC emissions in 1990-2000 (European Environment Agency 2003).

Although the mode-based transport emissions data from the European Environment Agency combines gasoline and diesel passenger cars, it can be reasonably assumed that most PM emissions from passenger cars come from diesel cars. Up until 2005, gasoline cars had been exempt from PM standards because of their relatively low PM emissions. Most buses are diesel-powered and light-duty (e.g. light-duty trucks) and heavy-duty diesel vehicles contribute over 70% of the total transport PM emissions (see Figure 4-13). PM emissions from road transport are clearly a problem attributable to diesels (European Environment Agency 2003).

³ Prior to the advent of catalytic converters, gasoline cars emitted more NO_x than diesel cars. Today, modern catalytic converter-equipped gasoline cars emit less NO_x than modern diesel cars.

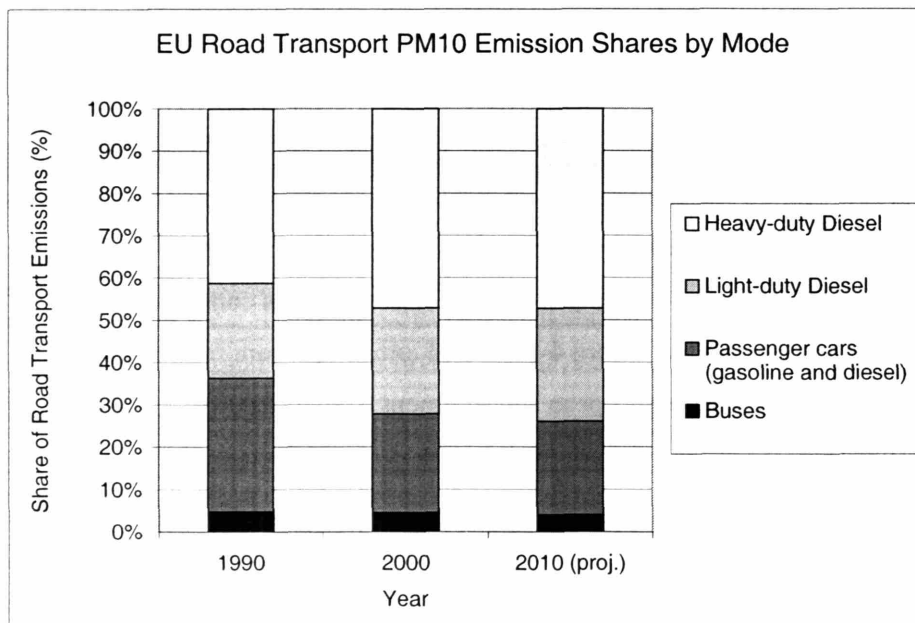
Figure 4-12: EU Road Transport Mode Contributions to NOx Emissions



*Note: Light-duty diesel refers to light-duty commercial vehicles like vans and trucks.

Source: European Environment Agency (2003)

Figure 4-13: EU Road Transport Mode Contributions to PM10 Emissions



Source: European Environment Agency (2003)

Japan

In Japan, diesel vehicles contribute to a disproportionate share of the PM, NO_x, and HC emissions from motor vehicles. Diesel vehicles accounted for 17.4% of the total Japanese vehicle fleet (including light-duty and heavy-duty) in 2000, but they contributed to 80% of the motor vehicle NO_x emissions and virtually all the particulate emissions. Particulates from gasoline vehicles were not included in their totals because they are considered negligible (JAMA 2004).

Table 4-5: Pollutants from Motor Vehicles in Japan in 2000

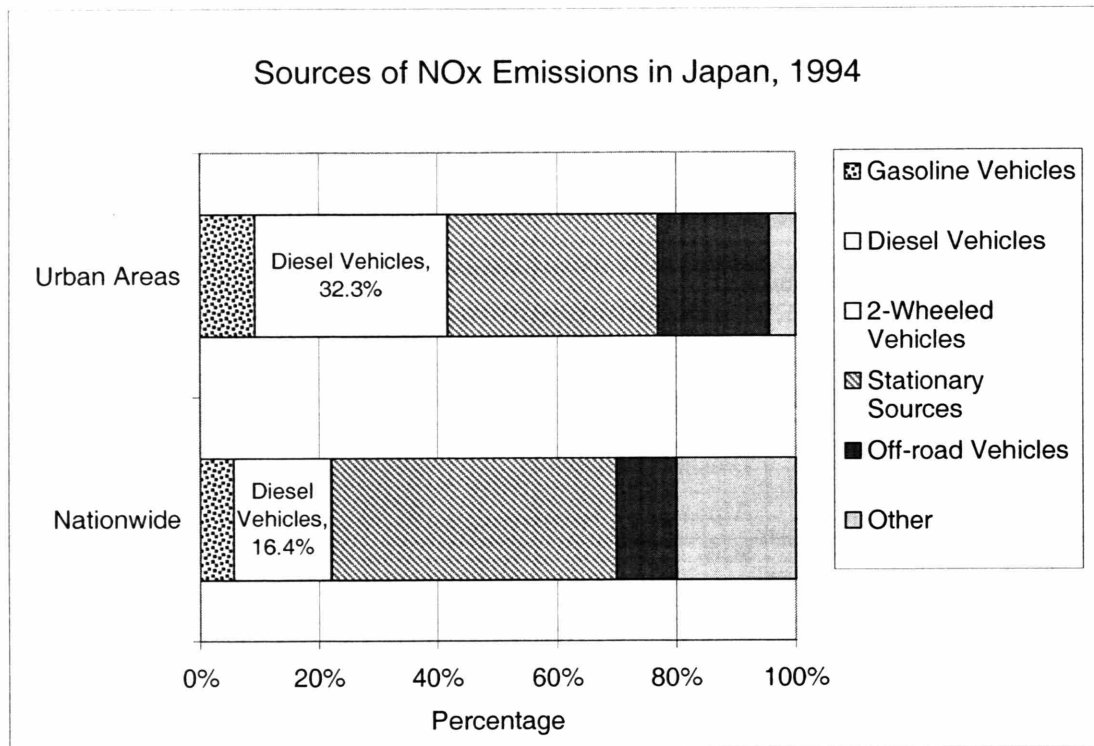
Pollutant	Pollutant quantity	Diesel contribution
PM*	79,000 tons	Almost 100%
NO _x	670,000 tons	80%
HC	200,000 tons	63%

*Because of the exclusion of gasoline vehicles, the diesel contribution to PM may be an overestimate.

Source: Japan Ministry of the Environment (2002; 2005)

If all emission sources are included, diesel vehicles are still a very significant source of NO_x emissions. In urban areas, diesel vehicles contribute to approximately one-third of all NO_x emissions. Although the NO_x shares in Figure 4-14 date back to 1994, they do reflect the relative magnitude of the diesel vehicles' share of NO_x emissions compared to gasoline vehicles and other sources. As of 2000, an estimated 44% of Tokyo's NO_x emissions and 52% of its PM emissions came from diesel vehicles (Tokyo Metropolitan Government 2005).

Figure 4-14: NOx Emission Sources in Japan



Source: Japan Ministry of the Environment (1999)

4.5.2 Off-road and marine sources of diesel emissions

As the highway diesel vehicle fleet becomes less polluting in response to increasingly stringent regulation, the next challenge is reducing diesel emissions from off-road vehicles and marine vessels. Off-road vehicles mainly consist of construction, farm, and industrial vehicles. Off-road diesel vehicles are responsible for 36% of PM2.5 emissions and 14% of NOx emissions from transportation sources. By 1996, off-road vehicles were already emitting more PM2.5 than highway diesel vehicles (EPA 2002d). The first off-road diesel engine regulations were not implemented until 1996 in the US, 1999 in the EU, and 2003 in Japan. Revised standards are already scheduled for implementation into the next decade. Fuel quality for off-road equipment must also improve in order to facilitate the use of emission control equipment. Off-road fuel sulfur is generally much higher than sulfur levels in highway fuel (e.g. in the EU, 2000ppm

compared to 50ppm), but by the 2009-2010 timeframe, the regulatory agencies in the US, the EU, and Japan have mandated the same diesel fuel sulfur levels for highway and off-road applications. Marine diesel engines have been subject to relatively lenient regulations compared to highway vehicles and off-road applications.

Regulators at different agencies consider marine emissions the “last frontier” of emission regulations, and have recently turned their attention to regulating marine vessels. The growth in international trade has led to more ship traffic and greater air pollution problems in ports, which are usually adjacent to populated urban areas. Because of the high sulfur content in marine diesel, usually ranging from 15,000 to 45,000 ppm sulfur, sulfur oxides (SO_x) are a primary concern. By mid-2006, the EPA is expected to issue a final rulemaking that would call for dramatic reductions in locomotive and marine diesel emissions (EPA 2006). In November 2002, the European Commission adopted a strategy to reduce emissions from seagoing ships. Numerous studies have been generated, along with policy recommendations for reducing ship emissions. In 2005, the Commission adopted a Directive requiring the reduction of marine fuel sulfur levels to 1000ppm. In 2005, upon discovering that the ships anchoring at the Tokyo Port emit 8 times more SO_x than all the automobiles in six Tokyo wards, the Tokyo Metropolitan Government began negotiations with industry groups to use lower-sulfur marine diesel fuel (Yomiuri Shimbun 2005)

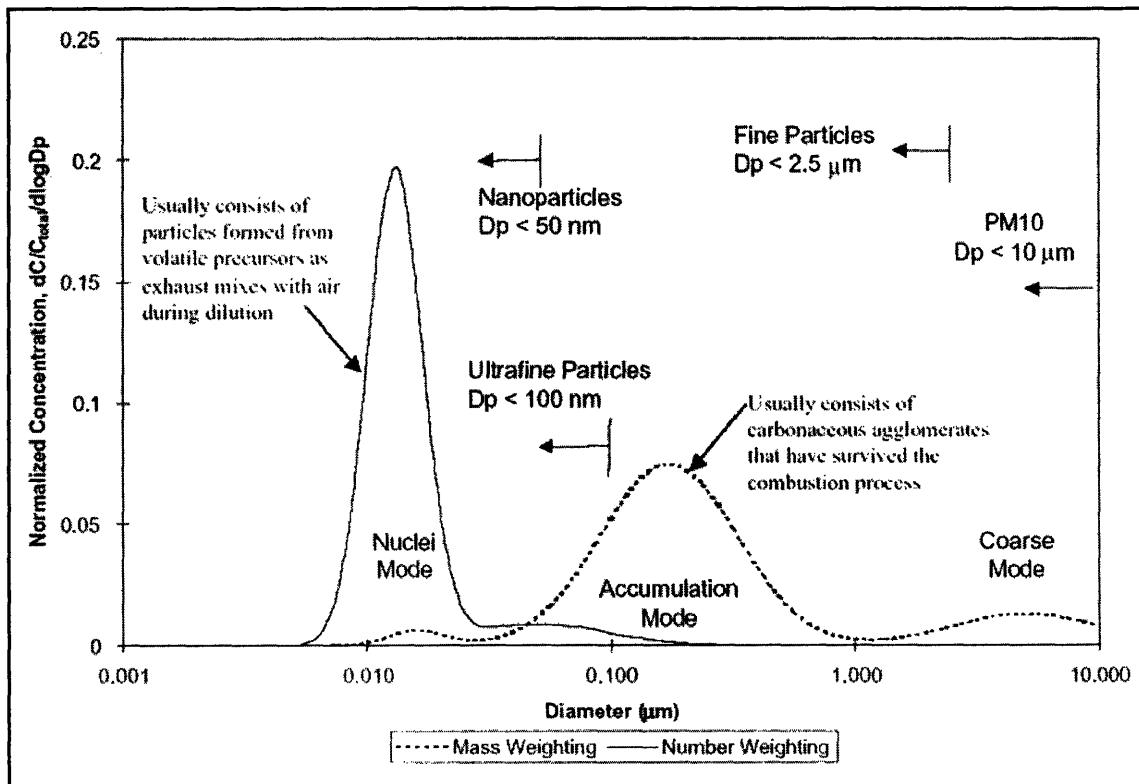
4.5.3 Diesel exhaust’s health effects

Most health concerns about diesel exhaust center around diesel PM, largely because of its long-term health effects. Diesel exhaust is a complex mixture of gases and particles. Gaseous constituents include CO₂, oxygen, nitrogen, water vapor, CO, NO_x and other nitrogen compounds, sulfur compounds, and various hydrocarbons. Several hydrocarbons are known to be individually toxic, including aldehydes, benzene, 1,3-butadiene, polycyclic aromatic hydrocarbons (PAHs), and nitro-PAHs (EPA 2002c). PM is composed of elemental carbon and adsorbed hydrocarbons, sulfate, nitrate, metals, and other trace elements. Particle size is important to the particle’s impact on human health. The heavier coarse-mode and accumulation-mode particles, with diameters ranging from 1 to 10 micron, are usually trapped in the nose,

mouth, and throat, never making it to the lungs. They can cause acute health problems, such as bronchitis or asthma, or exacerbate existing respiratory or cardiovascular problems. Smaller particles have a large surface area relative to their weight, making it easier to adsorb toxic hydrocarbons. Ultrafine particles with diameters 0.1 micron or less are more easily deposited in the deep lung, potentially leading to long-term respiratory problems (EPA 2002c).

When measured in terms of mass, the small nuclei mode particles can be easily overlooked. However, in number-based measurements, ultrafine particles make up the largest fraction of particles. Figure 4-15 shows how the concentration distribution varies depending on whether a mass or number weighting basis is used. Existing particulate regulations measure particulates on a mass basis. However, as emission control technology improves and particle mass decreases, the proportion of ultrafine particles in diesel exhaust has increased. In recent years, regulators have begun to consider regulating particle number as well.

Figure 4-15: Particle Size Distribution in Diesel Particulates



Source: Kittelson, Watts et al. (2001)

Since 1989, the World Health Organization’s International Agency for Research on Cancer (IARC) has classified diesel exhaust as “probably carcinogenic to humans.” This classification means that “there is limited evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in experimental animals.” It is one category short of saying that a substance is definitely carcinogenic. Most of the scientific evidence for carcinogenicity comes from occupational studies of lung cancer in workers exposed to diesel exhaust (EPA 2002c). Two influential cohort studies, the 1993 Harvard “Six Cities” study and the 1995 American Cancer Society study, drew attention to the health effects of fine diesel particles. They found that exposure to fine particles (PM2.5) significantly increases mortality rates. Following a reanalysis of the studies, the Reanalysis Team found that based on the Six Cities study, an 18.6 µg/m³ increase in fine particle concentration led to a 28% increase in mortality risk from all causes (including cancer, cardiopulmonary disease, and other causes). According to the reanalyzed ACS study, a 24.5 µg/m³ increase in fine particles led to a 18% increased mortality risk (Health Effects Institute 2000). In 1997, the US EPA adopted new particulate standards for PM2.5, not just PM10, largely based on the findings of these two studies.

Regulatory agencies have used scientific studies to calculate unit risk factors, which estimate diesel exhaust’s cancer risk. Unit risk is defined as the probability of contracting cancer per 1 µg/m³ diesel PM over a 70-year lifetime exposure. One of the most well-known unit risk estimates comes from the California Health Assessment of Diesel Exhaust. Its estimated unit risk of 3 x 10⁻⁴ is equivalent to 300 cancer cases out of a population of one million with an average lifetime exposure of 1 µg/m³ diesel PM (SRP/CARB 1998a). For the US EPA, an excess cancer risk exceeding one in a million for a single pollutant is considered unacceptable. Diesel exhaust’s cancer risk of 300 in a million is therefore considered very high, exceeded only by dioxin, chromium VI, cadmium, inorganic arsenic, and benzo(a)pyrene.

Table 4-6: Unit Risk Factors for Diesel Exhaust

Agency	Unit risk estimates (excess cancers)	Unit risk used for regulation
California EPA	1.3 x 10 ⁻⁴ to 2.4 x 10 ⁻³ (130-2400 per million)	3 x 10 ⁻⁴ (300 per million)
US EPA	10 ⁻⁵ to 10 ⁻³ (10-1000 per million)	none

Source: Scientific Review Panel, CARB (1998a); EPA (2002c)

Some recent research studies have drawn attention to the mortality risks of diesel exhaust. The World Health Organization (WHO) used a new study by Harvard researchers Pope et al. (2002) in its 2002 World Health Report review and recommendations. The new 2002 Pope et al. study conducted for the American Cancer Society showed that every additional $10 \mu\text{g}/\text{m}^3$ of $\text{PM}_{2.5}$ exposure increased the risk of all-cause, cardiopulmonary, and lung cancer mortality by 4%, 6%, and 8%, respectively. The linear exposure-effect relationship applied to a range of exposures from $7.5 \mu\text{g}/\text{m}^3$ to $50 \mu\text{g}/\text{m}^3$ (Pope III, Burnett et al. 2002). According to a report by Professor Dr. H.-Erich Wichmann at the National Research Center for Environment and Health in Neuherberg, Germany, 1-2% of the 800,000 annual deaths in Germany are attributable to premature death from diesel exhaust exposure. Of the 10,000 to 18,000 diesel-related deaths, 8,000-17,000 are from respiratory and cardiovascular diseases, and 1,100 to 2,200 are from lung cancer. In 2003, the average $\text{PM}_{2.5}$ exposure in Germany was $15 \mu\text{g}/\text{m}^3$ $\text{PM}_{2.5}$. Installing particulate filters on all diesel vehicles would bring the national average down to $3 \mu\text{g}/\text{m}^3$ $\text{PM}_{2.5}$. Wichmann estimated that equipping diesel vehicles with particulate filters would extend the average German's life expectancy by 1 to 3 months (Rodt 2003). A multi-country study by Kunzli et al. (2000) estimated that 6% of deaths in Switzerland, Austria, and France, equivalent to 40,000 deaths, are attributable to particulate pollution, half of which comes from motor vehicles.

4.6 Regulatory processes in the EU, Japan, and the US

Motivated by the health and environmental risks of air pollutants and diesel vehicles' significant share in NO_x and PM emissions, the EU, Japan, and the US have taken the global lead in establishing stringent emission and fuel standards. Each government has a different regulatory decision-making process, but all involve an initial proposal, consultation with scientific experts, industry, and other interested parties, and a final regulation. The regulatory decision-making process is also supported by research programs designed to establish a scientific basis for future standards. For example, each government sponsors auto-oil research programs designed to investigate the emission reduction possibilities through modifications in vehicles and

fuels. This section outlines the main actors and steps involved in each region, while the upcoming chapters explain the processes in the context of specific regulatory cycles..

United States

Since the Clean Air Act Amendments were passed by Congress in 1970, following the original 1963 Clean Air Act, sources of air pollution have been regulated to improve the country's air quality. The Clean Air Act was again amended in 1990, and subsequent laws and regulations have been added since then. Vehicle emission standards and fuel specifications have been used to reduce emissions from the motor vehicle industry. The US Environmental Protection Agency (EPA) sets National Ambient Air Quality Standards for six principal or "criteria" pollutants detrimental to human health – carbon monoxide, lead, nitrogen oxides, ozone, particulate matter, and sulfur dioxide. The Clean Air Act and its amendments grant EPA the regulatory authority to create national standards and strategies to control emissions of these criteria pollutants from both mobile and stationary sources.

EPA has a panel of outside experts that provides advice on air quality policy issues, especially in assessing the technical feasibility of proposed regulations. The Clean Air Act Advisory Committee (CAAAC) is comprised of approximately 60 senior managers and experts representing state and local government, environmental and public interest groups, academic institutions, unions, trade associations, utilities, and industry. CAAAC has subcommittees that convene to discuss more specific scientific and technical issues. The Mobile Sources Technical Review Subcommittee is still active in offering advice and recommendations on mobile source emissions and fuels. The Clean Diesel Independent Review Panel, which is no longer active, reviewed industry's progress in technology development to meet the new heavy-duty engine and fuel standards promulgated in 2001.

There are several steps that the EPA follows for new emission regulations. The EPA first issues a "Notice of Proposed Rulemaking" in the Federal Register. The notice explains the proposed rule and the motivation behind revising the existing regulations. It is accompanied by a Regulatory Impact Analysis (RIA) which provides analysis and supporting data for the new regulations. For example, the RIA for the 2004 on-highway heavy-duty diesel regulations covered the health impacts, technological feasibility, economic impact, environmental impact,

and cost-effectiveness of the proposed standards. There may also be additional documentation that provides the air quality modeling analyses used to support the proposed rule.

Along with the Notice of Proposed Rulemaking, the EPA schedules a comment period that allows interested parties to submit comments about the rule. It may hold public hearings, especially for major regulatory changes. Once the deadline for comments passes, the EPA reviews the comments and public hearing testimony. EPA staff members respond to them in the final rule, which may be amended or withdrawn depending on EPA's review of the comments.

In order to be sold in the US, engine and vehicle models must be certified by EPA as meeting emission limits under pre-specified test conditions. Separate certification may be necessary in California. California is the only state allowed to adopt more stringent light-duty vehicle emission standards because its state air regulations predated the EPA. Most states can choose between California and federal standards. Given the nature of interstate commerce, heavy-duty engines are required to adhere to federal standards only, but states and municipalities can impose restrictions on publicly-owned fleets. The Clean Air Act requires that EPA provides 4 years of lead time and 3 years of stability for heavy-duty engine and vehicle standards.

Europe

The European Union's emission and fuel standards are established by the European Commission, the executive body of the EU. The Environment DG (Directorate-General) is responsible for initiating and defining new environmental legislation, and is headed by the Commissioner for the Environment. Member State governments may also recommend new regulation to the Commission because of environmental concerns from constituents or pressure from domestic industries. For example, Germany has always taken an active role in shaping emission and fuel quality standards because of its population's environmental awareness and its strong domestic auto industry. All EU countries must adopt the same vehicle emission and fuel standards, but they are permitted to offer fiscal incentives to spur early adoption. Member States are responsible for granting type approval to vehicles and engines that meet the standards in accordance with the appropriate testing cycle.

Light vehicles are regulated under Directive 70/220/EEC and its amendments, and heavy vehicles are regulated under Directive 88/77/EC and its amendments. The amended Directives contain emission limit values and fuel quality specifications enforceable at a stipulated date. The

Parliament and the Council may fully articulate the upcoming standards in a Directive, but in some cases, Directives are incomplete and further clarification is needed.

When the European Commission prepares to amend a Directive, the European Commission prepares a preliminary draft proposal of new regulations. This draft proposal is based on discussions with key stakeholders (i.e. technical experts, manufacturers, national governments) and a technical review of ongoing research programs. To invite input from other interested stakeholders, the Commission initiates a public consultation process. Stakeholders can submit responses to the topics in the “call for evidence” or “call for consultation.” The responses are then reviewed and summarized by a panel of independent experts. Taking the responses into consideration, the Commission finalizes the proposal, which takes the form of an amendment to a Directive.

Japan

Japan’s Air Pollution Control Law, passed in 1968, gave the Director General of the Environmental Agency (called the Ministry of the Environment since 2001) the authority to establish emission limits for motor vehicles and specify standards for fuel quality (Japan Ministry of the Environment 1996). Motor vehicle emissions standards had already been enforced since 1966, beginning with the regulation of CO from gasoline vehicles. Over time, HC, NO_x, and PM regulations were added and revised. In 1995, the Air Pollution Control Law was amended to include permissible limits for gasoline and diesel fuel quality, which were implemented in 1996.

The Central Environment Council is the highest government advisory body on environmental policy. It regularly reviews progress towards Japan’s Basic Environmental Plan, and makes recommendations for improvement. In May 1996, the Director-General of the Environment Agency asked the Central Environment Council to make recommendations about the “Future Policy for Motor Vehicle Exhaust Emission Reduction.” In response to this request, the Central Environment Council has issued 8 reports between 1996 and 2005 (Japan Central Environment Council 2005). In each report, the Council proposes short-term and long-term emission and fuel quality targets. Like the US EPA’s reliance on expert panels, the Council consults with groups of experts. The Air Quality Committee of the Central Environment Council has an Experts Committee on Motor Vehicle Emissions, a group of 11 professors and research

institute directors. They continually conduct studies of future emission reduction measures by reviewing industry progress through investigations and hearings (Japan Central Environment Council 1997). The Committee then makes recommendations on future emission target values to the Environment Minister. After public and private meetings with interested parties, such as industry representatives and citizen groups, the Minister finalizes the target values proposed by the Council's report. In many instances, the Environment Minister, other government officials, and industry work collaboratively to agree upon emission target values and deadlines. In general, the consultation process is less transparent in Japan than in the EU or US, but the outcome tends to be a mutually acceptable agreement between government and industry.

4.7 Summary

All three regions' procedures for new regulations require soliciting input from industry, often at various points in the decision-making process. In addition to public consultations and private meetings with regulatory officials, industry has the opportunity to express its position through research programs, expert panels, and marketing/public awareness campaigns. While environmental regulations for the automobile have focused on air pollutants like PM and NO_x, growing concerns about CO₂ emissions and energy consumption suggest the need for reasonable trade-offs across multiple goals. The oil industry is also increasingly sharing the regulatory burden that had previously been shouldered mainly by the vehicle and engine manufacturers. The upcoming chapters will document a wide range of regulatory experiences, with varying degrees of cooperation between industry and government and diverse corporate responses.

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CHAPTER 5 – Light-duty Diesel Vehicles, 2004-2007

5.1 Introduction

This chapter covers the regulatory and market implications of the new light-duty diesel vehicle emission standards, set for 2004-05 in the EU, Japan, and the US. Regulatory and market conditions since the 1990s are described and compared in each region. Different outcomes stem from each region's specific regulatory priorities and economic incentives. The strength of the European diesel passenger car market has given European regulators added incentive to balance pollution concerns with preserving the booming market for the popular and fuel-efficient diesels. America's low fuel prices and the Japanese preference for small, gasoline or hybrid vehicles and have contributed to the two countries' lukewarm feelings toward diesels. Although US regulators had previously given diesel cars slight leniency on emission standards compared to the gasoline counterparts, recent technology-forcing regulations harmonizing gasoline and diesel standards will make compliance extremely difficult and costly for diesel cars. Japanese diesel standards previously had the reputation for lower stringency compared to the EU and the US, but recent anti-diesel regulation in Japan has made the regulatory environment more challenging for diesels.

By the 1990s, the motor vehicle industry had already experienced repeated cycles of increased regulatory stringency on emission levels. In the US, passenger vehicles were subject to the Tier 1 standards from 1997 to 2003. Meanwhile, cars sold in California had to reach the lower emission levels of the state's LEV I (Low Emission Vehicle) standards, which were in effect from 1994 to 2003. In Europe and Japan, standards change more frequently and at smaller increments, such that there are revised standards approximately every 4 years. Japan had new diesel passenger car standards in 1986, 1990, 1994, 1997, 2002, and 2005. The European Union had their Euro 1 standards starting in 1992, Euro 2 in 1996, Euro 3 in 2000, and Euro 4 in 2005. Because each region has a different timeline for establishing and implementing emission standards, one practical approach to comparing them is to take a representative year or narrow time window when vehicle manufacturers had to meet the standards.

Table 5-1 shows the regulatory timelines for the EU, Japan, and the US (including California).

Table 5-1: Regulatory Milestones for Vehicle Emission Standards Starting in 2004/2005

Event	EU Euro 4	Japan	US federal Tier 2	California LEV II
Standards proposed	1995	1998	1998	1998
Standards finalized	1998	2002	2000	1998
Start of compliance	2005	2005	2004	2004
Phase-in period	2005	2005	2004-07	2004-07

Sources: Dieselnets (2006), EPA (2000), European Commission (1998), Japan Central Environment Council (2002).

The following are the standards adopted for each region. Except for the US and California standards, they are not directly comparable because of each country's different certification test cycles and conditions.

Table 5-2: Light-duty Diesel Vehicle Emission Standards

Pollutant	Euro 4	Japan	US Tier 2 Bin 5* & CA LEV II LEV
NO _x	0.25 g/km	0.14 g/km	0.07 g/mi (0.044 g/km)
PM	0.025 g/km	0.013 g/km	0.01 g/mi (0.006 g/km)
CO	0.5 g/km	0.63 g/km	4.2 g/mi (2.61 g/km)
NMOG			0.09 g/mi (0.056 g/km)
HCHO			0.018 g/mi (0.011 g/km)
NMHC		0.024 g/km	
HC+NO _x	0.3 g/mi		
Full life	100,000 km	80,000 km	120,000 mi (193,080 km)

* The US does not have a single emission standard, but 8 different certification "bins" with different levels of stringency. Manufacturers may certify vehicles in any bin, but the average emission level of the total fleet sold must be equivalent to the emission standard of the middle bin (Tier 2 Bin 5). California's LEV II program has a single standard, which is the same as the Tier 2 Bin 5 level.

Sources: Dieselnets (2006), EPA (2000), European Commission (1998), Japan Central Environment Council (2002).

By the year 2005, the US was already in its second year of implementing its federal Tier 2 standards, with California and several Northeast states implementing California's LEV II standards. California is permitted to set more stringent regulations than the federal standards because its standards predated the creation of EPA, and the state's historically poor air quality requires stricter control strategies. Euro 4 had just gone into effect in Europe; Japan had a set of new standards for 2005. Although these regulatory deadlines converge in 2004-05, the processes for setting these regulations and the technological and political influences occurred at various points in the 1990s.

5.2 Europe

Since 1970, under Directive 70/220/EEC, the European Commission has regulated exhaust emissions from passenger cars. Amendments to this directive have required increasingly lower levels of pollutant emissions. By 1992, new vehicles were expected to meet Euro 1 standards limiting emissions of PM (diesel only), CO, HC, and NOx. Starting with Euro 2, diesel cars had to meet more stringent CO standards than gasoline cars, but less stringent NOx standards.

Table 5-3: EU Diesel and Gasoline Passenger Car CO and NOx Standards

Regulation	CO (g/km)		NOx (g/km)	
	Diesel	Gasoline	Diesel	Gasoline
Euro 1	2.72	2.72	0.97*	0.97*
Euro 2	1.0	2.2	0.9*	0.5*
Euro 3	0.64	2.30	0.50	0.15
Euro 4	0.50	1.0	0.25	0.08
Euro 5	0.50	1.0	0.20	0.07

* HC + NOx

Source: Dieselnets (2006), Original: European Commission (1998)

Vehicles are tested and certified as meeting these emission limits before they can gain type approval, a prerequisite for sales. In subsequent years, emission limits have become more stringent, with Euro 2 in 1996, and then Euro 3 in 2000. However, diesel vehicles are perceived

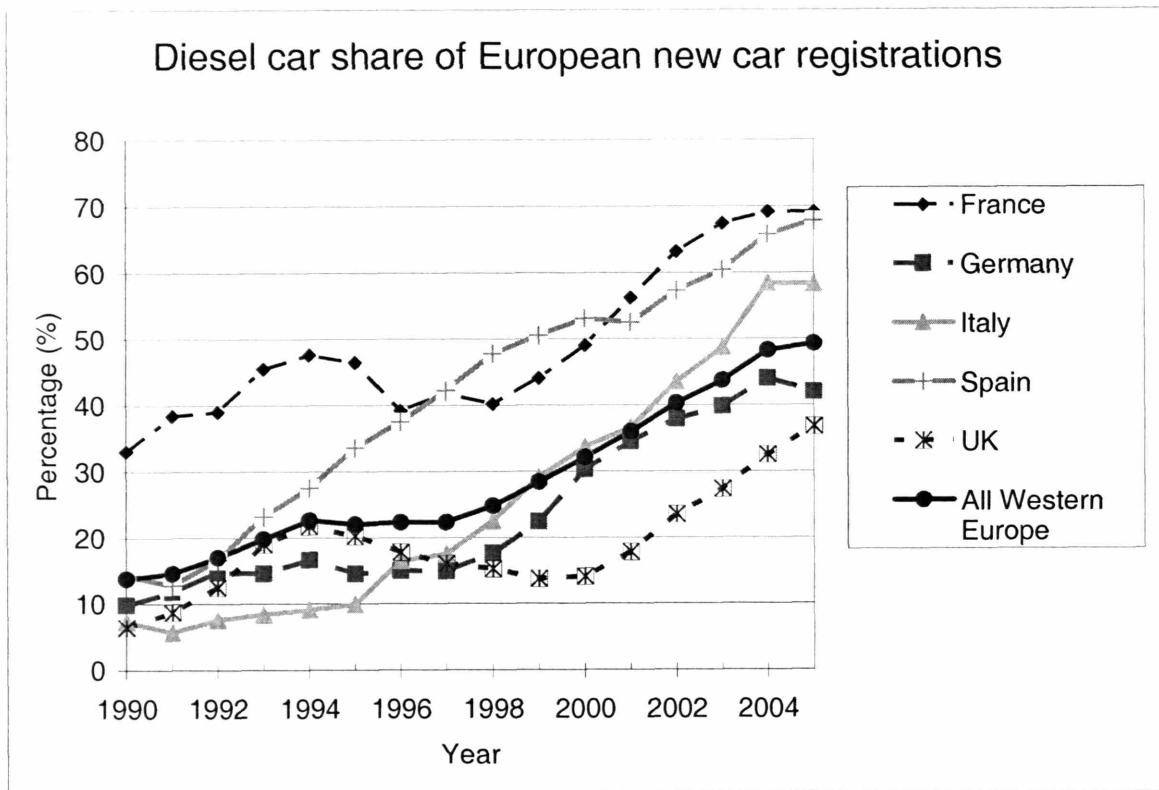
as receiving more lenient standards than their gasoline counterparts and benefiting from advantageous fuel policy. Europe may be giving more leeway for emissions from diesel vehicles in recognition of their higher fuel economy.

5.2.1 Market for diesels in Europe

The combination of the diesel car's greater fuel efficiency, high fuel taxes, and differential taxes favoring diesel has spurred diesel demand in Europe since the oil crises in the 1970s, with the greatest growth in the last decade. Diesel cars are approximately 30% more efficient than their gasoline counterparts. In 2000, gasoline prices in Europe averaged €0.80 per liter (US\$3.70 per gallon) and average diesel prices were significantly lower, equivalent to \$2.70 per gallon. Government agencies taxed diesel fuel at a lower rate to encourage fuel efficiency. Its use in commercial transport and strong lobbying by the freight sector also contributed to the lower diesel taxes. The greater efficiency of diesel vehicles and the preferential fuel taxing policy persuaded consumers to pay the higher price tag for diesel vehicles, which generally retail for €1000-1500 more than their gasoline counterparts. In Chapter 4, Figures 4-8 and 4-9 illustrated the high fuel prices and large diesel-gasoline tax differential in European countries, and to a lesser extent, Japan. High excise taxes make fuel prices in Europe and Japan approximately double that of the US.

In Europe, diesels' share of new passenger cars rose steadily from 13.8% in 1990 to 47.5% in 2004 (Figure 5-1). New car sales in Austria, Belgium, France, Luxembourg, and Spain are already around 70% diesels (ACEA 2005). They are also among the countries with the highest diesel-gasoline tax differentials. In a study of diesel taxation, Mayeres and Proots (2001) found that diesel penetration rates are higher in countries with the relatively low ownership and fuel taxes for diesels, indicating a clear economic explanation for the popularity of diesels. By 2004, Volkswagen, DaimlerChrysler, Renault and PSA Peugeot Citroën were selling more diesel than gasoline vehicles (Lewis 2004).

Figure 5-1: European Diesel Boom



Sources: ACEA 2003, AID Newsletter 2004, LMC-JD Power 2004

The diesel boom increased concern about the long-term health effects of exposure to diesel exhaust. NGO campaigns and greater public awareness put pressure on government regulations to set more stringent emission limits on diesel vehicles. While vehicle emission policies would encourage the adoption of cleaner diesel technologies, they also had the potential to greatly restrict the future growth of the diesel market. Ultimately, the development of the European emission policy for 2005, i.e. the Euro 4 standards, allowed the diesel market to continue to flourish. Financial incentives promoting the early introduction of Euro 4-compliant vehicles encouraged manufacturers to meet the standards up to 2 years ahead of schedule. However, some environmental critics have claimed that the EU standards are still too lenient for diesels.

5.2.2 Regulatory process in the EU

At an October 1992 conference, the European Commission discussed vehicle emission standards for 2000 and beyond. Previous discussions about vehicle emission policy had generated heated disagreements among the auto industry, oil industry, and the government. In particular, industry complained that the cost of further emission reductions would outweigh the environmental and health benefits. The auto and oil industries debated about the extent to which their respective industry should invest in cleaner technologies. Government and industry agreed that they should develop a more cooperative and integrated basis for future regulations. This led to the 1993 formation of the Auto Oil Programme, a collaboration among the European Commission, ACEA (the European auto companies' industry association) and EUROPIA (the European oil companies' industry association).

The purpose of the program was to find the most cost-effective ways to reduce vehicle transport emissions to reach air quality goals. It was designed to promote a collaborative, rather than antagonistic, relationship between government and industry. The parties sought to avoid the lawsuits that plagued the US emission standard-setting process (Automotive Environment Analyst 1996a). The automobile and oil industries would share the burden of emission reductions, based on the measures that would be the most cost-effective. The program included a technical research portion (European Programme on Emissions, Fuels and Engine Technologies), an air quality modeling study, and a cost-effectiveness modeling study. Recommendations were made for fuel quality and automobile emission standards. The first phase, Auto Oil I, ran from 1993 to 1997. It generated results that provided the basis for the 2000 Euro 3 standards and tentative 2005 Euro 4 standards (European Commission, Standard & Poor's DRI et al. 1999). By November 1995, the cost-effectiveness results from the Auto Oil Programme were released (European Commission, Standard & Poor's DRI et al. 1999). In December 1995, the Commission proposed the following Euro 3 and Euro 4 passenger vehicle emission standards:

Table 5-4: Draft Diesel Passenger Car Emission Standards, December 1995 Proposal

	CO (g/km)	NOx	HC + NOx	PM
2000 Euro 3	0.64	0.37	0.50	0.05
2005 Euro 4	0.53	0.28	0.39	0.04

Source: Automotive Environment Analyst (1996b)

The complete Auto Oil Programme results were released in early 1996. After reviewing the Auto Oil I results and consulting with the auto and oil industries, the Commission worked on a revised package of measures to reduce emissions. A revised proposal was adopted in June 1996. In the six months between the draft proposal and the revised proposal, the auto industry lobbied the Commission heavily, arguing that diesel technology was not advanced enough to reach the 2000 NOx target. Also, the ultra-low sulfur diesel fuel needed for some of the NOx reduction technologies would not be widely available until 2005. NGOs claimed that the reliance on the Auto-Oil I's cost-effectiveness methodology led the Commission to overlook the public health effects and to sympathize with the auto industry's complaints about high compliance costs (Europe Information Service 1996b).

Table 5-5: Revised Diesel Vehicle Emission Standards, June 1996 Proposal

	CO (g/km)	NOx	HC + NOx	PM
2000 Euro 3	0.64	0.50	0.56	0.05
2005 Euro 4	0.50	0.25	0.30	0.025

Note: Changes from December 1995 proposal are shown in shaded boxes.

Source: European Commission (1998)

As shown in Table 5-5, the June 1996 proposal did feature a significantly weakened Euro 3 NOx standard, from 0.37 g/km to 0.50 g/km, but it proposed a significantly more stringent Euro 4 PM standard. PM control strategies are generally easier and less costly for the auto industry than NOx control strategies. In exchange for the weakened 2000 NOx standards, the indicative standards for 2005 would be more stringent (Europe Information Service 1996a). The Commission promised to finalize the indicative standards in 1998, then run a review program to verify their feasibility in 2002 (EC 2000).

5.2.3 Role of the Auto Oil Programmes

The emission and fuel recommendations from the Auto Oil I Programme placed a significantly larger burden on the auto industry than the oil industry. The Auto Oil I study had shown that greater and less costly reductions came from vehicle improvements rather than fuel specification changes. Over a 15-year time horizon, the package of recommendations would cost the auto industry €2.44 billion per year and cost the oil industry €765 million per year. Even though both industries contributed resources to the research program, they disagreed about the fairness of the recommendations. The auto industry criticized the imbalanced contributions while the oil industry supported the results' reliance on cost-effectiveness. A Commission official responded by saying that "Auto-Oil is not based on a cost-sharing principle but on cost-efficiency" (Europe Information Service 1996a).

The second phase of Auto Oil, called the Auto-Oil II Programme, began in 1997. In addition to fulfilling a variety of air quality and related objectives, it was intended to provide a technical basis for confirming or revising the indicative 2005 standards that were proposed during the Auto Oil I process. By October 1998, the European Parliament was already prepared to finalize the 2005 vehicle emission standards with Directive 98/69/EC, using the same standards that had been proposed in June 1996 (EC 2000). The European Parliament and the Council issued an official document in December 1998, setting the Euro 3 and Euro 4 standards for 2000 and 2005. By the end of 1999, the Commission submitted a proposal to the European Parliament and the Council finalizing this Directive.

Because the Euro 4 standards were settled earlier than expected, the Auto Oil II Programme was not needed to provide meaningful input into vehicle emissions standards. As a result, the mission of Auto-Oil was revised in fall 1998 to assess future air quality policy options using a cost-effectiveness framework and to provide a methodological foundation for future air quality studies (European Commission, Standard & Poor's DRI et al. 1999).

5.2.4 A premature first mover

As reflected in the European auto industry's complaints about the high cost of emission regulation, it has generally been opposed to increased regulatory stringency. However, once the standards and implementation timeline are established, the companies do strive to produce compliant vehicles in a cost-effective manner. However, a regulatory requirement is not the only motivation behind developing environmental technology. Perception of customer demand or future regulatory demand has prompted some companies to introduce technology early or in advance of regulation. A company is unlikely to voluntarily pursue such an early or first-mover strategy unless it expects to derive some private benefit from it. It may desire to improve its environmental image, appeal to environmentally conscious customers, or to demonstrate its technology leadership.

Because the Euro 4 standards were established by 1996, 9 years before their implementation date, there were no first-mover companies at that point who introduced technology to meet the standards. The Auto-Oil Programme was committed to identifying cost-effective, best available technologies to meet upcoming standards, so it did not assume that still-developing technologies would be at a commercial stage to meet Euro 4.

One company that did make an attempt to act as a first mover in diesel technology in the pre-1996 time frame was Volkswagen (VW). In 1993, when Euro 1 standards were still in effect, VW announced its plans to introduce the "Ecomatic" Golf model with a hybrid diesel-electric powertrain. The company planned to market its Ecomatic as a more "ecological" version of its 1.9-liter Golf diesel. It expected that environmentally-minded consumers would be attracted to its lower emissions, fuel economy, and unique technology. The Ecomatic was VW's response to Europe's growing interest in battery-electric cars and other alternatives to gasoline and diesel-powered cars. Rival PSA Peugeot Citroën already had a test fleet of 50 electric cars on the road, and it planned to sell 5,000 of its electric cars in 1994. PSA even teamed with French national power generating company EDF to establish electricity refueling infrastructure. French and Italian automakers projected the Europe's electric car market to grow to 200,000 cars by 2000. VW sought to counter that with its hybrid diesel-electric technology (Marshall 1994).

After VW introduced the Ecomatic in Germany in January 1994, it introduced it in Britain in mid-1994, where it generated considerable excitement in the automotive press, but a

lukewarm reception from consumers. The vehicle was touted by one journalist as “a new car [which] leaps ahead of the pack” (Kemp 1993). Its hybrid diesel-electric engine turned off when the vehicle was not in motion and it could run on sunflower seed-derived biodiesel. According to VW’s 1995 Environmental Report, its fuel consumption, CO₂, pollutant emissions, and engine noise in average urban driving would be reduced significantly compared to the regular diesel Golf. For high-speed, highway driving, the reductions would not be as noticeable because of the relative lack of stop-and-go driving; the vehicle’s fuel economy would be no better than a regular Golf diesel.

Table 5-6: Volkswagen Ecomatic’s Fuel and Pollutant Reductions in Urban Driving

Characteristic	Reductions compared to regular diesel Golf
Fuel consumption	-22%
CO ₂ emissions	-22%
HC + NO _x	-25%
CO	-36%
PM	-60%
Noise emissions (from engine off periods)	-60%

Source: Volkswagen (1995)

The development cost of the Ecomatic was 20 million DM (US\$11.5 million in 1994 dollars). In the UK, it retailed for 1000 GBP (US\$1500) more than the normal diesel Golf, which was 10,000 GBP (US\$15,000). The price never had the chance to go down because production volumes were so low. VW had hoped to sell 10,000 vehicles in 1994, but changed its target to 3,000 by mid-year. It ultimately sold closer to 2,000 units (Kemp 1993; Marshall 1994). Electric car sales by PSA, Renault, and other automakers were also disappointing – annual sales were in the hundreds rather than the thousands (Diem 1996). Despite the promise of fuel savings, customers were unwilling to pay the higher price for the hybrid or battery-electric cars.

The Ecomatic’s higher retail price was not the only hurdle to consumer adoption. It operated differently from a typical diesel car. It lacked the quick, responsive acceleration of a normal diesel, because its engine shut off during idling (Catterall 1994). Citing poor consumer demand, VW pulled the Ecomatic off the market in 1995 after only one year of sales. Although

the emission reductions and fuel savings of the vehicle were impressive, the lack of financial incentives or regulatory requirements for this technology prevented its adoption.

There is no evidence that the performance of the Ecomatic influenced government regulators, at the country or EU level, to consider more stringent regulations. Moreover, while the Ecomatic emission reductions were significant compared to the regular diesel Golf, they were not large enough to be compliant with the proposed Euro 3 regulations.

5.2.5 Countries and companies as early adopters

Some European countries – Sweden, Finland, Germany, and the Netherlands, among others – have a long record of introducing tax incentives to encourage early compliance with future regulations. Promoting cleaner technologies and penalizing the more polluting ones help to accelerate the environmental and health benefits of emission requirements. Governments also have national interests in mind. They recognize that emission regulations are becoming more stringent around the world. If they can encourage their domestic firms to market advanced technology in their home market, their domestic industry will be well poised to capture more market share when other countries tighten their standards. For this reason, these “first-mover countries” often lobby other countries to harmonize their standards upward.

In an effort to encourage early adoption of Euro 4-compliant technologies, individual national governments began offering tax incentives for customers to purchase Euro 4 cars before the 2005 deadline. In Germany, a diesel car is taxed at an annual rate more than twice that of a gasoline car to compensate for its higher particulate emissions and lower fuel prices, but diesels complying with Euro 3 or Euro 4 standards early receive larger tax breaks. If a diesel car complied with Euro 3 before 2000 or Euro 4 before 2005, it received a tax break equivalent to US\$553. If it also emitted less than 90 g of CO₂ per km, it would be eligible for a US\$1,012 tax reduction (GTZ and UNESCAP 2002). In the UK, company cars, which comprise 50% of new car purchases, are taxed according to CO₂ emissions, measured in gram per kilometer. Cars with lower CO₂ emissions pay a higher tax rate, so diesels have an inherent advantage. However, because of concern about diesels’ higher particulate emissions, the British government added a 3% supplemental tax on the purchase price of diesels in 2002. To encourage the adoption of new clean diesel technology, the government waived the 3% tax if the vehicle was Euro 4-

compliant before 2005 (Burt 2001). Although the cleaner vehicles may have a higher retail price, these tax policies made the lower-emitting technologies cost-neutral or even cost-effective compared to the older technologies.

At the time that Germany and the UK offered tax incentives for diesel cars compliant to Euro 4 standards before 2005, no auto manufacturer had any such vehicles on the market. Although Fiat had announced in 1998 that its new prototype common-rail turbo diesel was already capable of meeting the Euro 4 standards, it did not put any such models into production until years later, once other manufacturers had introduced Euro 4-compliant models (Automotive Environment Analyst 1998).

5.2.6 First early mover Toyota, followed by the rest

In December 2002, Toyota announced that its new Corolla and Avensis models would be Euro 4-compliant, 2 years in advance, thanks to their new D-4D engines. The models would be available in the UK first, in March 2003, and then in the rest of Europe in April 2003. Toyota's announcement as the first mover preempted other companies' announcements of Euro 4-compliant vehicles. In early 2003, when the new Avensis was already on the market, Toyota introduced its even cleaner D-CAT (Diesel Clean Advanced Technology) engines for the Avensis. D-4D already meets the Euro 4 standards, but D-CAT surpasses the NO_x limit by 50% and the PM limit by 80% (Toyota 2003). However, it requires ultra-low sulfur fuel, below 50 ppm sulfur and preferably 10 ppm. In its first years, the vehicle could only be offered in countries with fuel sulfur levels 50 ppm or lower, such as the UK, Germany, and Sweden (Auer 2002). Toyota introduced the technology in advance of regulation and fuel availability largely to demonstrate itself as a clean diesel technology leader in a diesel vehicle industry dominated by European automakers. It recognized that introducing the D-CAT system early would prepare the system for widespread introduction in 2005, once ultra-low sulfur fuel was available throughout the EU (Toyota 2003). D-CAT's impact on subsequent regulations is discussed further in the next chapter.

By summer 2003, several other manufacturers followed with their Euro 4 announcements. PSA Peugeot Citroën, which was already receiving a lot of publicity for its particulate filter system, announced that their third generation of their filter system, available June 2003, would

be fully Euro 4-compliant. Previously, it had not met the NO_x limit of the Euro 4 standard. In July, Volkswagen announced that most of its VW and Audi models would reach Euro 4 standards by 2004. Many other manufacturers showcased their Euro 4-compliant vehicles at the September 2003 Frankfurt Motor Show. A review of press releases and industry publications from that time indicates that Toyota, PSA, Volkswagen, Audi, Vauxhall, Fiat, Ford, BMW, and Renault had Euro 4-compliant models ready for 2003. Other auto manufacturers followed shortly in early 2004 (Maslen 2003; Peckham 2003b).

When the Euro 4 standards were proposed in 1995, it was expected that the PM standards would require the installation of PM filters on all diesel cars. However, improvements in engine technology allowed most cars to meet the PM standards without filters. Because the NO_x standard was not as stringent as proposed earlier in December 1995, engineers had more flexibility to optimize for PM reduction. Emission control manufacturers had anticipated huge demand for their aftertreatment devices, but most automobile manufacturers were able to use in-house technology to meet the Euro 4 standards.

5.3 United States

5.3.1 Market for diesels in the US

The last time that light-duty diesel vehicles were popular in the U.S. was in the late 1970s and early 1980s, when the fuel crises prompted Americans to buy more fuel-efficient diesel-powered cars. Despite the fuel savings, diesels then were considered noisy, dirty, and unreliable (Winter 2002; Wright 1999). Sales of diesel passenger cars peaked at 6.1% in 1981. Once fuel prices fell, the diesel share tapered off to below 0.5% in 1986-2004 (Ward's Automotive Yearbook 2005). Light-duty trucks have a higher proportion of diesel-powered engines than passenger cars. However, even when they are included in the figures for the broader category of light-duty vehicles, the US diesel share is still only 3.2% (J.D. Power and Associates 2006). As described in Chapter 4, the relatively low fuel prices and the lack of diesel bias in fuel tax policies have offered US customers little incentive to purchase diesels.

5.3.2 Regulatory process in the US

In 1997, just as the Tier 1 vehicle standards went into effect, the US Environmental Protection Agency (EPA) was already preparing the Tier 2 standards, new federal vehicle emission and fuel standards for 2004 onwards. EPA held informal workshops and consultations to lay out the issues and solicit input from interested stakeholders, i.e. companies, NGOs, other government agencies. Several key issues pertaining to diesel vehicles were under discussion:

- (1) Should light-duty diesel vehicles be subject to the same NO_x limits as gasoline vehicles?
- (2) Should PM limits be based on the performance of diesel engines or gasoline engines, which have lower PM levels?
- (3) Should passenger cars and light-duty trucks/SUVs face the same emission standards?

Ultimately, US regulators harmonized the light-duty vehicle regulations across powertrains and vehicle sizes, and used the cleanest gasoline-powered vehicles as a basis for the standards. This biggest regulatory challenge for diesel vehicles is NO_x emission reduction, which is far more difficult for diesels than for gasoline vehicles. Very low sulfur fuels are essential to significantly reducing NO_x and other pollutant emissions. In order to convince regulators that clean fuels was necessary, automakers had to demonstrate very clean prototype vehicles early to show that their technology would be ready once very low-sulfur fuel was available. For this reason, auto industry opposition to Tier 2 was not as strong as it would have been had the EPA not also proposed significant reductions in gasoline and diesel fuel sulfur levels.

EPA issued a proposal of the Tier 2 regulation in May 1999, and gave notice of a 3-month comment period, during which interested parties could submit comment letters in response to the proposal. During the summer of 1999, EPA also hosted public hearings in four cities and received oral and written comments. EPA completed its Regulatory Impact Analysis in December 1999, and published the final version of the Tier 2 regulation in the Federal Register in February 2000 (EPA 2000). The federal Tier 2 standards were primarily based on the California LEV II standards, which had been finalized in 1998, well before the Tier 2 proposal. EPA sought greater harmonization between the federal and California standards, a move supported by manufacturers seeking a single standard.

Table 5-7: US Tier 2 and California LEV II standards

Pollutant	Proposed Tier 2 (as of 1997)	Tier 2 Bin 5 (average)	California LEV II
CO	1.7 g/mi	4.2 g/mi	4.2 g/mi
NMOG		0.09	0.09
NO _x	0.2	0.07	0.07
PM		0.01	0.01
HCHO		0.018	0.018

Sources: EPA (1997), CARB (1999), EPA (2000).

5.3.3 California's lead in standard-setting

In an April 1997 Tier 2 Study White Paper, EPA outlined the need to solicit information about the cost of requiring diesel vehicles to meet the same standards as gasoline vehicles as well as the potential air quality impact if leniency to diesels were allowed. Originally, according to the 1997 white paper, the national standards would be different from California's standards (EPA 1997). However, this changed when automakers and northeastern states entered into an agreement that led to the voluntary National Low Emission Vehicle program. By 1999 in the northeastern states and 2001 nationally, auto makers were expected to sell cars and light-duty trucks cleaner than federally mandated by the Tier 1 standards (Dieselnet 2006). The National LEV program harmonized the federal and California standards, so it was not a surprise that EPA would use the California LEV II standards as a template for the Tier 2 standards.

California LEV II standards

Table 5-8: Light-Duty Vehicle Emission Standards for 120,000 Miles (Full Useful Life)

Category	NMOG	CO	NO _x	HCHO	Diesel PM
LEV	0.090 g/mi	4.2 g/mi	0.07 g/mi	0.018 g/mi	0.01 g/mi
ULEV	0.055	2.1	0.07	0.011 g/mi	0.01
SULEV	0.010	1.0	0.02	0.004 g/mi	0.01

Source: CARB (1999)

The California LEV II standards were finalized in November 1998, with a phased-in implementation from 2004 to 2007. In 2004, only 25% of each manufacturer's fleet must meet

the LEV II standards; the remaining vehicles must meet interim standards. For every year until 2007, the LEV II-compliant share must increase another 25% until it reaches 100% in 2007. Diesel and gasoline vehicles face the same standards, and medium-duty vehicles (trucks, SUVs, vans) below 8,500 lbs must meet the same standards as passenger cars. Vehicle manufacturers must produce a certain percentage of vehicles in the more stringent ULEV and SULEV emission categories, which increase during the implementation period. The full useful life was increased from 100,000 miles to 120,000 miles. CARB had proposed a 0.07 g/mi NO_x standard from the beginning, and it is reflected in the final standards (CARB 1999).

Matching the California regulations, EPA changed its full-life durability requirements to 120,000 miles. Full-life durability refers to the distance of testing for which vehicles must meet emission requirements to receive certification. While California has three emission categories – LEV, ULEV, and SULEV, Tier 2 has a fleet bin averaging system, with 8 certification bins. Each manufacturer can certify vehicles in any bin, but their fleet must have an emission average equivalent to Bin 5, which matches the California LEV II standards (EPA 2000).

Because Tier 2 was based on the California standards, which were finalized 2 years prior, it is more meaningful to focus on the LEV II regulatory process – technical submissions and regulatory documents from 1998 and earlier, and the influence of technology development on California rulemaking. For example, in EPA’s technical feasibility analysis, EPA cited the California Air Resources Board (CARB) and the Manufacturers of Emission Control Association (MECA) evaluation programs targeted toward the LEV II standards because it was known that the Tier 2 standards would be the same as the LEV II standards. California had a crucial role in leading the way for emission standards.

Testing and public statements

CARB and EPA relied on their own testing as well as technical submissions from industry to set emission standards. The testing conducted by CARB and MECA demonstrated that gasoline-powered light-duty vehicles would be capable of meeting the proposed emission standards. Much of the focus was on the NO_x standard, which was arguably the most challenging standard to meet. MECA sponsored a test program at the Southwest Research Institute (SwRI) to demonstrate the ability of Tier 1-compliant vehicles to meet Tier 2 and LEV

II standards when equipped with advanced catalytic converters provided by MECA members. Catalysts were aged to 100,000 miles, and all the retrofitted vehicles achieve NO_x levels below 0.07 g/mi.

CARB also ran tests on MY1997-1998 models of passenger cars. They measured it without alterations, and then again after modifying them to meet LEV II standards. However, they were not aged so the effectiveness of the modifications may have degraded over time. CARB even tested modified 1998 Ford Expeditions, which had been certified to 0.14 g/mi. Meanwhile, EPA conducted tests on large heavy light-duty trucks (LDT3 and LDT4), modifying the trucks to meet Tier 2 standards at intermediate useful life (50,000 miles, as opposed to the full life of 100,000 miles).

Both CARB and EPA conceded the difficulty for diesel vehicles to meet the new emission standards. In its preliminary staff report, CARB acknowledged the uncertainty about whether diesels would meet the new standards in the near term: “The data for light-duty diesel vehicles suggest that significantly more development is needed for these vehicles to meet a 0.010 g/mi PM standard. Recent certification data from two light-duty diesel vehicles shows PM emissions of 0.05 g/mi and NO_x emission of 0.7 g/mi. Given the low NO_x standards being proposed for LEV II and the difficulty associated with simultaneously achieving both low NO_x and PM emissions from diesel engines, it is unclear whether diesel vehicles will be able to achieve a 0.01 g/mi LEV or ULEV PM standard in the foreseeable future” (CARB 1998). In the Tier 2 Regulatory Impact Analysis, the EPA shared this recognition.

The ability of some gasoline-powered light-trucks and SUVs to meet NO_x emission levels below 0.07 g/mi as early as 1999 had the effect of convincing regulators that there was justification for reducing all vehicles to that emission level. “[CARB] concluded that the more stringent standards for the remaining vehicle emission categories could be met by a full range of gasoline and alternative fuel vehicles, making it inappropriate to allow substantially higher NO_x and particulate levels to assure availability of diesel cars and light trucks” (CARB 2001). EPA also believed that light-duty diesels should not receive greater leniency, especially when most U.S. light-duty vehicles were gasoline-powered. Weaker diesel standards would “undermine the emission reductions expected from this program” (EPA 1999).

During CARB’s rulemaking processes in 1997-1998 and EPA’s in 1999-2000, there were no diesel vehicle manufacturers that stepped forward with technologies capable of meeting the

proposed standards. Emission control manufacturers were characteristically optimistic about the ability of their developing technologies to meet the standards, because they stand to sell more products with more stringent standards. However, a truck/bus manufacturer and an engine manufacturer publicly acknowledged that the proposed standards might be attainable in the future. A few years later, but prior to the regulatory deadlines, they introduced low-emission diesel vehicle prototypes capable of meeting the Tier 2 standards.

Navistar International, which specializes in medium-duty trucks and buses, submitted comments for EPA's Tier 2 "Notice and Comment" period. Navistar claimed that Tier 2 standards would be "challenging but achievable" if low-sulfur fuel were available (EPA 1999). Cummins, a leading diesel engine manufacturer, indicated to the trade press in 1999 that it could meet the interim Tier 2 standards for vehicles and trucks in the early years of Tier 2 through future development of currently available engine technology (Hart Diesel Fuel News 1999). EPA's Regulatory Impact Analysis for the Tier 2 rulemaking made note of this statement in justifying the stringency of the emission standards and articulating the later phase-in dates of the diesel vehicles (EPA 1999). EPA was in agreement with manufacturers about the need for ultra-low sulfur fuel to meet the final diesel standards in 2007 for light-duty cars and trucks and in 2009 for heavy light-duty trucks (EPA 1999).

Navistar International and Cummins' expression of confidence in reaching the new Tier 2 standards was indicative of their technology readiness. In 1999 and 2000, their public announcements and technology demonstrations confirmed this readiness. Navistar International had already been developing their Green Diesel Technology for the school bus market. In June 1999, the company strategically demonstrated their Green Diesel school bus outside the EPA hearings on Tier 2 regulations. The bus had a continuous regenerative particulate trap capable of reducing PM by over 90%, so that PM emissions were well within the EPA's Tier 2 PM limit (Automotive Environment Analyst 1999). Buses are typically regulated with heavy-duty engine regulations, which are separate from the light-duty vehicles regulations in Tier 2. Showcasing a school bus when the hearings were focused on cars and light-duty trucks may have appeared confusing. Navistar's main goal was not to show support for the Tier 2 vehicle emission limits, but to stress the necessity of ultra-low diesel fuel (PR Newswire 1999). Cummins continued working on light-duty diesel engines, trying to get them to meet the elusive Tier 2/Bin 5 emission standards. In the 2001 Diesel Engine Emissions Reduction (DEER) conference,

Cummins presented a prototype diesel engine for light-duty trucks and SUVs that could reach the Bin 5 standards. In 2003, it conducted durability testing for the engines, in hopes to ready them for commercialization (Peckham 2003a).

The strongest opponents of the Tier 2 regulations were not the automakers, or even the oil industry, who wanted more time to meet the low-sulfur fuel standards. Instead, it was the users of commercial vehicles - the trucking associations and business organizations - that raised the greatest opposition to the Tier 2 proposal. The American Trucking Association and other business groups brought a case against the EPA before the federal appeals court in May 1999. They claimed that the new standards were unconstitutional because of inadequate scientific basis for the rulemaking. The judges ruled in favor of ATA 2 to 1 (Winter and Zoia 1999). However, EPA went on to appeal the decision and successfully defended the standards in the Supreme Court.

5.3.4 Tracking technology development

Not all industry positions on technology were publicly stated or demonstrated. Regulators often meet with individual companies on a confidential basis to discuss the progress of proprietary technologies. Although outside access to those interactions is prohibited, accounts from regulators and the review of corporate behavior following the finalization of the standards indicate the technology leaders that might have influenced LEV II or Tier 2 rulemaking. In addition to developmental work done by EPA engineers, input from technology vendors, and engineering analysis by EPA staff, the EPA used previous years' certification data to form a basis for the Tier 2 emission levels. EPA staff examined which models were able to achieve emission levels a significant margin below the mandated levels. Then they investigated the companies and technologies behind these margins, and used the information for the Tier 2 standards.⁴

Examination of the certification data for gasoline-powered vehicles indicates that many automakers were already well below the EPA Tier 1 standards in 1997, by as much as 80% less than the limit. The majority of the gasoline vehicles already had NO_x emission levels of 0.1 to

⁴ Interview with Margo Oge, Director, US EPA Office of Transportation and Air Quality, December 8, 2005.

0.2 g/mi for a 100,000-mile useful life, even though Tier 1 requirements were 0.6 g/mi and California LEV requirements were 0.3 g/mi. By 1999, several manufacturers, such as Mazda, Ford, Honda, Volvo, Hyundai, Volkswagen, and Mercedes already had multiple models with NO_x emissions at or below the 0.07 g/mi Tier 2 Bin 5 level (EPA 1997-2003). Most of these low-emission vehicles were passenger cars, with the exception of several large trucks and SUVs sold by Ford.

Meanwhile, diesel vehicles were at the most lenient end of the Tier 2 bin systems. The model year 2001-2003 diesel Volkswagen Jetta Wagon had NO_x emissions between 0.5 to 0.7 g/mi (see Table 5-9). However, the EPA Tier 1 requirement for diesels at that time was 1.25 g/mi and the California requirement was 1.0 g/mi. Since the diesel Jetta Wagon's NO_x emissions were well below the requirement, the EPA may have taken that into consideration in designing its fleet bin averaging system. The most lenient bin, Bin 10, has a NO_x limit of 0.6, very close to the Jetta Wagon's range.

The major source of contention in the Tier 2 rulemaking was not the emission standards themselves, but the requirement that most light-duty trucks, SUVs, and vans would have to meet the same emission standards as passenger cars. With the previous Tier 1 standards, emission requirements varied depending on vehicle weight. A 6,000-lb truck had more lenient standards than a 3,000-lb car. Tier 2 would eliminate that distinction. As expected, manufacturers which sold many large vehicles felt that the proposed Tier 2 regulations were biased against large vehicles. Nevertheless, following the finalization of the Tier 2 standards, Ford did have large gasoline-powered vehicles, including the Expedition, Ranger, F150, and F250, certified in 1999 as meeting the 2004 standards (EPA 1997-2003). This implies that their emission control technology was ready at the time that EPA conducted technology reviews for the Tier 2 rulemaking. Ford's progress may have contributed to EPA's confidence that its Tier 2 standards were feasible for heavier vehicles.

In interviews, EPA and CARB regulators expressed the usefulness of private meetings with individual automakers. Automakers may be reluctant to reveal the details of their technology developments publicly, but may share proprietary information with regulators on a confidential basis. Regulators observed greater candidness in private one-on-one meetings with automakers compared to public statements.

5.3.5 Impact of LEV II/Tier 2 standards on diesel sales in the US

Requiring diesel-powered light-duty vehicles to meet the same emission standards as their gasoline counterparts has virtually closed the U.S. market to diesel passenger vehicles, at least in the near term. The few diesel cars that have been certified in 2004-2005 to sell in the US cannot be sold in California, which has more stringent NOx standards than the federal ones. Several northeastern states – New York, Massachusetts, Maine, and Vermont – have chosen to adopt California’s standards as well. California Tier 1 standards, effective 1994-2003, gave diesel passenger cars the option to meet a 1.0 g/mi standard, which is more lenient than the gasoline cars’ 0.6 g/mi NOx requirement, but more stringent than the 1.25 g/mi standard set by EPA for 1994-2003. Table 5-9 lists the diesel passenger cars certified by the EPA between 1999 and 2005. Larger light-duty vehicles, between 6,000 and 8,500 lbs, used to have more lenient Tier 1 emission standards. Under Tier 2, however, vehicles below 8,500 lbs will all be part of the bin averaging system. The table also lists their certified NOx levels and standards for the full useful life, 100,000 miles (which was changed to 120,000 miles as of 2004).

Table 5-9: Diesel Passenger Cars Certified by the EPA, 1999-2005

Manufacturer and model	Year	NOx level	Standard to meet
Chevrolet Tahoe	1999	1.35-1.41	1.53 (EPA Tier 1 HLDT)
Mercedes E300	1999	0.8	1.25 (EPA Tier 1)
Volkswagen Golf	1999	0.9	1.0 (CA Tier 1 diesel)
Volkswagen Jetta and New Jetta	1999	0.6	
Volkswagen New Beetle	1999, 2000	0.6-0.9	
Volkswagen Jetta Wagon	2001, 2002, 2003	0.5-0.7	
London Taxi	2004	0.814	
Volkswagen Touareg	2004	1.295	1.53 (EPA Tier 1 HLDT)
Volkswagen New Beetle	2004, 2005	0.25	0.3 (EPA Tier 2 Bin 9)
Volkswagen Jetta Wagon	2004	0.46	0.6 (EPA Tier 2 Bin 10)
Volkswagen Jetta Wagon	2005	0.55	
Volkswagen Passat Wagon	2005	0.45	
Mercedes E320 CDI	2005	0.39	

Note: Prior to 2004, diesel cars had the option of meeting a 1.0 g/mi NOx standard instead of the 0.6 g/mi standard required of gasoline cars.

Up until 2004, when diesel cars only had to meet a 1.0 g/mi NO_x standard in California, some passenger car models manufactured by Volkswagen and Mercedes could still meet California's standards. However, under the LEV II program, California's stringent NO_x standard of 0.07 g/mi has in effect banned diesel passenger car sales in California, New York, Massachusetts, Maine, and Vermont, whose populations comprise 24% of the passenger car market (US Bureau of Transportation Statistics 2005). Diesel models could not meet the NO_x or PM standards. Adding a particulate filter could solve the PM problem, but there were no feasible technologies at the time for reaching such low levels of NO_x. The lowest NO_x level reached by Volkswagen was 0.25 g/mi with their 2005 VW New Beetle. While this can be certified as meeting the Tier 2 Bin 9 requirement under the federal standards, it exceeds California's 0.07 g/mi requirement. Several models that had been previously sold in the U.S. fell short of the 0.6 g/mi NO_x limit required by Tier 2 Bin 10, the most lenient of the bins. The Mercedes E300 had NO_x emissions of 0.82 g/mi; the Volkswagen Golf and Jetta TDI had 0.9 g/mi NO_x; the Volkswagen New Beetle Sedan, Golf Sedan, and Jetta Sedan TDI had 0.8 g/mi NO_x (EPA 2000). Because there were few diesel models on the market in the late 1990s, EPA and CARB did not place much emphasis on ensuring that diesel vehicles would be viable for Tier 2. Moreover, Volkswagen and Mercedes' diesel models sold considerably fewer units than their gasoline equivalents. Out of its 194,149 Mercedes cars sold in 2004, only 4,000 were diesel; for Volkswagen, only 25,000 of its 301,487 cars sold were diesel (Truett 2005; Ward's Automotive Yearbook 2005). As foreign companies, they arguably had less sway with government officials than domestic automakers.

Tier 2 and LEV II's equivalent treatment of light-duty diesel and gasoline vehicles in terms of emission levels has made it very difficult for manufacturers to sell diesel cars in the U.S. EPA and CARB held firm about not giving diesel cars and light trucks any preferential treatment, despite their significant fuel economy advantage. Also, the unavailability of ultra-low sulfur diesel fuel, at least until mid-2006, makes effective NO_x and PM reduction extremely challenging.

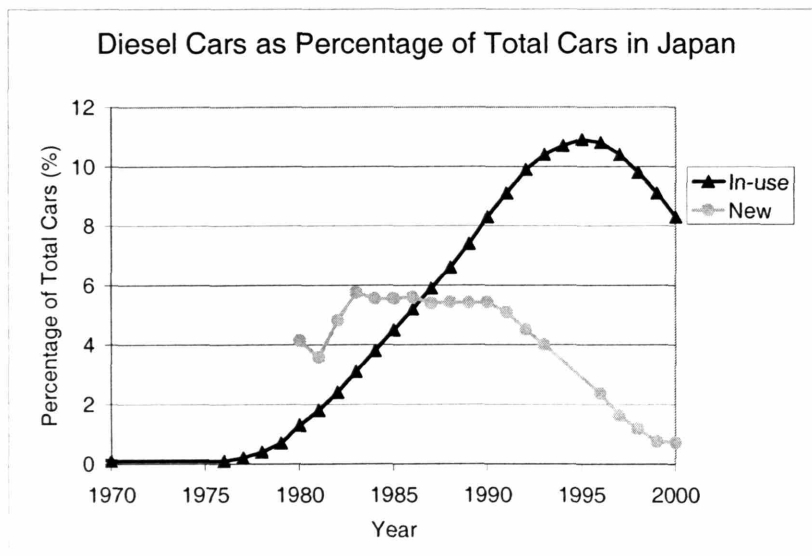
5.4 Japan

Japan shares Europe's high fuel prices, fuel tax differential in favor of diesel, and concern about CO₂ emissions. However, it has not shared the diesel popularity witnessed in Europe. Air quality concerns and strict local standards on particulates have limited the spread of diesels.

5.4.1 Market for diesels in Japan

While diesel-powered vehicles dominate the bus and special-purpose vehicle market (e.g. construction, mining, and farming equipment), and make up over 30% of trucks, they command a relatively small share of the passenger car market. Even at the time of high worldwide oil prices in the 1980s, the diesel share barely peaked at 6% of total new passenger cars. In terms of in-use vehicles, diesel cars did reach an 11% share of the total car fleet in Japan in the early 1990s, a holdover from the higher sales of diesels in the 1980s. However, since 1990, purchases of new diesel cars have significantly declined. By 2002, the percentage share of diesel cars fell to 0.1% of all new car sales (Green Car Congress 2005; JAMA 2004).

Figure 5-2: Share of Diesel Cars in Japan



Source: JAMA (2001), Japan Ministry of Transport 2001.

5.4.2 Regulatory process in Japan

Japan has enforced motor vehicle emission standards since 1966. Beginning in 1989, it published its Future Policy for Motor Vehicle Exhaust Emission Reduction to present its recommendations for future regulatory action on emission and fuel standards. In subsequent updated policy reports in 1996, 2000, 2002, 2003, and 2005, the Japan's Central Environment Council, an advisory body to the Ministry of the Environment, has recommended increasingly stringent targets for pollutant emissions from motor vehicles and specifications for automotive fuels. For diesel vehicles, the "Future Policy" recommendations have focused on NO_x and PM emissions reduction and sulfur reduction in diesel fuel.

The reports stipulate both long-term and short-term targets. In 1998, in their Third Report, the Council anticipated setting short-term standards for 2002-2004 and long-term standards to be met by 2007. The short-term targets were designed to reduce emissions by 30-70%, as an intermediate standard before the long-term targets went into effect. Between 1998 and 2000, the Air Quality Committee consulted with the Experts Committee on Motor Vehicle Exhaust Emissions, which is comprised of experts in academic and research institutions. Citing the rapid progress of emission control technology, the Committee felt justified in shortening the amount of time allowed to meet the long-term standard. Backed by the auto and oil industries' March 2000 commitment to meet the standards in 2005, the Council published its Fourth Report in November 2000. The report announced that new long-term emission standards would come into effect by 2005 but did not specify the exact levels. The targets would be finalized by the end of fiscal year 2001. The Ministry of the Environment estimated that compliance with the 2005 long-term standards, which are listed in Table 5-2, would reduce motor vehicle PM by 67%, NO_x by 44%, and HC by 70%, even when accounting for traffic growth, changes in vehicle mix, and gradual penetration through the existing fleet (Japan Central Environment Council 2002).

The Council was able to accelerate the deadline only after government officials successfully persuaded the representatives from the auto and oil industries to agree to meet the long-term targets 2 years early. Prior to the announcement of the accelerated deadline, Japanese Environment Agency chief Kayoko Shimizu had conferred with the heads of the Japanese auto and oil trade associations – the Japanese Automobile Manufacturers Association (JAMA) and the Petroleum Association of Japan. She sought their cooperation in accelerating the adoption of

new emission reduction technologies and reduction of fuel sulfur (Japan Economic Newswire 2000). JAMA announced that they would meet the long-term diesel standards by 2005, and that some vehicles would be capable of meeting the new PM emissions standards by 2003-04 (Japan Central Environment Council 2000; Jiji Press 2000a). This was made possible by the Petroleum Association of Japan agreeing to offer low sulfur diesel fuel (< 50ppm) by the same time, enabling advanced but sulfur-sensitive aftertreatment technologies. Therefore, by the time the government released Fourth Report, industry was already in agreement with the accelerated deadline.

The April 16, 2002, Future Policy for Motor Vehicle Exhaust Emission Reduction (Fifth Report), finalized the long-term diesel emissions standards for 2005. The long-term targets for light-duty diesel vehicles constitute a 50% reduction in NO_x, 75% reduction in PM, an 80% reduction in HC, and no change in CO. The new 2005 standards are more lenient on diesel vehicles than gasoline vehicles in terms of NO_x, but diesel passenger cars and diesel light-duty trucks are expected to adhere to the same standards. The new PM emission standard of 0.013 g/km is significantly tighter than the 2002 value of 0.052 g/km. The dramatic reduction of the PM level is designed to require particulate traps: “Accomplishment of the new long-term targets calls for the adoption of new technologies, such as diesel particulate filters (DPFs).” Yet the report expresses some doubt about the durability and fuel efficiency of such systems, and advocates more research and testing. The Council is also receptive to catalysts requiring the addition of urea (Japan Central Environment Council 2002).

In March 2003, the Ministry of the Environment officially adopted the new 2005 standards. These apply to all new vehicles sold in Japan, but the government has issued additional, more stringent policies which affect both new and in-use vehicles. These policies arguably have had greater impact on spurring technological development and adoption of cleaner diesel vehicles than the federal new vehicle standards.

5.4.3 Lawsuits put pressure on PM reduction

A series of pollution-related lawsuits in metropolitan areas put pressure on local Japanese governments to accelerate emission reduction deadlines and reduce PM emissions. In 1988, 483 Amagasaki residents filed suit against the government and the Hanshin Expressway Public

Corporation for failing to adequately regulate vehicle particulate emissions. The plaintiffs allegedly suffered respiratory ailments from vehicle exhaust. In 2000, the Kobe District Court ruled that the government must pay 212 million yen (\$1.97 million) and the public corporation 121 million yen (\$1.12 million) to the 50 plaintiffs who lived closest to the highway.⁵ Additionally, the court ordered the government to keep levels of suspended PM below 0.15 mg/m³, with a specific recommendation to restrict diesel vehicles from road access. This was the first court ruling to require the government to cut exhaust emissions (Kyodo 2000).

Another vehicle pollution lawsuit was filed in 1996 by 99 Tokyo residents and their families. The plaintiffs in the suit held the national government, the Tokyo Metropolitan Government, Metropolitan Expressway Public Corporation, and seven automakers responsible for high air pollution levels, which caused their respiratory ailments. The plaintiffs sought 2.24 billion yen (US\$20.6 million) and demanded specific measures to improve air quality (Corliss 2002). In 2002, a Japanese court awarded 79.2 million yen (US\$634,000) to 7 plaintiffs.⁶ The court reprimanded the national government, the Tokyo metropolitan government, and Metropolitan Expressway Public Corporation for not adequately protecting public health and required them to pay the plaintiffs' damages. The seven automakers were not held responsible.

These prominent lawsuits put great pressure on local governments in Tokyo and Kobe to reduce PM emissions by placing strict limits on diesel vehicles. The courts had found them negligent in protecting residents from air pollution, and demanded that they do something specifically about diesel PM. The 2003 Tokyo Diesel Retrofit Program and the more broadly applied Automobile NO_x/PM Law, modified in 2002 to include diesel passenger cars, were government responses to these lawsuits and the subsequent public pressure.

5.4.4 Automobile NO_x and PM Law

Under a 1992 law called the "Automobile NO_x Law," the Japanese government is allowed to regulate NO_x emissions from automobiles in 196 designated areas in the Tokyo, Saitama, Kanagawa, Osaka and Hyogo Prefectures, areas with the worst air quality problems. Since diesel vehicles are the biggest contributors to mobile NO_x, diesel trucks and buses became

⁵ Historic rates obtained through FXTOP.com. In 2000, 100 Japanese yen = US\$0.928.

⁶ Historic rates obtained through FXTOP.com. In 1996, 100 Japanese yen = US\$0.920. In 2002, 100 Japanese yen = US\$0.800.

the focus of this regulation. It regulated in-use vehicles retroactively. Existing vehicles will be banned from the designated areas if they cannot meet the in-use standard, even if they met the standards at the time they were sold. This shifts the burden of compliance to the vehicle owner rather than the vehicle manufacturer, whose sales would actually benefit from accelerated turnover of vehicles. Emission control manufacturers would also benefit from product sales as owners retrofit their vehicles.

The Automobile NO_x Law was revised in June 2000. PM was added as a designated pollutant because government authorities were increasingly concerned about the carcinogenicity of diesel particulates. The law is now referred to as the Automobile NO_x/PM Law. It also includes a certification system for ultra-low PM diesel vehicles.

Originally, the law was designed to regulate heavy-duty vehicles, but by 2002, diesel passenger cars were also subject to this law. These new procedures, effective October 2002, apply the 1997/1998 new vehicle standards onto vehicles already on the road. All vehicles have a 9- to 12-year grace period during which they must be taken off the road or retrofitted with catalyst filter systems. The vehicle inspection program works in conjunction with these standards so that they are enforced (JETRO 2004).

The auto industry had requested that the government offer subsidies and tax breaks to cover the cost of purchasing filter-equipped vehicles, and policymakers agreed. Most of the subsidies in 2001-03 went to help defray the costs of diesel particulate filters on trucks and buses; there were no such policies for diesel passenger cars. However, vehicle owners who purchased a new 2005 emission-compliant diesel car between April 2004 and September 2005 received a 1% reduction in their vehicle acquisition tax (JAMA 2005). This was designed to promote early introduction of the cleaner vehicles, which were not required until October 2005. Cars registered less than 7 years before were still exempt from having to meet the Automobile NO_x/PM Law.

5.4.5 Tokyo Diesel Retrofit Program

Restrictions on diesel vehicles did not end with the Automobile NO_x/PM Law. The Tokyo Metropolitan Government (TMG), which sets local standards for the Tokyo area, adopted an “Ordinance on Environmental Preservation” in December 2000 that includes, among other

pollution control measures, a diesel retrofit program. Starting October 2003, in-use diesel vehicles had to be retrofitted with PM emission reduction equipment or face a ban in the TMG area. Older vehicles are subject to higher PM reduction requirements (in percentage terms), while relatively newer vehicles (MY1997-99) have more lenient requirements. The goal is to target to the highest polluting vehicles and to encourage turnover of the older vehicles. Vehicles have a 7-year grace period to meet the requirements. By 2005, the diesel PM requirements became even more stringent. The TMG diesel retrofit program was intended to coexist with the national Automobile NO_x/PM Law, but the TMG requirements for PM are far more stringent than the Central Government's requirements. The TMG program applies to the 420,000 diesel vehicles registered in Tokyo (as of 2000) and any vehicles that travel through Tokyo (Dieselnet 2005). The program was set to go into effect in the Tokyo, Kanagawa, Saitama and Chiba prefectures.

5.4.6 Industry response

The central government and local governments' requirements for diesel vehicles were influenced by the readiness of industry to provide cost-effective emission control technology for new and in-use diesel vehicles. The commitment to meet the long-term emission targets in 2005 was made collectively by all the Japanese auto companies, as represented by JAMA. Since they all agreed to the level set by the Japanese government, there was little opportunity for one company to maneuver ahead of the others in terms of supporting even more stringent regulation. However, the Japanese government's aggressiveness in pushing for greater stringency and earlier compliance helped Japanese companies become first movers in other markets. Emission control manufacturers with technology capable of meeting the new standards also stood to benefit from the regulation-induced market demand for their products.

5.4.7 Early movers and first movers in other markets: Toyota and Hino Motors

Toyota began working on its Diesel Particulate-NO_x Reduction (DPNR) System starting in the mid-1990s. The system reduces emissions of PM and NO_x through the combination of a NO_x storage reduction catalyst and a particulate filter. Toyota was initially motivated to pursue

this technology by the increasingly stringent heavy-duty diesel emission standards in Japan, but it saw the potential to spread the technology to the light-duty vehicle market, particularly in Europe.

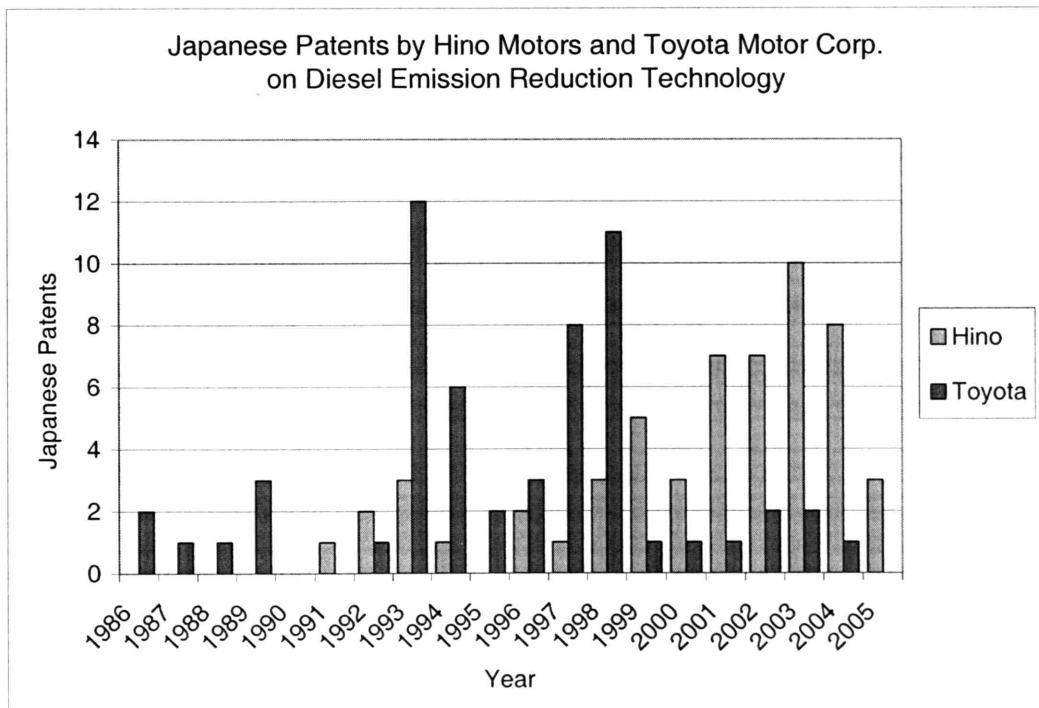
In July 2000, Toyota Vice-President Shinichi Kato announced that Toyota would provide the DPNR technology to Hino Motors, a Toyota affiliate specializing in heavy-duty vehicles. The Toyota announcement hinted that they hoped to license the DPNR technology to other auto manufacturers (Jiji Press 2000b). At that time, Toyota expected to start offering the system in heavy-duty diesel vehicles in Japan first, in 2003, and then expanding to the light-duty diesel market in Europe.

DPNR technology represented a major breakthrough for Hino Motors. In 1998, it was still working on a catalyst prototype capable of cutting NOx emissions by only 25%, with the expectation that improved versions would cut NOx emissions by 50%. With Toyota's DPNR technology, NOx and PM reductions were as high as 80%. In its 2001 Environmental Report, Hino Motors claimed that it would use this technology to meet the anticipated 2005 long-term PM and NOx regulation. At this time, it was known that 2005 standards would be very stringent, but the exact standards were not settled until spring 2002. The 2005 heavy-duty diesel engine standards would require the adoption of this technology. Some municipalities began banning diesel vehicles without advanced emission control equipment as early 2002, so this put pressure on Hino to have low-emission vehicles ready before 2002. By FY1999, Hino already had 65 catalyst-equipped vehicles approved by the "LEV-6 Designation System" in Japan's Kansai region (Hino Motors 2001).

Toyota's motivation for developing the DPNR system was the anticipation of new stringent truck and bus regulations. It began selling the small trucks equipped with these devices in October 2003. Those first models were the Dyna and the Toyoace, which earned the top 4-star rating for PM emissions in the Ministry of Land, Infrastructure, and Transport's tests. Since the vehicles' emissions were 85% below the required 2000 level for PM, the vehicles could be labeled as ultra-low PM vehicles. Toyota went on to market other DPNR-equipped vehicles in 2003 – the Dutro, a Hino Motors truck (Hino is part of the Toyota Group) and Avensis, a medium-sized sedan sold in Europe. The problem is that the DPNR only works well with fuel having sulfur content less than 10 ppm.

Figure 5-3 is based on a patent abstract search of the Japanese Patent Database for the terms “diesel” and “emissions.” It is not meant to be exhaustive in accounting for patents related to diesel emission control, but it does indicate periods when higher rates of relevant patenting occurred. Based on the timing of their patent filings for diesel emission control technology, Toyota Motor Corporation began working on diesel emission reduction technology in the 1980s and ramped up research in the 1990s, while its truck manufacturing affiliate, Hino Motors, pursued the bulk of its clean diesel R&D in the late 1990s and early 2000s. The timing corresponds roughly with the regulatory developments in Japan. Light-duty diesel vehicles were subjected to regulations for the first time in 1986, and then to increasingly stringent levels in 1990, 1994, 1997, 2002, and 2005. Heavy-duty vehicles were subjected to emission standards somewhat later. The first set of regulations came in 1988/89, followed by updated standards in 1994, 1997, 2003, and 2005. The revised 2002 Automobile NOx/PM Law and 2003 Tokyo Retrofit Law requiring retrofits of in-use diesel vehicles contributed to Hino Motor’s ramp-up of research in the early 2000s.

Figure 5-3: Hino and Toyota Patents on Diesel Emission Reduction Technology



Source: Patent Abstracts of Japan (2005)

5.4.8 Influence on regulations

While stimulated by regulatory requirements in Japan, Toyota's DPNR technology had more impact as a first-mover technology in outside markets, in Europe and US. DPNR was expected to meet 2005 Japanese regulations, and based on its performance, it also would be marketed to meet the 2008 Euro 5, and possibly post-Tier 2 (after 2007) US standards. Starting in 2002, Toyota began publishing technical papers through the well-known Society of Automotive Engineers (SAE) and making presentations about DPNR in the US, for the light-duty passenger car and truck market (Nakatani, Hirota et al. 2002). They filed international and Japanese patents for the DPNR technology in 2003 (Japan Patent No. JP2003254038).

Toyota even tested the Toyota Avensis DPNR at the EPA's National Vehicle and Fuel Emissions Laboratory, but their primary intent was to ready this vehicle for introduction in Europe. Although the vehicle was tested in the US, under US testing conditions, it would not be offered for sale in the US. The system's need for very low sulfur fuel was the strongest reason – it was tested with 9 ppm fuel. EPA used the test data to evaluate the progress towards clean diesel technology that can meet the Tier 2 standards for 2004-07. Tests show that at least for 50,000 miles, the Toyota Avensis can meet the mid to upper bins (Bins 5-8) of Tier 2 (McDonald and Bunker 2002). The next chapter discusses Toyota DPNR system's impact on the European discussion of Euro 5 standards (for 2008/09).

The Automobile NO_x/PM standard had the effect of benefiting vehicle manufacturers because it increased vehicle turnover. For example, diesel truck and bus manufacturer Hino Motors a 23.7% increase in revenues from FY2002 to FY2003. Industry sources primarily attribute the increase to the Tokyo government's more stringent diesel emission standards (CBR 2005).

5.5 Summary

Industry experts argue that the Euro 4 standards, though initially criticized by industry as very difficult to attain in the late 1990s, actually enabled diesel penetration to continue growing in Europe. The EU has focused on reduction of CO₂, where diesel has an inherent advantage over gasoline. The amounts of fuel consumed and CO₂ emitted by diesels are 30% less than their

gasoline counterparts. Meanwhile, PM standards have been relatively tough but greater leniency has been given on NO_x, which is probably the hardest pollutant to reduce (Visnic 2001). Japan has shared the high fuel taxes and demand for more fuel-efficient cars seen in Europe, but it has gone down the avenue of small gasoline or hybrid-powered cars rather than diesel cars. Although industry experts have claimed that the Japanese government has had less stringent emission standards in the past than Europe or the US, their regulations have been increasingly more challenging. The Tokyo government's explicit policy of targeting polluting diesels has reduced consumer interest in diesel vehicles. Moreover, their stringent in-use vehicle restrictions for diesel cars and trucks have made it financially less attractive to own a diesel vehicle. In California and the US, the LEV II and Tier 2 standards have such strict PM and NO_x standards that they have virtually eliminated the chances for light-duty diesel vehicles in the U.S. Mercedes and Volkswagen, have had limited diesel sales in the US. Tier 2 threatens to effectively lock them out of the light-duty vehicle market in the US unless their R&D progress enables them to technically and economically overcome the NO_x emission hurdle. Some have argued that the US emission standards have acted as non-tariff trade barriers to European auto manufacturers seeking to sell diesel vehicles to the US.

The EU, Japan, and the US have different expectations as to the level of technology-forcing their future standards require. The European Auto-Oil Programme considered standards based on Best Available Technology (BAT) rather than requiring technologies that were not yet available. The focus was on the most cost-effective options. The Japanese government worked collaboratively with industry to set standards that were attainable with existing, albeit costly, technology. In the US, especially California, vehicle emission standards are intentionally technology-forcing. Regulators acknowledge that existing technology cannot meet future standards, but expect the regulations to spur industry to develop new products.

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CHAPTER 6 – Light-duty Diesel Vehicles, 2008 and Beyond

6.1 Introduction

This chapter focuses on industry and individual corporate behavior that influenced the regulatory process for the light-duty vehicle emission standards starting in 2008-09. Although activities in Japan and the US are discussed briefly, this chapter deals primarily with technology development leading up to the finalization of the EU's Euro 5 standard. The US has not yet set light-duty standards beyond Tier 2, which will be in effect through 2010. Although the US standards are not updated as frequently as the Japanese or EU standards, the Tier 2 standards, to be phased in between 2004 and 2007, are at least as stringent as Euro 5 and Japan's 2009 standards. Japan did recently set diesel emission standards for 2009; their stringency has the potential of further squeezing diesels out of the passenger car market. The difficulty of meeting emission standards in the US and Japan means that diesel automakers must focus their attention on regulatory decision-making in Europe, which is the focus of this chapter.

In Europe, first movers PSA Peugeot Citroën and Toyota introduced their emission reduction technologies ahead of any regulatory requirements. PSA's particulate filter technology for passenger cars gained popularity among the environmental community, regulators, and the greater public in Germany. Although the filter system adds to the vehicle cost, the potential for tax incentives and some automakers' readiness to follow PSA's lead resulted in widespread adoption of filters in many European countries. Although national governments usually champion their own domestic companies, German regulators surprisingly supported French company PSA, signaling that environmental protection outweighed industrial competitiveness. The early filter introduction also shaped the PM standards in upcoming Euro 5 standards, which had yet to be finalized. Toyota's Diesel Clean Advanced Technology (D-CAT) system is capable of dramatic PM and NO_x reductions from Euro 4 levels and far surpasses the proposed Euro 5 levels. However, the timing and public reception of the technology, its reliance on ultra-low sulfur diesel fuel, and regulators' prioritization of PM over NO_x control gave Toyota less influence over the Euro 5 regulations compared to PSA's filter introduction.

The cold, and occasionally hostile, reception given to these new technologies by the rest of the auto industry suggests other companies' aversion to more stringent and costly regulation. Meanwhile, regulators and environmental groups are enthusiastic about first-mover behavior and early adoption. Even if private financial benefits are not easily attributable to these first-mover strategies, companies often benefit from improved relations with regulators and interest groups, and are better prepared for future regulations.

6.2 Regulatory processes

As soon as the new 2005 vehicle emission standards went into effect in Japan and Europe, their governments were already releasing draft proposals of the next phase of emission standards. Their timelines are shown in Table 6-1. The US (including California) has not yet held discussions about the next round of standards after Tier 2.

Table 6-1: Timing of the Japanese and European Regulatory Processes

	Japan	Euro 5
Standards proposed	2005	1996
Standards finalized	2005	2005
Start of compliance	2009	2008

Source: European Commission (2005b), Jiji Press (2005b)

Table 6-2 lists the standards adopted for each region, as of October 2005, including the US Tier 2 and California LEV standards from the previous round of regulations. Except for the US and California standards, they are not equivalent because each country's test cycle and test conditions differ.

Table 6-2: Light-duty Diesel Vehicle Emission Standards Beyond 2008

Pollutant	Euro 5 (2008)	Japan (2009)	US Tier 2 – Bin 5 & CA LEV II LEV
NOx	0.20 g/km	0.08 g/km	0.07 g/mi (0.044 g/km)
PM	0.005 g/km	0.005 g/km	0.01 g/mi (0.006 g/km)
CO	0.5 g/km	0.63 g/km	4.2 g/mi (2.61 g/km)
NMOG			0.09 g/mi (0.056 g/km)
HCHO			0.018 g/mi (0.011 g/km)
NMHC		0.024 g/km	
HC+NOx	0.25 g/mi		
Full life	160,000 km	80,000 km	120,000 mi (193,000 km)

Sources: CARB (1999), EC (2005b), EPA (2000), ICCT (2005).

6.3 Europe

In the early 2000s, before the Euro 5 standards were proposed, automakers were already conducting research into vehicle technologies that would enable diesel cars to meet increasingly stringent emission regulations. Two auto companies – PSA Peugeot Citroën and Toyota – developed technologies well in advance of Euro 5, and therefore influenced the Euro 5 standard-setting process that began in 2004.

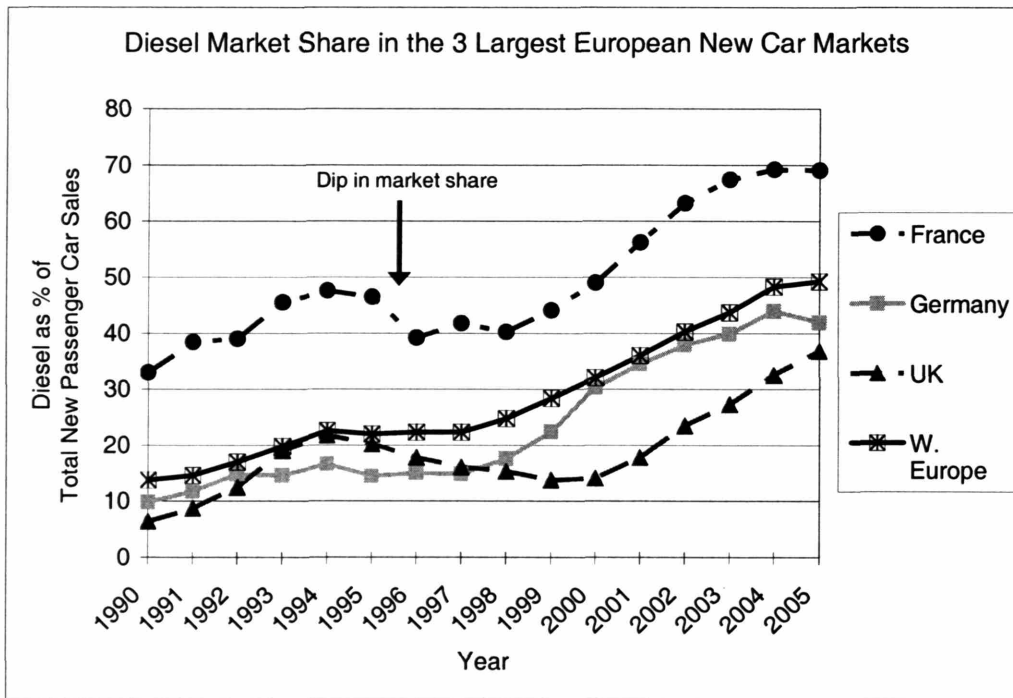
6.3.1 PSA’s particulate filter stems diesel criticisms and sets the stage for Euro 5

In 1996, when the European Commission adopted the 2005 Euro 4 standards, it expected that the PM standard would require the installation of diesel particulate filters. Filters trap particles in the engine exhaust, before they exit the tailpipe. However, because of technological progress in engine design, auto manufacturers were able to meet the Euro 4 standards in the early 2000s without filters. Various auto companies and emission control manufacturers continued to develop filter technology in anticipation of one day needing it to meet more stringent PM regulations. It was expected that filter equipment manufacturers would be supportive of

regulations requiring filters, and that auto manufacturers, who would have to purchase the additional equipment, would be opposed to any filter requirements. However, the French automaker, PSA Peugeot Citroën, emerged as a first mover on filter technology, even before the Euro 4 standards went into effect.

PSA had already been developing filter technologies at a small scale starting in the mid-1990s. Jean-Martin Folz, who became CEO in 1997, led a restructuring effort in early 1998 (Farhi 2000). The new management board pushed environmental issues to the forefront, and began to consider the introduction of diesel particulate filters as a strategic decision. They were concerned about medical studies reporting on the negative effects of diesel exhaust.⁷ Because of PSA’s focus on small and medium diesel cars, growing attention to the health impacts of diesels threatened to dampen diesels’ popularity and erode PSA’s future market share. From 1994 to 1996, the diesel market share in France, Germany, and UK actually dropped, attributed largely to concerns about diesel exhaust’s health effects (ACEA 2005).

Figure 6-1: Diesel Market Share in Europe



Source: ACEA (2005).

⁷ Interview with Bruno Costes, Technical and Political Affairs, PSA Peugeot Citroën, September 3, 2004.

In the late 1990s, partly in reaction to these environmental concerns, Folz put pressure on PSA engineers to develop vehicles with filters for commercial introduction.⁸ The filter itself was developed by Faurecia, a PSA subsidiary. By April 1999, PSA announced its plan to offer its new diesel particulate filter system as standard in its Peugeot 607 model by May 2000. According to PSA, the system took 18 months and €66 million (US\$71 million) to develop.⁹ Over the next three years, it introduced the system as standard on six more Peugeot and Citroën models (PSA 2000-2005).

The effectiveness of the filter system was validated by a third-party study published in August 2001. PSA provided Germany's environmental agency (Umweltbundesamt, or UBA) and the German Auto Club (ADAC) with a filter-equipped Peugeot 607 diesel car for a testing project. Durability testing demonstrated that the filter had a 99.999% efficiency in removing fine diesel particles from the exhaust tailpipe. The diesel car emitted 0.001g/km PM over a 80,000-km distance, 25 times lower than the level required by the 2005 Euro 4 standard (Rodt 2003). The filters also performed well in on-road tests. From 2001 to 2003, PSA conducted field testing with a Paris taxi fleet of four Peugeot 607s over 80,000 km of urban driving. The study was designed to evaluate the durability of the first-generation filter prior to its first maintenance. The filters removed over 95% of the particles throughout the 80,000 km interval, with an average of 0.0027 g/km from the all the tests (Jeuland, Dernenthon et al. 2004; Jeuland, Dernenthon et al. 2002).

Following the public announcement of the new filter system's effectiveness, health and environmental NGOs seized upon PSA's filter introduction as an opportunity to criticize other auto manufacturers for not adopting filters. In Germany, where environmental awareness is particularly strong, an alliance of organizations – health insurance companies, the auto club, environmental organizations, children's groups, travel/transport agencies, and health groups – launched a coordinated “shame campaign” in November 2002, aimed at German automakers (VW, DaimlerChrysler, BMW) which did not offer filter-equipped diesel cars. With the tagline, “No Diesel without Filter,” the campaign called for a government mandate requiring filters on all diesel cars, while commending PSA for already voluntarily equipping six of their car models with filters (Peckham 2003a).

⁸ Interview with Bruno Costes, Technical and Political Affairs, PSA Peugeot Citroën, September 3, 2004.

⁹ Historical exchange rate from FXTOP.com. In April 1999, €1 = US\$1.07.

The “No Diesel without Filter” alliance held press conferences and issued press releases to build awareness about the value of filters on diesel cars. Their dramatic public displays garnered mainstream media attention. Posters depicted people wearing T-shirts printed with their “dirty” hearts, “soiled” from breathing diesel exhaust. Television news showed campaign leaders holding a soiled cloth next to an unfiltered tailpipe and a clean white sheet next to a filtered tailpipe. The activists specifically targeted individual companies, especially VW, which holds the largest passenger car market share in Germany. They projected a giant “Diesel Causes Cancer” slide on VW’s headquarters and used costumed protesters to deter customers at VW dealerships (Peckham 2003a). The campaign had a dramatic effect in Germany. A 2003 consumer awareness survey showed that 93% of Germans surveyed were familiar with diesel particulate filters (PSA 2005a). Although PSA did not fund the alliance’s activities and made a concerted effort to keep its marketing activities separate, it was a beneficiary of the campaign.¹⁰

Government interest in the campaign was strong. UBA (the German environmental agency which supports the Environment Ministry) and the World Health Organization were partners in the alliance. Their presence at the campaign’s press events and fact-filled presentations about diesel particulate filters lent credibility to the more activist portion of the campaign. The media attention gave the campaign “free advertising.” Government officials, such as Axel Friedrich, frequently spoke at press conferences alongside NGO alliance leaders. Even though UBA usually tries to keep government and NGO activities separate, its active participation in the filter campaign was frowned upon by other parts of the German government.¹¹

German Environment Minister Jürgen Trittin was sympathetic to the call for particulate filters. He called for the voluntary adoption of filters and floated the proposal of a €600 tax break for filter-equipped diesels.¹² The alliance placed pressure on individual companies to offer filters, offering to help publicize a company’s filter adoption, even if it only offered the filter in one model.¹³ In 2003, other companies, such as Fiat, Ford, Toyota, Renault, and Opel

¹⁰ Interview with Jürgen Resch, Executive Director, Deutsche Umwelthilfe e.V., September 3, 2004, and with Bruno Costes, Technical and Political Affairs, PSA Peugeot Citroën, September 3, 2004

¹¹ Interview with Dr. Axel Friedrich, Head of the Division of Environment, Transport and Noise, Umweltbundesamt (UBA), August 31, 2004.

¹² Historical exchange rate from FXTOP.com. In 2003, €1 = US\$1.13.

¹³ Interview with Jürgen Resch, Executive Director, Deutsche Umwelthilfe e.V., September 3, 2004.

began promising to offer filters in some of their diesel models, but the German auto companies – VW, BMW, and Mercedes-Benz – stood firm in refusing the filter option until mid-2003.

Table 6-3: Automaker Filter Announcements at the 2003 Frankfurt Auto Show

Maker	Models	Expected availability
Audi	A4, A6, A8	Early 2004
BMW	5er	Early 2004
Citroën	C3, C5, C8	In production
Fiat-Alfa	Stilo, Alfa 156	2004
Ford	Focus C-Max, Mondeo (2004)	End-2003
Honda	Accord	2004
Jaguar	X-Type	2004
Mazda	Mehrere Modelle	2004
Mercedes	C-, E-Classes	Oct. 2003
Opel	Vectra, Signum, Astra (ab 2004)	End-2003
Peugeot	304, 406, 607, 807	In production
Renault	Vel Satis, Espace	End-2003
Toyota	Avensis	Nov. 2003
Volvo	Mehrere Modelle	2004
VW	Passat	2004

Source: Peckham (2003b); Original source: Ferdinand Dudenhoeffer, B&D Forecast (2003)

VDA, the German auto association, challenged the durability of PSA’s filter technology, pointing out the first-generation filter’s inability to meet the Euro 4 NOx standards, and emphasized the uncertainties of diesel exhaust’s health effects. VDA lobbied hard against the government’s proposed €600 filter incentives. VDA claimed that such an incentive would give an unfair advantage to foreign manufacturers who had already chosen to adopt filters. Many of their models already met Euro 4 standards early, and they were likely frustrated that public attention had shifted from their early Euro 4 compliance to a demand for filters, which VDA viewed as a costly and inelegant technical solution. Equipping cars with filters did result in a 3% fuel penalty (Michelin, Figueras et al. 2000). Manufacturers claimed that the filters would add €300-800 to their vehicle prices. Meanwhile, the UBA estimated the real additional costs to be €150-300, perhaps assuming costs would spread across larger volumes (Rodt 2003). Ultimately, the German auto companies relented and began offering filters in some of their diesel models. For example, DaimlerChrysler began offering filters as a €580 option in October 2003. By mid-

April 2004, it made them standard in diesel models sold in Germany, Austria, Switzerland and the Netherlands, but also increased list prices by €800 (DaimlerChrysler 2005b).

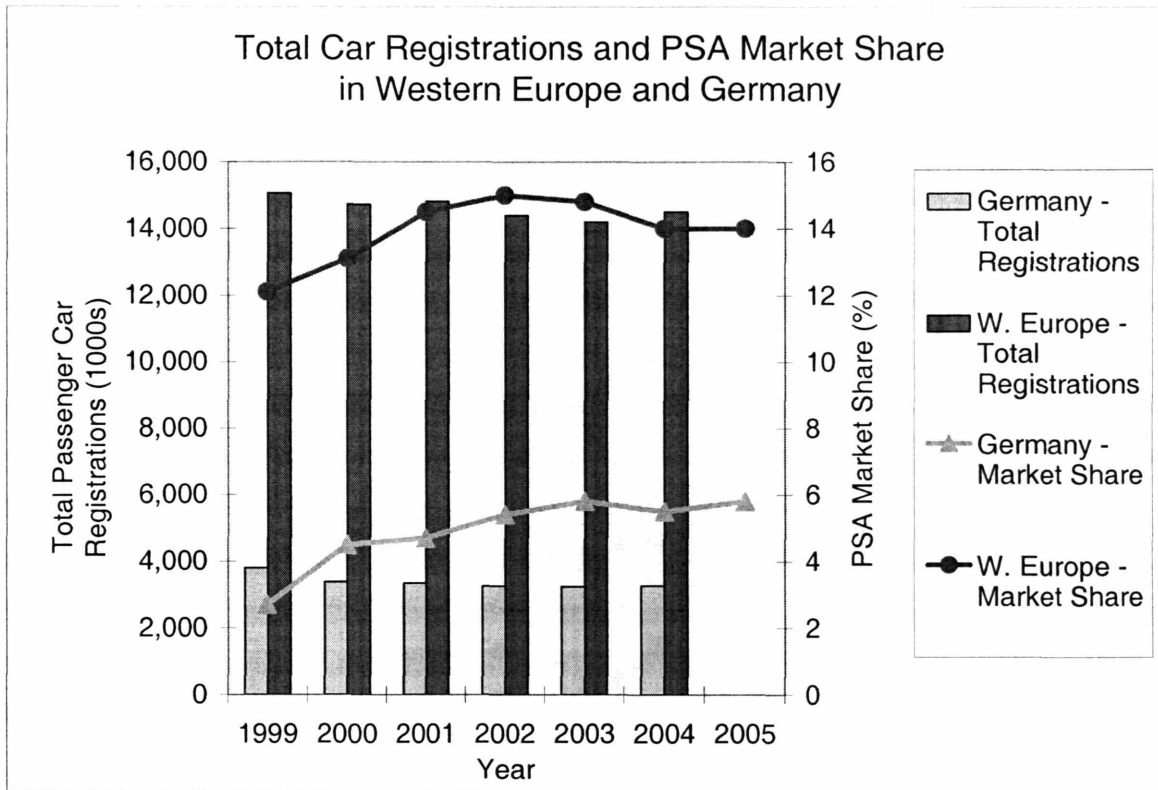
Besides concern about environmental protection, customers purchased filter-equipped cars for economic reasons. The trade press predicted that cars without filters would depreciate faster. Customers anticipated that tax incentives would eventually be offered. Also, some cities proposed limiting inner city access to all diesel cars, unless they were equipped with filters. The response to filters by German customers was very different from the customers in the rest of Europe. Both Ford Europe and DaimlerChrysler reported that over 80% of diesel car customers purchased the extra filter option in Germany, whereas only a minority of customers in other countries, even France, chose the option (DaimlerChrysler 2005). Ford Europe chose not to even offer the filter option in the UK because of the lack of filter demand.¹⁴

Private benefits to PSA

PSA posted strong sales following the debut of its first filter-equipped model. In Germany, its passenger car market share climbed from 2.7% in 1999 to 5.8% in 2003; in Western Europe, its market share increased from 12.1% in 1999 to 14.8% in 2003 (see Figure 6-2). During this time period, PSA was able to increase its sales even as total passenger car sales in Western Europe declined. PSA's market share has since fallen slightly in Western Europe, to 14% in 2004-2005, but this is still substantially higher than its pre-2000 levels.

¹⁴ Interview with Dr. Wolfgang Schneider, Vice President of Legal, Governmental, and Environmental Affairs, Ford of Europe, August 31, 2004.

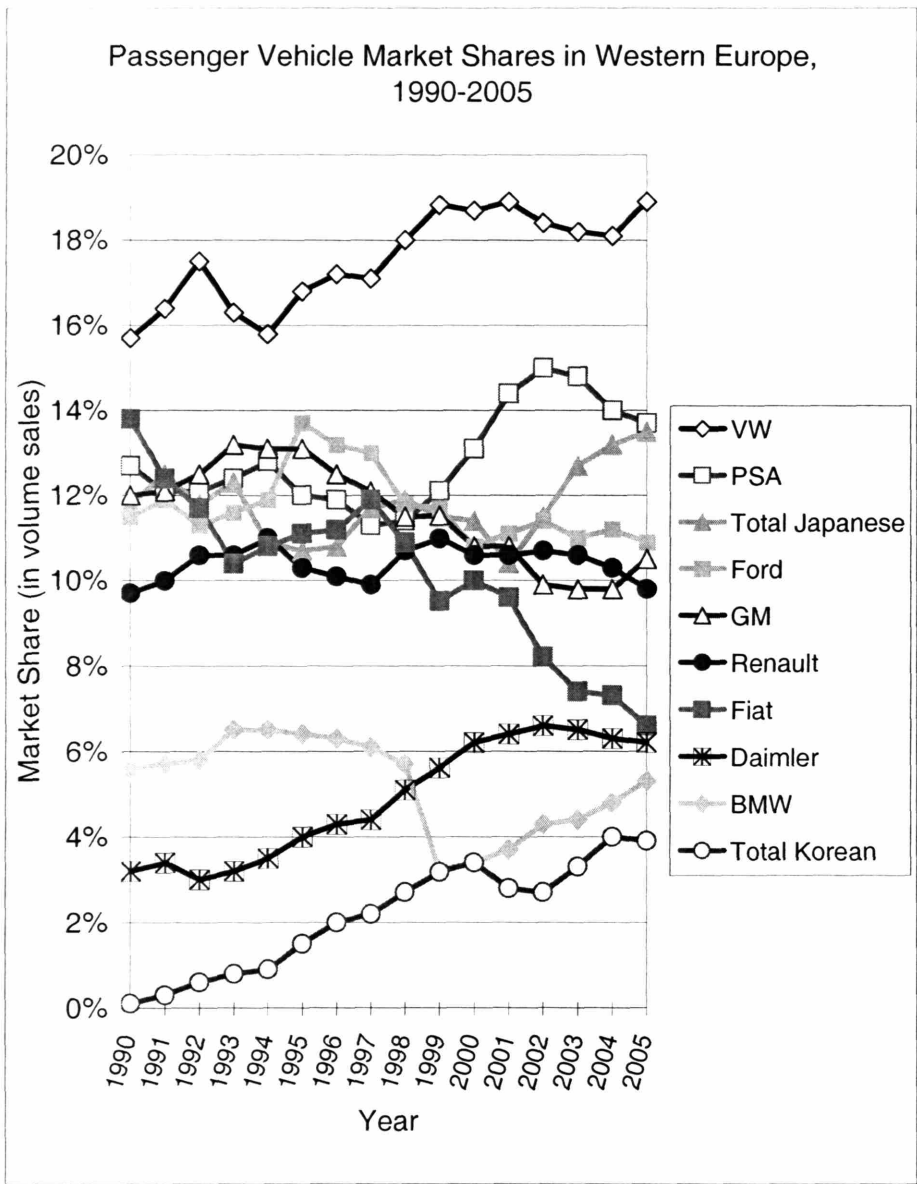
Figure 6-2: PSA Market Share Growth



Source: ACEA (2005), PSA (2000-2005)

PSA’s performance in the 1999-2003 time period in Western Europe is even more striking when compared to its competitors, as shown in Figure 6-3.

Figure 6-3: Manufacturer Market Shares in Western Europe



Source: ACEA (2005)

PSA executives have been hesitant to attribute any quantifiable financial benefits from their early filter introduction, because it is difficult to separate out the impact of the popularity of their new car models and the restructuring of their sales and distribution system, which also began in 1999-2000.¹⁵ However, praise from environmental groups and government agencies undoubtedly boosted PSA's reputation. Because of its particulate filter, PSA has won numerous awards from environmental groups, automobile clubs, and auto enthusiast magazines in France, Germany, Italy, UK, and Austria (PSA 2000-2005; PSA 2005a).

By being the first to embrace DPF technology, PSA generated enthusiasm about filters from government agencies and the environmental community, and put its competitors at a disadvantage when filters became popular. In addition to the free publicity, PSA got a head start on technology development and experience with filters. Even before German manufacturers had their filters ready, PSA had sold 500,000 filter-equipped cars and was already on its third generation of filter systems by mid-2003. PSA had sold its one millionth filter-equipped diesel by January 2005 (PSA 2005a). PSA's filter supplier, Faurecia, a PSA subsidiary, held onto 60% of the filter market in 2004 as other manufacturers also sought its filter expertise to equip their cars (PSA 2005a).

Following PSA, Mercedes-Benz was a distant second in filter-equipped diesels sales, selling 110,000 cars with filters by the end of 2004 (DaimlerChrysler 2005b). Of all the German brands, Mercedes was probably the best equipped to introduce filters because it had introduced them in the US in the 1980s and had continued research on them, anticipating their use in future regulation. Despite its filter technology readiness relative to other manufacturers, Mercedes is still in favor of in-engine controls that reduced emissions upfront instead of end-of-the-pipe controls, provided the desired emission levels can be achieved. Also, the company's past experience in California with filter regeneration problems and the fuel consumption penalties associated with the filter technology contributed to its initial reticence in 2003-2004 to support filter requirements.¹⁶ Even in mid-2005, when Mercedes was offering the filters as standard in all diesel models, they were available in only 4 European countries (DaimlerChrysler 2005a). Volkswagen, the leading automaker in Europe and among the most resistant to filters, moved

¹⁵ Interview with Bruno Costes, Technical and Political Affairs, PSA Peugeot Citroën, September 3, 2004.

¹⁶ Interview with European auto industry representative, November 2004.

more slowly. Although it began to offer the filter in all Audi models by 2005, it did not offer the filter in all Volkswagen models until 2006 (Volkswagen 2005).

The German manufacturers' slowness to adopt filters hurt their image as innovative technology leaders. The German research firm Media Tenor evaluated 20,704 German news and business stories about the automobile industry in the first 8 months of 2005. According to the researchers, foreign manufacturers like the Renault-Nissan alliance and PSA were praised for qualities usually associated with German firms, like safety, reliability and innovation. German automakers were frequently criticized in the media for missing the trends in hybrids and diesel particulate filters (Krix 2005).

Impact on regulation in Germany

The "No Diesel without Filter" campaign and customer and government pressure for filter options eventually led the German automakers to reconsider their position on filters. By summer 2003, German manufacturers announced their plans to offer filter options in 2004 models. However, unlike PSA, they initially planned to offer the filters for an additional €600-700. This was counterbalanced by the existing reductions in registration taxes, up to €614 less, for Euro 4-compliant cars. German manufacturers continued to object to the proposed filter-specific tax incentive (Peckham 2003b).

The attractiveness of the diesel particulate filter as an effective emissions-reducing technology created tension within the German government. Environment Minister Trittin supported a €600 tax incentive for cars with PM levels below 2.5 mg/km, a level attainable only through filters. On the other hand, Finance Minister Hans Eichel openly criticized the proposed tax incentive in an interview with the Financial Times Deutschland. Concerned about the competitiveness of the German auto industry, he claimed that the incentive served as an incentive to foreign firms (i.e., PSA, Renault, Fiat) that had already adopted the filters (Walsh 2004). Prime Minister Gerhard Schroeder brokered a compromise in a series of meetings with German automakers. They promised that by 2009, all their diesel models would have filters. New cars meeting a 8.5 mg/km limit between 2005 and 2009 would receive a €600 euro tax break. By February 2005, disagreement among the Environmental and Finance Ministries was

resolved, and the German government agreed to offer the tax break starting January 2006 (AFX 2005).

Regulatory agencies use PSA as an example

PSA's early introduction of filter-equipped diesels spurred widespread industry adoption of filters and prompted discussion of more stringent emission standards at the EU level. Since 2003, the German and French environmental agencies have been pressuring the European Commission to adopt a stricter Euro 5 PM standard as low as 2.5 mg/km (Peckham 2003a; Peckham 2003b). The German environmental agency, Umweltbundesamt (UBA), featured PSA's filter technology (known as FAP technology) prominently in its 2003 "Future Diesel" report. The report authors cited the emissions testing conducted by the German auto club ADAC in 2001 on the effectiveness of the filter technology on the Peugeot 607. They comment on PSA's major influence on future regulations: "FAP technology therefore defines the state of the art and the possibility of setting limit values on that basis" (Rodt 2003).

Prior to proposing the Euro 5 emission standards, the European Commission issued a document in January 2005, entitled, "Fiscal Incentives for Motor Vehicles in Advance of Euro 5." It suggests that Member States base their fiscal incentives for diesel passenger cars on a PM limit value of 5 mg/km and acknowledges that this value can currently be reached by particulate filters only (EC 2005a). Even though Euro 5 requirements may have ultimately necessitated filters, PSA's early action mobilized interest groups and government officials and accelerated the adoption of the technology. By the time the Euro 5 regulatory process began, PSA had already demonstrated that filter-equipped diesel cars were technically and economically feasible and attractive to consumers.

6.3.2 Toyota's D-CAT system shows promise

In the 1990s, Toyota began working on its D-CAT (Diesel Clean Advanced Technology) system to reduce NO_x and PM emissions from diesel engines. The D-CAT system features DPNR, the diesel particulate-nitrogen oxides reduction system, which is capable of reducing PM by 80% and NO_x by 50% from Euro 4 levels (Toyota 2003). DPNR combines a diesel

particulate filter with a NO_x adsorber. The NO_x adsorber adsorbs and stores NO_x under lean conditions (normal for diesel engines). During brief periods of rich conditions, the NO_x is released (“desorbed”) in the presence of CO and catalytically reduced to N₂. Because the adsorber also adsorbs sulfur oxides, which interferes with NO_x adsorption, it is important that the diesel fuel used has very low sulfur content (AECC 2006). The system also incorporates other new technologies, such as a common-rail fuel injection system, exhaust port fuel injection, low temperature combustion, and exhaust gas recirculation (EGR). Its first commercial use was in heavy-duty diesel engines developed by Toyota’s affiliate, Hino Motors. However, Toyota saw the opportunity to apply the technology for light-duty vehicles for the European market.

Beginning in March 2002, Toyota conducted an 18-month field test of 60 Avensis models in seven European countries – Germany, UK, Austria, Norway, Italy, Finland, and Belgium. Most of the models were tested in Germany and the UK, which later became the first markets in which the diesel Avensis with D-CAT was introduced (Toyota 2002).

Toyota launched its Avensis 2.0 D-CAT car in Germany and the UK in November 2003 as a Euro 4-compliant car eligible for reduced registration fees in several EU countries. Its ability to meet the Euro 4 standards early was not particularly unique – many other vehicles from Volkswagen, BMW, Mercedes, etc. were also able to reach Euro 4 in 2003. Even Toyota’s own D-4D engines, the basis for the D-CAT engines, met the Euro 4 standards in early 2003. However, the D-CAT system performance significantly surpassed Euro 4, getting to 2 mg/km PM and 110 mg/km NO_x, a 90% PM reduction and a 50% NO_x reduction over Euro 4 standards. Toyota viewed the D-CAT-equipped Toyota Avensis as its “flagship” car for the upcoming Euro 5 standards.¹⁷ The proposed Euro 5 NO_x standard was 200 mg/km, easily attainable by the D-CAT system.

Toyota has actively promoted its D-CAT system, publishing trade articles, presenting at industry meetings, and discussing the technology with regulators. Yet Toyota’s management in Europe claims that there has been no explicit intention to influence Euro 5 levels with these numbers. Intentional or not, Toyota’s technology did make a strong favorable impression with environmental groups and regulators, but their enthusiasm about the D-CAT system was dampened by the other automakers’ opposition to significant NO_x reductions.

¹⁷ Interview with Didier Stevens, Manager of Government Affairs, Toyota Motor Europe, August 24, 2005.

Support from environmental groups and auto clubs

The diesel Avensis' performance on emission reduction was cited by various groups during the discussion leading up to the Euro 5 proposal. When ADAC, the German Automobile Club, submitted its comments for the Euro 5 consultation to the Commission, it referred to the Avensis' performance in its EcoTest program. FIA Foundation, a worldwide association of automobile clubs, sponsored ADAC's EcoTest program to help customers select low-emission vehicles and to encourage competition by manufacturers on emission characteristics. ADAC assigned points to 276 models based on their pollutant and CO₂ emissions. Of the diesel cars, the Toyota Avensis scored the highest, performing the best of all diesels on pollutant reduction, and among the best for CO₂ emissions (ADAC 2005). In presentations and reports, the German Environmental Agency, UBA, cited the performance of Toyota's DeNOx technology in its argument for lowering the NOx limits to as low as 80 mg/km, from the proposed limit of 200 mg/km (Rodt 2003).

Private benefits to Toyota

Early sales of Toyota cars with the D-CAT system were limited, because in 2003, the system was only offered on the 2.0L D-4D diesel engine in the Avensis. Toyota was also constrained by the limited availability of low-sulfur diesel fuel – sales were restricted to the UK and Germany, where fuel sulfur levels were less than 50ppm. To get around the problem of misfueling with higher sulfur fuel, the D-CAT system is equipped with a switch that the driver can turn off if ultra-low sulfur diesel is unavailable (Nayer 2004). Clearly, with the switch off, the dramatic PM and NOx reductions do not occur. Toyota's limited release of its D-CAT technology in 2003 was in preparation for its more widespread introduction in 2005, when 50 ppm sulfur diesel became widely available. According to Toyota's own European Environmental Report: "The success of these field trials means that the DPNR-equipped Toyota Avensis will have a limited launch in the UK and Germany, where low sulphur diesel is available, before the end of 2003, and an anticipated pan-European market launch from 2005 onwards when low sulphur fuel will be mandatory in EU Member States" (Toyota 2003). The early introduction allowed Toyota to improve the technology prior to large-scale production.

By 2005, the D-CAT was standard in the new 177 hp 2.2L engine, which became available in the Avensis, Corolla Verso, RAV4, and Lexus IS 220d. Due to the lack of legal obligation and the availability of Toyota's less expensive 4-D4 engine systems already meeting the Euro 4 standards, sales of D-CAT equipped cars were minor. From January to July 2005, only 2,657 cars with the 2.2L D-CAT engines were sold.¹⁸ Meanwhile, Toyota sold 145,111 units of Avensis cars in 2004 (Toyota 2004).

The Avensis has been popular with fleet owners because of its affordability and features (Meredith 2003). In spring 2003, the 2.0-litre D-4D diesel engine in the Avensis, even without the D-CAT system, was the first in its class to meet the Euro 4 standards, allowing UK fleet car owners to avoid the 3% diesel car tax. The Avensis won the New Fleet Car of the Year in the 2004 Fleet Excellence Awards, which is given by UK fleet owners. From 2003 to 2004, sales of the Avensis model have increased by 25% (Toyota 2004). Offering the D-CAT technology in such a popular vehicle may have hinted at Toyota's hopes to make D-CAT mainstream.

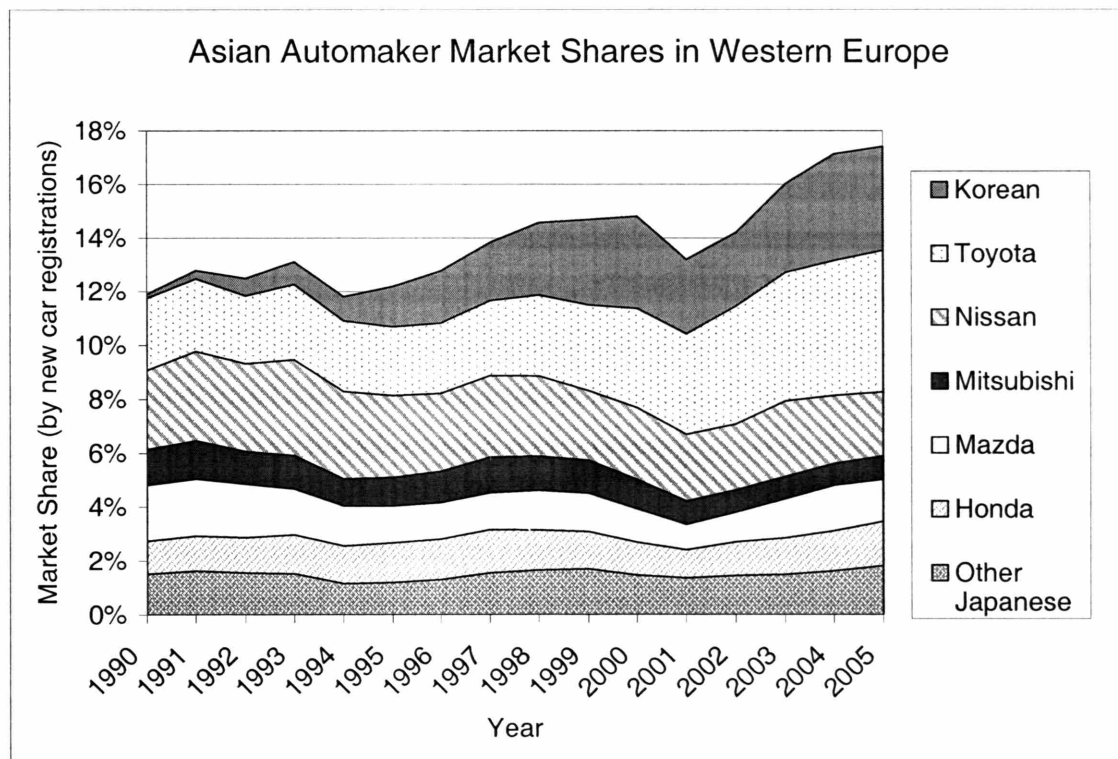
Toyota's limited influence on Euro 5 regulation but continued growth in the EU

Despite Toyota's efforts to publicize D-CAT technology and the enthusiasm of environmental and auto clubs, Toyota was less successful with European regulators. Unlike US regulators, who tend to base standards on levels attainable by the industry leaders, European regulators prefer to set standards based on technology that can be met by most automakers. Moreover, Toyota's status as a foreign company in a market dominated by French and German automakers limited its influence in Europe. In 2003, when the European Commission met with ACEA, the European automobile manufacturers association, to discuss Euro 5 regulations, the Japanese auto manufacturers were excluded from the meetings. ACEA is comprised of European auto manufacturers and also Ford Europe and GM/Opel because they are considered European firms despite their American parent companies. Toyota expressed its frustration to the trade media about being shut out from the Euro 5 discussions because it considered itself a major player in the European passenger car market. However, its growing sales are already challenging the European manufacturers' stronghold in the diesel passenger car market. Toyota has the largest market share of the Japanese auto companies, which together command 14% of European

¹⁸ Interview with Didier Stevens, Manager of Government Affairs, Toyota Motor Europe, August 24, 2005.

passenger car market. As shown in Figure 6-4, Toyota's sales growth has been the main driver behind the growing market share of Japanese companies in Europe. The success of Toyota and the Korean automakers has primarily come at the expense of American automakers Ford and GM/Opel and struggling Italian automaker Fiat (ACEA 2005). Toyota has also strengthened its position in the diesel passenger car market, such that in 2004, diesels accounted for 37% of Toyota's European sales, compared to only 21% in 2001 (Toyota 2005).

Figure 6-4: Rise of Toyota and Korean Manufacturers in the European Car Market



Source: ACEA (2005)

PSA's large-scale introduction of diesel particulate filters and the subsequent "No Diesel without Filter" campaign in Germany shifted the focus of regulators and auto companies to PM reductions rather than NOx reductions. Tackling dramatic PM and NOx reductions at the same time would have been politically difficult, especially when many automakers had already been fiercely opposed to PM filters. Also, NOx is considered more challenging and costly to reduce.

However, Toyota was convinced in 2003 that its D-CAT technology could accomplish significant NO_x and PM reductions (Automotive News Europe 2003). Jim Rosenstein, Toyota Motor Europe's communications vice-president was quoted in the press as saying, "The industry believes Euro 5 may kill the diesel...At the moment, we are probably the only carmaker who could meet eventual Euro 5 standards" (Automotive News Europe 2003). Other automakers saw Toyota's ability to reach substantially lower NO_x levels – 110 mg/km v. Euro 5's 200 mg/km – as counter to their desire for more lenient NO_x standards.

Toyota's D-CAT technology came under a lot of fire from automobile associations in Europe and US, who questioned its durability. In a 2002 EPA diesel progress report, the US EPA cited Toyota's diesel Avensis and D-CAT system as preliminary evidence of a diesel vehicle capable meeting the US Tier 2 standards. US automakers, as represented by the Alliance for Automobile Manufacturers (AAM), claimed that EPA was overly optimistic and that Toyota's system still fell short of meeting the supplemental test cycle limits and durability limits (Peckham 2002). In Europe, German auto manufacturers criticized the system, and showed data illustrating the shortcomings of the D-CAT system. BMW's development head, Burkhard Göschel, expressed doubts about the NO_x adsorber system, arguing that urea-SCR technology was the only viable NO_x emissions solution (Dieselnet 2005). An unnamed Toyota supplier released data showing that the D-CAT-equipped Toyota Avensis could not meet the Euro 4 NO_x standard after 20,000 to 40,000 km of testing. This goes against the fact that the Toyota Avensis received official Euro 4 type approval from the European Commission, which requires 100,000 km of testing. Toyota Europe's Manager of Government Affairs Didier Stevens claimed that the durability testing overseen by the other manufacturers did not adhere to the same test conditions used by Toyota's testing, resulting in the discrepancy.¹⁹

Some critics speculate that Toyota was purposely supporting greater NO_x reductions not to promote its D-CAT technology, but to encumber diesel passenger cars with more costly regulations. Its gasoline-electric hybrid technology, in which Toyota is the world leader, would then become more cost competitive with diesels. Toyota has denied such intentions, but statements made by Toyota executive vice-president Akikhiko Saito in a 2003 Financial Times article on diesel standards reveal the company's clear preference for hybrids over diesels. He stated that if diesel and petrol cars had the same NO_x and PM standards, diesels would be priced

¹⁹ Interview with Didier Stevens, Manager of Government Affairs, Toyota Motor Europe, August 24, 2005.

out of the market. "European manufacturers are trying to emphasize their European (diesel) technology...But it is predicated on rather lax NO_x regulations on diesel compared to gasoline...If those NO_x regulations are brought into line much more effort will be needed for diesel. The diesel-driven cars' cost could be higher than gasoline-driven hybrid vehicles" (Mackintosh 2003).

Despite Toyota's exclusion from the ACEA talks and hostility from other manufacturers, European regulators did look favorably upon Toyota's D-CAT technology. Other European automakers' proposed NO_x reductions had not been significant, so Toyota's claim of reducing NO_x by 50% over Euro 4 levels stood in direct contrast to their proposals (Mackintosh 2003). The European Commission is generally not comfortable making regulations that only one manufacturer can meet. They prefer to wait until NO_x aftertreatment technology is mature on a larger scale.²⁰

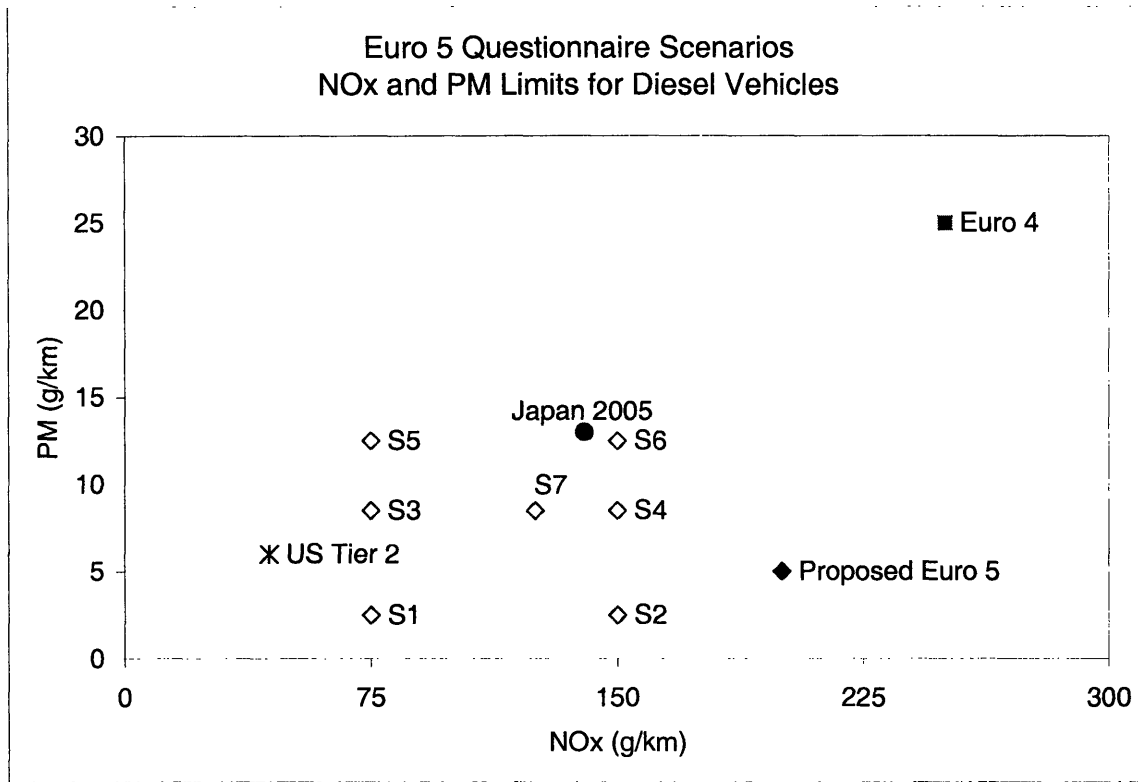
The next section describes the formal Euro 5 consultation process, which began in 2004. By that time, the European Commission had already conducted preliminary technology assessments.

6.3.3 Euro 5 consultation process

In early 2004, the European Commission sent out questionnaires to stakeholders to get feedback on the upcoming Euro 5 standards. The questionnaires presented 7 scenarios with varying PM and NO_x limit values as alternatives to the previously proposed Euro 5 standards, and sought information on the technology and cost required for meeting those limits. HC and CO limits were presumed to remain the same as in the Euro 4 standards. Based on feedback from the questionnaires, the Commission produced a preliminary draft proposal for the Euro 5 standards. It invited comments during 2-month consultation period in summer 2005.

²⁰ Interview with Didier Stevens, Manager of Government Affairs, Toyota Motor Europe, August 24, 2005.

Figure 6-5: Proposed NOx and PM Limits for Future Diesel Standards



Source: European Commission (2005b)

Note: US Tier 2 and Japanese 2005 standards are included in the diagram for reference, but since the certification test conditions are different, they are not exactly equivalent to the European standards.

All seven scenarios in the questionnaire featured NOx limits of 150 mg/km or less and three of them had NOx limits of 75 mg/km. However, when the Commission released its draft regulation, the proposed Euro 5 NOx limit was higher than any of the scenarios. The NOx level would be reduced by only 20% from 2005 levels, from 250 mg/km to 200 mg/km. In the questionnaire responses and technology submissions, the auto industry had convincingly persuaded the Commission of the technology and cost challenges of more significant NOx reduction.

Technology reports by vehicle manufacturers cast doubts about the availability of NOx aftertreatment devices for Euro 5. As a result, the Commission supported setting standards that would not require NOx aftertreatment on light-duty vehicles (EC 2005a). In the Commission's

draft Euro 5 proposal, it remarked: “This emission limit has been set so that reductions can be achieved by further internal engine measures, to avoid the need for NO_x aftertreatment to be installed at this stage. As the technology for further NO_x reduction is not yet mature, it is therefore proposed not to reduce NO_x emissions beyond the 200 mg/km limit value.” It was generally accepted by the Commission and industry stakeholders that to maintain the fuel economy and CO₂ emission benefits from diesel vehicles, they had to be less aggressive about NO_x reduction. Industry and environmental groups disagreed about the difficulty of a 20% NO_x reduction. Auto manufacturers argued that the 20% reduction would be “significant and challenging,” while environmental groups and emission control suppliers provided evidence of the feasibility of lower NO_x limits.

Environmental agencies in Germany, Sweden, Switzerland, Denmark, and the Netherlands, the European Environment Bureau, and some environmental NGOs expressed their disappointment in the minor NO_x reduction. They supported lower NO_x limits, suggesting values as low as 75 mg/km. They felt that the proposed 200 mg/km level was not sufficiently technology-forcing. A lower limit would encourage manufacturers to use urea SCR systems or other NO_x aftertreatment. In the case that the technology is not ready for Euro 5, some commenters suggested setting up Euro 6 standards at this time to encourage R&D. Many of these organizations also expressed support for a PM limit of 2.5 mg/km rather than 5 mg/km, since existing vehicles with particulate filters were already capable of getting down to 1 mg/km.

Unlike US and Japan, Europe will still have different emission standards for diesel and gasoline-powered vehicles after this latest set of regulations. If diesel cars were held to the same NO_x standards as gasoline cars – 60 mg/km instead of 200 mg/km – no existing diesel car would be able to meet it. According to industry perspectives in the trade press, such a move in the near term would essentially ban diesel cars. However, large passenger vehicles, like SUVs and light trucks, will be subject to the same Euro 5 standards as passenger cars, much to the chagrin of the auto industry.

Expected supporters: emission control manufacturers

Emission control manufacturers are consistent supporters of more stringent emission standards because regulatory-driven demand helps them sell more products. The Association for

Emissions Control by Catalyst (AECC), a European-based trade association representing the interests of emission control manufacturers, felt that the proposed Euro 5 NO_x and PM standards were not ambitious enough. They offered technical evidence that vehicles were capable of meeting much lower limits.

An AECC test programme showed that a “state-of-the-art” Euro 4-compliant vehicle with good fuel economy would already reach a 150 mg/km NO_x limit. According to the UK’s Vehicle Certification Agency’s database of vehicles receiving type approval, 45% of Euro 4 diesel vehicles already meet the proposed 200 mg/km limit (AECC 2005). AECC acknowledged vehicle manufacturers’ concerns about the cost and vehicle integration issues for the new aftertreatment systems (NO_x adsorber, urea SCR), but felt that manufacturers and their suppliers needed more significant NO_x targets to spur progress: “However, if there is no prospect of NO_x control systems being required for future European vehicles, then there will be no impetus for their application in Europe and hence no forward movement on their development.” AECC also hinted that stricter standards would better prepare European manufacturers to compete in other markets; technological advances were already happening in the US (AECC 2005).

In terms of the PM limits. AECC observed that current new vehicles, when outfitted with diesel particulate filters, were already well below the 2.5 mg/km limit proposed by one of the Commission’s scenarios. In contrast to vehicle manufacturers, it supported the development of a particle number limit, since vehicles with low PM mass emissions could still emit a large number of ultrafine particles, which are more damaging to lungs. AECC agreed with ACEA that the lead time of 18 months for type approval of new vehicles is too short, but thought two years, rather than ACEA’s preferred three years, was enough (AECC 2005).

6.3.4 Impact of PSA and Toyota as first movers

Why did PSA’s diesel particulate filter technology have such a strong impact on the Euro 5 regulations, while Toyota’s D-CAT technology did not? There are several reasons: (1) timing, (2) NGO and public involvement, (3) ease of technology diffusion, and (4) less urgency to reduce NO_x than PM.

PSA introduced its diesel filter technology in 2000, three years earlier than Toyota’s first offering of the Avensis with D-CAT technology. This gave PSA more time to showcase its

technology to customers and regulators prior to discussion about the Euro 5 regulations. By 2003, enthusiasm about diesel particulate filter had already spread throughout Europe, especially in Germany and France. PSA had sold 500,000 cars with filters by mid-2003. Toyota did not begin selling any Avensis models with the D-CAT system until November 2003. It offered D-CAT as an option with added cost, so the vast majority of Avensis buyers did not order D-CAT.

PSA's introduction of diesel filter technology triggered environmental NGO activity in Germany, culminating in the "No Diesel without Filter" campaign. The organized campaign and media publicity placed pressure on the auto industry to adopt filters. While Toyota's D-CAT technology caught the eye of trade press, automobile clubs, and some regulators, it did not generate the same kind of activism from the environmental community.

Diesel particulate filters are not a new technology – they have been around since the mid-1980s (Johnson 2001). For example, by 2000, the leading diesel filter manufacturer, Johnson Matthey, had already sold over 20,000 catalyzed diesel particulate filters for installation on heavy-duty diesel engines for trucks and buses (MECA 2000). The major challenge was not the technology, but making it affordable enough for light-duty vehicles. A crucial part of PSA's achievement was getting the filter cost low enough to make it standard in every car. Although the other automakers lagged PSA in adding filters to their cars, it did not take long for them to develop and market their own systems. When the Euro 5 consultations were underway, most manufacturers had already begun voluntarily installing filters in some of their diesel car models. By this time, it was easier to persuade them to accept a very low PM limit. NO_x reduction is much more difficult to accomplish. Other automakers were not prepared to follow Toyota's lead with NO_x adsorbers, still considered a developing technology. Most of the other manufacturers supported urea SCR systems as the favored NO_x reduction technique, so it did not help that Toyota's technology of choice deviated from the majority's preference. Another problem with Toyota's technology is that it requires very low fuel sulfur levels – definitely below 50 ppm, and preferably below 10 ppm. PSA's filter technology did not require any special diesel fuel. Since fuel suppliers in European countries were not required to sell fuel with 50 ppm sulfur levels until 2005, Toyota was constrained to introduce their D-CAT-equipped Avensis in countries which had introduced 10 ppm early.

From a public health standpoint, particulates cause more serious respiratory and cardiovascular problems than NO_x. In recent years, attention to particulate emission control has come to the forefront of the public and regulatory arena because of many medical studies linking diesel particulates with increased cancer and mortality rates. Therefore, regulators have decided to tackle PM before NO_x. Images of soot-covered cloths placed near diesel engine exhaust pipes and clouds of black smoke from cars have more salience and emotional appeal with the public than explaining how complex interactions among NO_x, VOCs, and sunlight in the atmosphere create ozone.

6.3.5 Beyond Euro 5

In the past few years, Toyota's relationship with European regulators has improved significantly. Because of its introduction of hybrids and D-CAT diesels, Toyota is perceived as a technology leader. On several occasions, European Commission officials have contacted Toyota to ask them about specific issues, and treated Toyota as a sounding board for ideas.²¹ Toyota may not have had influence over Euro 5, but in the next round, in Euro 6, regulators may feel more confident setting more stringent NO_x standards and identical standards for light-duty diesel and gasoline vehicles. However, by this time, other manufacturers may have developed effective and commercially viable NO_x emission reduction strategies, challenging Toyota's 2004 status as having the "cleanest diesel car" in the world in terms of PM and NO_x emissions.

6.4 United States

The US EPA has not begun its regulatory process for the next round of light-duty vehicle emission standards after Tier 2. However, it is clear that federal and state regulators and environmental groups are closely following the developments in Europe and Japan.

German environmental officials have been eager to share the success of their country's filter technology introduction with the US. Stefan Rodt, the head of the transport pollutant emissions at the German environmental agency (UBA), gave a presentation about European

²¹ Interview with Didier Stevens, Manager of Government Affairs, Toyota Motor Europe, August 24, 2005.

diesel emission standards at the Diesel Engine Emissions Reduction (DEER) conference in San Diego, California in 2002. Rodt compared the dramatically reduced particulate emissions of a filter-equipped Peugeot 607 to a Mercedes E220 CDI without a filter. He showed that filters reduced particulates for all sizes of particles, and the resultant levels of particulates were below those detected by the particulate number test procedure (Rodt 2002). He and Axel Friedrich, the UBA's Head of Environment and Transport, have been very vocal about their support of diesel filter technology and eagerness to see other manufacturers follow PSA's lead. Unlike the US EPA, which tries to keep its activities distinct from environmental interest groups, the UBA teamed up with Deutsche Umwelthilfe (DUH), the German environmental NGO that led the "No Diesel without Filter" campaign, to make presentations to U.S. environmental groups. They held a special conference at the Washington, D.C., office of the non-profit group Environmental Defense, to pass on their experiences and inspire their American counterparts to support diesel particulate filter adoption (Peckham 2003).

So far, the PSA diesel filter technology and the Toyota Avensis D-CAT system have shown their relevance to discussions about Tier 2 regulations, but their current inability to meet the full Tier 2 requirements have prevented them from influencing the next round of US regulations. Even so, the Toyota Avensis' progress toward reaching Tier 2 PM and NO_x standards may reaffirm EPA's preference for NO_x adsorbers over urea SCR systems. The latter requires a national urea distribution infrastructure to supply the urea additive to vehicles. Approval of urea SCR systems would require a rewrite of current EPA requirements, which require emission control systems to go without maintenance for at least 120,000 miles. Cars with urea SCR systems would need to be refilled with urea every 5,000-10,000 miles for NO_x reduction to occur. If EPA sees that NO_x adsorbers work sufficiently well to meet standards, they may not see the need to modify the regulations.

Even though the EU and Japan have more frequently updated their emission standards than the US, US standards are actually on par or more stringent with the Japanese and EU standards in the 2008-09 timeframe. According to the German UBA, the US Tier 2 standards are 80% lower in NO_x and almost 70% lower in PM than the Euro 5 standards.

6.5 Japan

Japan's Central Environment Council submitted a draft proposal for the 2009 light-duty vehicle emission limits to the Environment Minister in February 2005. The proposal, entitled the Eighth Report on Future Measures to Reduce Vehicle Pollutant Emissions, was open to public comment in February and March 2005, with plans to finalize it at the end of 2005 (Jiji Press 2005).²² The Council had originally intended to reduce PM and NOx emissions by 90% from the 2005 levels, but chose to make the reductions less dramatic – only 60% for PM and 45% for NOx. This may have resulted from consideration of energy efficiency and CO₂ emission reduction, which can be at odds with pollutant reduction (Kyodo 2005).

6.5.1 Negotiating the NOx-PM trade-off

Although the US and Japanese standards are associated with different test conditions, the 2009 Japanese standards – 80 mg/km NOx and 5 mg/km PM – are considered comparable to the 2004 US Tier 2 standards in PM, but weaker in NOx. In its 2003 report on future emissions policy, the Japanese Central Environment Council had already articulated its prioritization of PM reduction over NOx reduction: “The new long-term targets for diesel motor vehicles to be adopted in 2005 emphasize regulation of PM emissions over that of NOx. For this reason, it is estimated that in 2010, while the volume of PM emissions from diesel motor vehicles will have decreased by two-thirds from the 2000 level, NOx emissions will have decreased by no more than about 30%” (Japan Central Environment Council 2003b). Japan's 2009 NOx standard is more stringent than the Euro 5 (post-2008) standard of 200 mg/km. The 2009 regulation is also the first time that diesel cars will have the same emission limits as gasoline cars, which has yet to happen in Europe. Arguably, any diesel car that can be certified in Japan will receive type approval in Europe, keeping Japanese auto manufacturers competitive in the European diesel market.

²² The environmental ministry estimates the proposed regulations will reduce PM emissions from 79,000 tons in FY2000 to 5,300 tons in FY2015 and NOx emissions from 566,000 tons to 188,000 tons.

As part of the Kyoto Protocol agreement, Japanese manufacturers had to produce cars to meet the EU's midterm target of 165 to 175 g/km CO₂ by 2003, and long-term target of 120 g/km CO₂ by 2010. Japanese manufacturers met the 2003 targets one year early, with a new car average of 174 g/km. This achievement has been attributed to a recent increase in diesel vehicle sales in Europe. By modeling Japanese diesel emission standards closer to those in Europe – strict on PM but more lax on NO_x, the Japanese government has helped their manufacturers compete on a level playing field with European manufacturers. As Japanese manufacturers sell more diesel cars in Europe and develop more effective emission reduction technology, the Japanese government has become more open to greater diesel car sales in Japan. The Japanese Ministry of Economy, Trade, and Industry (METI) has encouraged the development of clean diesel technology. METI issued a report in August 2003 recommending government and industry work together to develop advanced diesel and hybrid diesel passenger cars. In particular, greater investment would help Japanese manufacturers harness their technology lead over foreign automakers in hybrid technology (Kyodo 2003). Increased diesel car use over gasoline cars could reduce CO₂ emissions and fuel consumption and take advantage of the existing diesel fuel surplus. In 2005, METI identified the 2009 emission standards and improvement of public perception of diesels as the main challenges (Ito 2005).

The proposed 2009 standards are an effort by Japan's national government to build on the stringent measures already adopted by Tokyo and other metropolitan areas. The new country-wide limits have stringent PM limits which all but require particulate filter technology on new diesel vehicles. The NO_x standards are not yet attainable in commercially available cars but the Japanese government expects technology to progress sufficiently to meet the standards by 2009. Technological progress by the automakers on diesel particulate filters made it easy for the Japanese government to call for such low PM levels.

6.5.2 Auto industry response

The stringency of the 2005 Japanese diesel emission standards have already posed a large barrier for diesel car manufacturers hoping to sell to the Japanese market. European manufacturers such as DaimlerChrysler and Volkswagen have wanted to sell diesel models, but in recent years the emission requirements have been prohibitively stringent. As of 2005, the

diesel NO_x standard of 140 mg/km has only been met by the Toyota Avensis, equipped with the D-CAT system. However, the D-CAT-equipped vehicle still falls short of meeting Japan's 2009 80 g/mi NO_x standard.

Despite METI's interest in diesels, diesel cars produced by Japanese manufacturers have been primarily destined for sales in Europe. Diesel cars are better suited to long-distance, high speed driving, and are not as well suited to the short-distance, stop-and-go driving typical in Japan. The Japanese vehicle industry has never seriously invested in a domestic diesel car market, choosing to focus its diesel sales on Europe, where diesels make up half the new car market. Even JAMA, the Japanese auto industry association, sees hybrid gasoline-electric vehicles as superior to diesels in terms of fuel efficiency, CO₂, and emission reduction (JAMA 2001).

Like the US Tier 2 standards, the 2009 Japanese standards will probably create a nearly insurmountable hurdle for diesel automakers, at least in the next 3-5 years. Diesel power may remain the purview of trucks and buses.

6.6 Summary

Stringent US and Japanese standards have made it increasingly difficult to market emission-compliant and affordable light-duty diesel vehicles in those countries. However, advanced technology developments and regulatory decisions in Europe are likely to shape American and Japanese regulators' attitudes towards diesels' future in their countries. PSA's diesel particulate filter and Toyota's D-CAT system demonstrate that some companies will market cleaner technologies in advance of regulatory requirements. Influencing regulations may not be their main motivation, but those technology introductions do affect future policy. PSA's filter introduction had a dramatic effect on the support for filters in Germany. Pressure on other automakers and countries to adopt filter technology ultimately influenced the stringency of the Euro 5 PM standard. Although Toyota's D-CAT system had limited impact on Euro 5, further refinement of the system, along with other automakers' development of similar systems, could prompt European regulators to significantly tighten NO_x regulations in Euro 6.

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CHAPTER 7 – Heavy-duty Diesel Engines, 1990s to Early 2000s

7.1 Introduction

The next two chapters cover emission regulations and technology development of heavy-duty diesel vehicles. The previous two chapters on light-duty diesel vehicles showed instances where certain companies complied with emission standards early or supported more stringent emission standards. In some instances, the companies with cleaner technologies did well in the marketplace and also influenced the design of regulatory policy. This chapter on heavy-duty diesel engines from the mid-1990s to the early 2000s tells a different story. It documents situations where individual companies or the entire industry were non-compliant. Disputes over technical details and unchecked noncompliance hampered air quality improvements. Examples from the US, Europe, and Japan document cases where companies that delayed or circumvented regulatory compliance improved their market share over their competitors. While manufacturers remain accountable for any illegal activities that hamper air quality improvements, customer demand and regulatory design can contribute to perverse outcomes. Once the motivations and mechanisms behind these outcomes are understood, regulators have the opportunity to revise testing and enforcement procedures to strengthen safeguards against noncompliance in the future.

7.2 Heavy-duty diesel engine regulations and test cycles

Heavy-duty diesel vehicles are regulated in terms of engine emissions, not vehicle emissions. Engine manufacturers must obtain emission certification before selling their new engine models. Whereas light-duty vehicles are tested on a chassis dynamometer, which varies speed only, heavy-duty engines are tested on an engine dynamometer, which varies both speed and load. As a result, emissions are measured in terms of mass per unit of work (g/bhp-hr in the US or g/kWh in the EU and Japan), rather than mass per unit of distance (g/mi or g/km). Test cycles consisting of timed combinations of speed and load vary by country, and usually try to simulate driving conditions typical to that country. The emissions from each portion of the test

cycle are recorded, weighted, and averaged to produce a weighted average that must fall within the regulatory limits. An engine model must receive emission certification or approval from regulators to be eligible for sale. Table 7-1 summarizes the emission standards for several regulatory cycles from the mid-1990s to 2004.

Table 7-1: Heavy-duty Diesel Engine Emission Standards for Mid-1990s to 2004

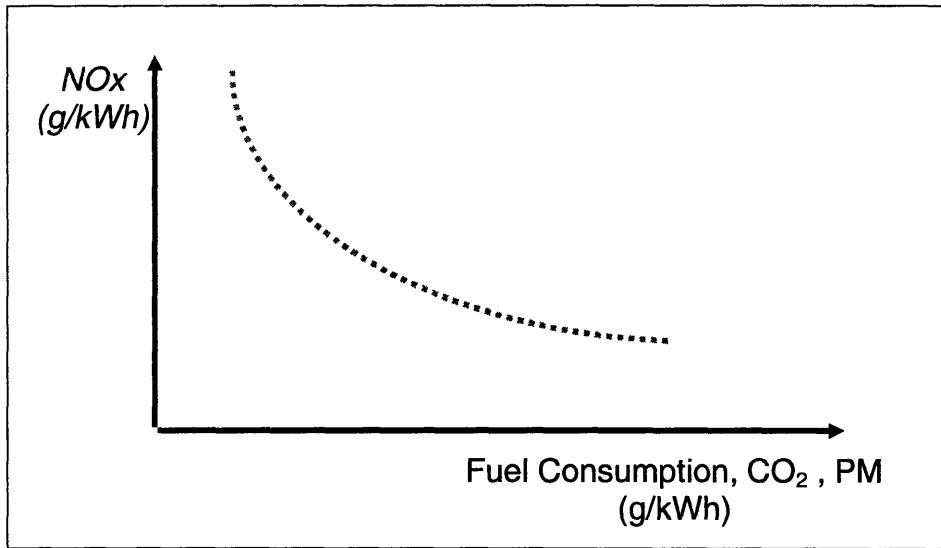
	US (1994)	US (1998)	US (2002/04)	Japan (1994)	Japan (1997)	Japan (2003)	Euro 2 (1996)	Euro 3 (2000)
CO	15.5 g/bhp-hr (20.8 g/kWh)			7.40 g/kWh		2.22 g/kWh	4.0 g/kWh	2.1 g/kWh on ESC, 5.45 on ETC
HC	1.3 (1.7)			2.90		0.87	1.1	0.66
NMHC + NOx			2.5 (3.25)					
NMHC			0.5 (0.65)					0.78
NOx	5.0 (6.5)	4.0 (5.2)	2.0 (2.6)	6.0	4.50	3.38	7.0	5.0
PM	0.10 (0.13)			0.70	0.25	0.18	0.25 0.15 (1998)	0.10 on ESC, 0.16 on ETC
Weight	> 8500 lb (3860 kg)			> 2500 kg			> 3500 kg	
Test	FTP	FTP	FTP, SET, NTE	13-mode test			ECE R-49	ESC, ETC, ELR

Note: FTP = Federal Test Procedure, SET = Supplemental Emission Test, NTE = Not-to-exceed Limits; ECE R-49 is a 13-mode steady-state test, ETC = European Transient Cycle, ESC = European Stationary Cycle, ELR = European Load Response (for smoke opacity).

Sources: US EPA, Japan Ministry of the Environment, European Commission (2005); Dieselnets (2006).

By the 1990s, the EU, Japan, and the US were regulating hydrocarbon (HC), carbon monoxide (CO), nitrogen oxide (NOx), and particulate (PM) emissions from heavy-duty engines. Of those pollutants, NOx has been the most difficult and expensive for the manufacturers to reduce. Reducing HC, CO, and PM coincides with improving combustion efficiency, and consequently, fuel economy. Since fleet operators highly value fuel economy to save on fuel, manufacturers have an incentive to invest in such improvements. However, reducing NOx requires retarding combustion to lower combustion temperatures, which decreases fuel economy. Figure 7-1 shows the general relationship between NOx emissions and fuel consumption. Reducing fuel consumption also reduces carbon dioxide (CO₂) and PM emissions.

Figure 7-1: NOx-Fuel Consumption Trade-off



Source: Gill (1988), Dieselnets (2002)

Increasingly stringent regulations required diesel engine manufacturers to reduce NOx emissions from 10.7 g/bhp-hr in 1988 to 5.0 g/bhp-hr in 1991 and then to 4.0 g/bhp-hr in 1998. According to Khair (1992), going from 10.7 g/bhp-hr to 4.5 g/bhp-hr requires injection timing retard which causes a 6% fuel economy loss. Increasing fuel injection pressure is one way to mitigate to this fuel consumption loss. Manufacturers relied on a more effective but legally questionable technique to reconcile the problem.

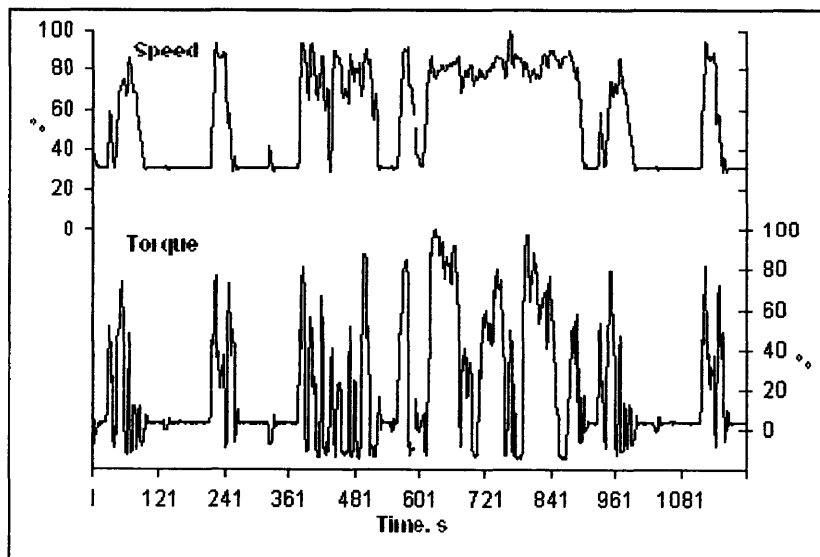
With the rise of electronic controls in vehicles, engine manufacturers incorporated software to electronically adjust the NOx-fuel consumption trade-off depending on the engine's drive cycle. An industry-wide circumvention of NOx controls was first exposed in the US in the late 1990s, accompanied by later evidence that similar practices were common in Europe. The discovery of these "defeat devices" changed the landscape of the diesel engine industry as well as engine certification test procedures.

7.3 United States

7.3.1 Heavy-duty diesel consent decree

In 1998, seven heavy-duty diesel engine manufacturers, comprising 95% of the US diesel engine market – Caterpillar, Cummins, Detroit Diesel, Mack, Navistar International, Renault, and Volvo Truck – were charged with violating the Clean Air Act by installing “defeat devices” that circumvent emission controls. Most model year 1993-99 US engines operated with dual-mapping software. It keeps emissions below the limits during EPA certification test cycle conditions, but optimizes for fuel economy and power during the off-cycle (U.S. House Committee on Commerce 2000). Engine maps dictate engine operating parameters under different combinations of speed and load. An engine is expected to stay below emission limits for these various combinations. During certification testing under the EPA’s transient FTP (Federal Test Procedure) test, the on-board diagnostic software would detect that the engine was on one of the speed-load combinations in the EPA test cycle. As shown in Figure 7-2, the transient FTP cycle reflects urban driving conditions, where there is frequent acceleration and deceleration.

Figure 7-2: US Transient Federal Test Procedure (FTP) for Heavy-Duty Engines



Source: Dieselnet (2004)

Under such conditions, the engine operated so that NO_x emission levels were below the EPA limit. However, in actual highway driving conditions, when the engine entered a steady-state mode (e.g. 55 mph on a highway), the “defeat device” software overrode the emission controls by advancing the fuel injection timing relative to the timing used for NO_x control (U.S. House Committee on Commerce 2000).

This improved combustion efficiency but increased NO_x emissions by up to three times the allowable EPA limit, which was 5 g/bhp-hr from 1991 to 1997 and 4 g/bhp-hr from 1998 onwards (EPA 1997a-a). Therefore, the resulting higher emission levels during highway travel exceeded the pre-1988 level of 10.7 g/bhp-hr. A new 1998 engine could be emitting more NO_x than its decade-old predecessor. Truck drivers and fleet owners value fuel savings and engine performance well above emissions reduction, so manipulating emission controls with dual-mapping software was aligned with their self-interest. Aware of their customers’ sensitivity to fuel costs, all major heavy-duty engine manufacturers used some form of “defeat device” software.

The problem surfaced during a routine EPA enforcement audit of an engine in 1997. Test results indicated the existence of questionable calibration strategies. EPA conducted an industry-wide compliance investigation and software review, and learned that the use of defeat devices was widespread (U.S. House of Representatives 2000). In October 1998, opting to avoid a drawn-out litigation process, the manufacturers settled with EPA for over \$1 billion, the largest settlement in Clean Air Act history. As part of the \$1 billion, they had to cover \$83.4 million in civil penalties, \$109.5 million for environmental projects, and over \$850 million in R&D, engine rebuild, recalls, and new emissions testing. A portion of this settlement was paid to the California Air Resources Board as part of the related California Settlement Agreement. The manufacturers sold 1.3 million engines between 1988 and 1998 with these defeat devices, resulting in the release of almost 16 million tons of excess NO_x in that decade. The excess emissions for 1998 alone was 1.3 million tons, representing 6% of total NO_x emissions from mobile and stationary sources, equivalent to an additional 65 million cars on the road (EPA 2004a). Highway heavy-duty vehicles account for 12% of total US NO_x emissions, so the excess NO_x emissions were a significant share (EPA 1997a-b).

NOx is a key precursor to ground-level ozone, which is formed chemically in the presence of NOx, VOCs (volatile organic compounds), and sunlight. Ozone exposure causes respiratory symptoms, decreased lung function, and even premature death. Children are particularly susceptible to asthma attacks. NOx also leads to environmental damage, such as reduced crop yield and forest growth, excess nutrients in aquatic systems, and acid rain. Because ozone depends on photochemical processes, the impact of excess NOx varies by geographical region, depending on whether it is NOx or VOC-limited. Although NOx does not have as serious health effects as diesel particulates, it was particularly egregious for these excess NOx emissions to surface when EPA was setting forth new 2004 NOx standards. It would not make sense to propose more stringent standards for 2004 when previous standards were not properly enforced. Table 7-2 lists each manufacturer's NOx excess emissions and penalty.

Table 7-2: 1998 Diesel Engine Consent Decree Settlements

Engine manufacturer	Engines sold with defeat devices	Years engines sold	Excess NOx emissions in tons and % of total	Civil penalty	Expenditures on environmental projects
Caterpillar	320,000	1988-98	2,100,000 (13.3%)	\$25 million	\$35 million
Cummins	400,000	1991-98	3,600,000 (22.9%)	\$25 million	\$35 million
Detroit Diesel	430,000	1988-98	9,000,000 (57.2%)	\$12.5 million	\$12 million
Mack/Renault	90,000	1990-98	860,000 (5.5%)	\$13 million	\$18 million
Navistar International	78,000	1994-98	40,000 (0.25%)	\$2.9 million	--
Volvo	10,000	1994-98	148,000 (0.94%)	\$5 million	\$9 million
TOTAL	1.3 million		15,748,000	\$83.4 million	\$109 million

Source: EPA (2004)

As part of the consent decree, all the manufacturers, except for Navistar International, agreed to meet the model year 2004 standards 15 months early, by October 2002 (U.S. EPA 1998). Navistar had a separate consent decree with the EPA in which it was not required to “pull ahead” the MY04 standards because of the relatively small amount of excess NOx emissions from their engines (Samuelsohn 2002a).

7.3.2 Minimal media coverage of the settlement

Although news of the \$1 billion settlement between the engine manufacturers and EPA made it to the front pages of the New York Times and the Washington Post on the days immediately after the settlement, few details about the illegal “defeat devices” themselves or the company decision-making processes were revealed. The first indication in a major US paper of the suspected illegal “defeat devices” was tucked away on page 16 of the February 11, 1998 New York Times, with the headline: “Makers of Diesel Truck Engines Are Under Pollution Inquiry.” At the time, the case was still before the Justice Department, so many details were kept confidential since negotiations between national and state pollution officials and engine manufacturers were underway. By settling out of court, the manufacturers avoided the more intense public scrutiny that would have resulted from having to present their case in court. As part of the agreement, they did not have to defend their intent or admit that they violated the law.

7.3.3 Early signs of a defeat device problem

While the manufacturers’ behavior was legally questionable and detrimental to public health, they argued that they had adjusted engine controls within the bounds of the certification requirements. The Federal Test Procedure (FTP) heavy-duty transient cycle has long been criticized for being flawed and outdated. As early as 1978, EPA was aware of the existence and increasing use of sophisticated electronic engine controls that could potentially be used to circumvent the test procedures, and even issued an advisory called “Prohibition on Emission Control Defeat Devices.” Circumventing electronic controls has not been limited to the heavy-duty diesel industry. From 1995 to 1999, there were four cases of automobile manufacturers using “defeat devices.” In separate cases, General Motors, Honda, Ford, and Toyota settled out of court after they were sued by EPA or CARB for circumventing emission controls and emitting excess CO, HC, or NO_x in their gasoline-powered cars. Compliance audits or field tests shed light on the discrepancy between actual in-use emissions and certification test cycle emissions.

A US House of Representatives Commerce Committee report, entitled “Asleep at the Wheel,” claims that as early as 1991, various sources informed EPA of the existence of

electronic engine control software which was being used to circumvent emission control systems (U.S. House Committee on Commerce 2000). EPA insists that it did not know of the defeat devices until 1997. The diesel engine manufacturers contend that EPA learned in 1994 how flaws in the FTP test allowed actual NO_x emissions to be much higher than those reflected in the test. The issue was discussed at a meeting of a working group for the UN Economic Commission for Europe's Group of Rapporteurs on Pollution and Energy (ECE-GRPE). The ECE-GRPE's informal working group on the worldwide heavy-duty certification procedure (WHDC) meets periodically to develop a new international testing cycle for heavy-duty engines. Reportedly, an EPA observer was present at their 1994 Geneva meeting, when the International Organization of Motor Vehicle Manufacturers (OICA for Organisation Internationale des Constructeurs d'Automobiles) presented data on the weaknesses of the US transient FTP. As an OICA member, Volvo had a team that measured emissions from a US engine running on the steady-state Euro 2 test cycle. They discovered NO_x emissions 2-3 times higher than those of the US regulatory limit. The EPA observer claimed to not recall hearing the Volvo presentation, and EPA declined to state whether anything relevant to defeat devices was learned (Parker 1998; U.S. House Committee on Commerce 2000).

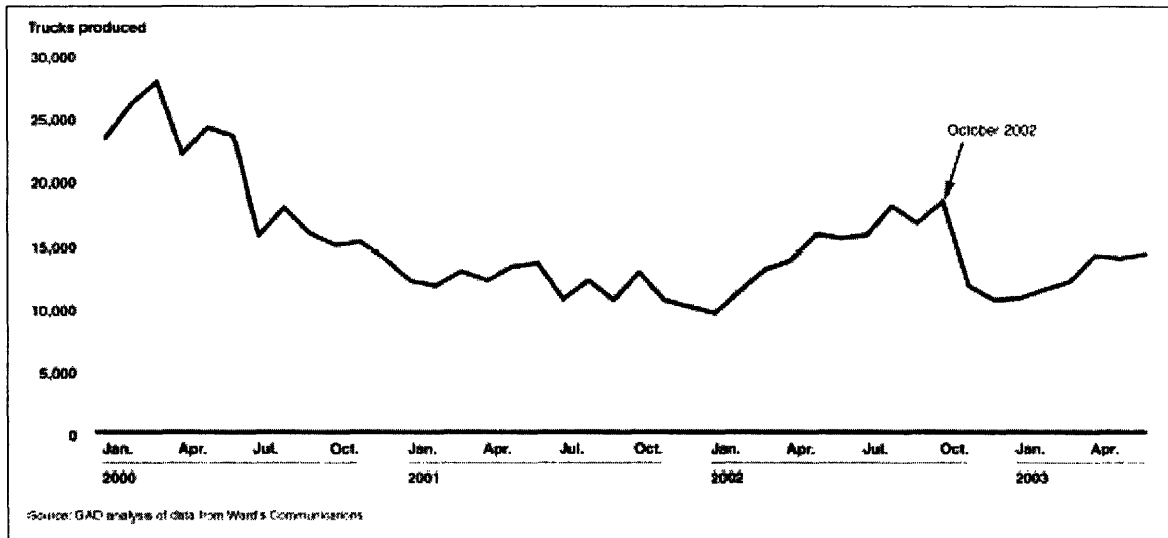
Even if the EPA genuinely did not know about these excess emissions until 1997, the EPA was sensitive to the possibility of "defeat devices" once electronic controls became widespread in engines. In 1996, an explicit prohibition of defeat devices was added to Part 86 in Title 40 of the US Code of Federal Regulations, which describes vehicle and engine emission control regulations. It also gives EPA authority to test for defeat devices using normal driving conditions outside of the standard FTP test: "The manufacturer must show to the satisfaction of the Administrator that the vehicle or engine design does not incorporate strategies that unnecessarily reduce emission control effectiveness exhibited during the Federal emissions test procedure when the vehicle or engine is operated under conditions which may reasonably be expected to be encountered in normal operation and use" (40 CFR §86.000-16). The language of the federal code also implies that EPA has the authority to regulate off-cycle emissions, even though engine manufacturers argued that their circumvention of the NO_x controls during highway conditions was legal.

7.3.4 Pre-buy

The civil penalties and environmental project expenditures were insignificant compared to the engine manufacturers' agreement to meet the previously established 2004 emission standards by October 1, 2002. This required the manufacturers to accelerate product development, which also decreased the amount of time for field testing the new engines. Industry press estimated that the new emission technologies increased engine prices \$3,000 to \$5,000 per engine on average, which was well above EPA's \$1,000 estimate. Those figures did not even account for the possible reduction in resale value and increases in operating and fuel costs (Hampton 2004; Mercer 2002). According to manufacturers' submissions to the EPA in 2001, fuel consumption of the new engines was expected to drop by 2-5% (Moulis 2002b). Engine manufacturers also cut back on the number of engine models and power ratings offered (Heavy Duty Trucking 2002). Many truck fleet owners purchased trucks prior to the introduction of the new October 2002 trucks, held onto their older vehicles longer, bought used trucks, or purchased engines not subject to the accelerated compliance deadline. By 2003, Mercedes, which was not a party to the settlement, experienced a quick rise in heavy-duty engine market share to 10% as a result of the consent decree (Ward's Automotive Yearbook 2005). According to a Bear Stearns survey of truck fleet owners, 54% intended to keep existing trucks longer and 16% planned to buy used trucks (Wolfe and Yagerman 2003). All these options resulted in higher emissions than if they had purchased vehicles with the new, compliant engines, thereby compromising the emission benefits associated with the accelerated deadline.

Suspecting misconduct by manufacturers, EPA conducted an investigation of the manufacturers' sales and marketing practices to determine if they encouraged customers to buy engines before the October 2002 deadline (Angelo 2002). Manufacturers denied engaging in any activity that encouraged pre-buy, and no evidence was found to suggest otherwise. It is likely that the concern about the new engines' performance, durability, and cost, and the truncated field testing time were enough to motivate the pre-buy.

Figure 7-3: Monthly US and Canadian Production of Class 8 Diesel Trucks



Source: GAO (2004)

According to the US Government Accountability Office (GAO)²³, the increase in production volume between April and September 2002 shown in Figure 7-3 cannot be explained simply by economic growth rate or fuel prices. The GAO estimates that 20-26% of the Class 8 trucks sold in that 6-month time period were attributable to the accelerated October 2002 deadline. During those 6 months, orders for trucks with pre-October 2002 engines were so high that engine and truck manufacturers had to operate their production lines 24 hours a day, 7 days a week. Their capacity was not even enough to meet the surging demand. Many had to hire temporary workers, only to fire them a few months later. After the October 2002 deadline passed, engine and truck orders plummeted, and engine and truck companies laid off thousands of temporary and full-time employees (Associated Press 2002; Gordon 2002; Inside Fuels and Vehicles 2002b).

²³ Prior to 2004, known as the General Accounting Office.

7.3.5 To comply or not to comply?

Not all the manufacturers met the October 2002 deadline. The table below lists the manufacturers' introduction of their first compliant engines, the technology used, and their certification levels. The NO_x+NMHC limit, originally intended for a 2004 deadline, was 2.5 g/bhp-hr, which meant a NO_x limit of 2.0 g/bhp-hr.

Table 7-3: EPA Emissions Certification by Engine Manufacturers

Manufacturer	First compliant engines certified (date)	Technology	NO _x +NMHC certification levels by end of 2002
Caterpillar	C9 (1/17/03)	Diesel oxidation catalyst and proprietary ACERT	2.8-3.2 g/bhp-hr
Cummins	ISX (4/2/02) ISB (8/15/02) 11L ISM (10/28/02)	Cooled EGR with variable geometry turbocharger	2.0-2.5 g/bhp-hr
Detroit Diesel	Series 50 (10/14/02) Series 60 (10/14/02)	Cooled EGR with variable nozzle turbocharger	2.4-2.5 g/bhp-hr
Mack/Renault	ASET (7/02)	Cooled EGR with variable geometry turbocharger	2.2-2.7 g/bhp-hr
Navistar International*	4000, 7000, 8500 (1/04)	Cooled EGR	2.7-3.8 g/bhp-hr
Volvo	VED12 (9/30/02)	Cooled EGR with fixed geometry turbocharger and variable pulse technology	2.4 g/bhp-hr
Mercedes Benz**	MBE 4000 12.8L MBE 900 (1/04)	Cooled EGR with fixed geometry turbocharger and waste gates	3.6-3.9 g/bhp-hr

* Under separate consent decree and not required to meet the standard until January 2004.

** Not party to the consent decree, and therefore not required to meet the standard until January 2004.

Sources: Arnum (2003), Inside Fuels and Vehicles (2002a), Samuelsohn (2002), Trailer/Body Builders (2002; 2003).

7.3.6 Noncompliance penalties

Prior to the implementation date of new emission standards, EPA establishes noncompliance penalties (NCPs) for engines that do not meet the standards. According to the Clean Air Act, NCPs can be used by the EPA when an emission standard is more difficult to meet, substantial R&D is required to meet the standard, and/or a “technological laggard” may develop. NCPs are designed to encourage long-term compliance while preventing manufacturers from being forced out of the marketplace if they cannot meet the standard. Penalties increase after a year of noncompliance (EPA 2001; EPA 2002a).

For the MY2004 standards, which had been accelerated to October 2002 for most manufacturers, the per-engine penalty varied depending on the engine type and emission levels. It was based on a formula that also accounted for manufacturers’ estimated compliance costs and fuel economy loss. EPA issued a proposed set of penalty rates in January 2002, but revised their penalties downward for the final rule in August 2002 after receiving lower cost estimates from the emission control industry. Table 7-4 lists the proposed and revised penalties for heavy heavy-duty engines for the first year of noncompliance; there were also penalties for light and medium heavy-duty diesel vehicles. The NCPs are meant to be very costly so that companies prefer to comply rather than continue paying the penalties.

Table 7-4: Penalty Rate per Non-compliant Heavy Engine in 2001 Dollars

NHMC+NO _x compliance level (g/bhp-hr)	Proposed Rule (as of 1/2002)	Final Rule (as of 8/2002)
2.5	\$0	\$0
3.0	\$4,680	\$3,640
3.5	\$9,043	\$6,946
4.0	\$10,193	\$7,999
4.5	\$11,342	\$9,052
6.0	\$14,790	\$12,210

Source: EPA (2002a)

Basing the penalties on the manufacturers' expected costs was not an easy task because of the wide range of cost estimates given by the manufacturers. For example, in anonymous cost submissions for the heavy-heavy truck engines, the estimated fixed costs per engine were \$273, \$407, \$516, \$1,013, and \$1,775. Other reported costs such as hardware costs and warranty costs also exhibited great variability (Moulis 2002a). Moreover, since some estimates were submitted as early as 1998, they were only rough projections of the actual costs (EPA 2002b).

7.3.7 Attacking the accelerated deadline

Leading up to the October 2002 deadline, the engine manufacturers were at different stages regarding the readiness of their technology. Cummins and Mack publicly expressed confidence that they would be able to certify their new engines in time. However, Caterpillar and Detroit Diesel were more hesitant, and tried to turn to the courts for relief. In July 2002, they filed lawsuits against the EPA in the US District Court for the District of Columbia, contending that unexpected cost increases would make compliance to the consent decree more expensive than previously estimated and less beneficial to the public (US v. Caterpillar 2002; US v. Detroit Diesel 2002). At the same time, the American Trucking Association (ATA), which represents the trucking industry, petitioned the EPA to reconsider the early October 2002 implementation of the 2004 rule. ATA argued that new information about costs and performance, as well as the pre-buy, undermined emission reduction goals. Caterpillar even urged some lawmakers to postpone the noncompliance penalties (Samuelsohn 2003). On September 5, 2002, the US District Court denied them any modifications of the consent decree, and defended EPA's commitment to levy noncompliance penalties for each engine sold not meeting the MY2004 emission standards (US v. Caterpillar 2002; US v. Detroit Diesel 2002).

After Cummins became the first manufacturer to successfully certify a compliant engine with EPA, Caterpillar attacked Cummins' technology, using the legal system and the media. Caterpillar filed a separate motion before the US Court of Appeals for the District Columbia, contesting EPA's certification of Cummins engines in April 2002. Caterpillar argued that Cummins' technology did not really reduce emissions but was another form of defeat device (Samuelsohn 2002b). According to a senior Cummins executive, the negative attacks by the

country's leading diesel engine manufacturer hurt Cummins sales as many customers began to doubt the quality and durability of Cummins EGR technology.

In addition to bringing cases to court, some companies operated in the "court of public opinion" and lobbied Congress members to delay the onset of the October 2002 deadline. Caterpillar spokespeople frequently brought up doubts about the reliability of the other manufacturers' new engines, justifying the company's decision to delay the introduction of their compliant engines. Caterpillar Engine Division Vice-President James Parker sent letters in March 2002 asking its customers to write EPA, Congress, and the US Chamber of Commerce to postpone the implementation of the new standards (Samuelsohn 2002b). Caterpillar's public skepticism toward other manufacturers' technology and efforts to delay the new standards coincide with its decision to take a different technology path than its peers.

7.3.8 Latecomer Caterpillar

Of the manufacturers involved in the consent decree, Caterpillar was the only one that did not use cooled EGR in its new engines, opting instead to go with its own Advanced Combustion Emission Reduction Technology (ACERT). Its decision to use ACERT instead of EGR represented the largest US heavy-duty engine technology divergence in at least 20 years.²⁴ Leading up to October 2002, Caterpillar was very vocal about ACERT's ability to outperform EGR, claiming that EGR had reliability and performance problems. Tapping into truck owners' worries and capitalizing on its status as the heavy-duty engine market leader, Caterpillar touted ACERT's higher fuel economy and resale value (Arnum 2003). While Cummins, Detroit Diesel, and Volvo introduced compliant engines by the October deadline, Caterpillar's first ACERT engine was not certified until January 2003. In the meantime, Caterpillar sold "bridge engines" that were above the NO_x+NMHC limit and subject to a per-engine noncompliance penalty (NCP). Caterpillar's noncompliance penalties (NCPs) for FY2003 totaled \$128 million. Since the ACERT engines had certification test emissions of 2.8-3.2 g/bhp-hr NO_x, Caterpillar probably paid around \$3,640, the per-engine penalty for engines emitting 3.0 g/bhp-hr. On average, the Caterpillar priced their "bridge engines" \$5,000 more than pre-October 2002

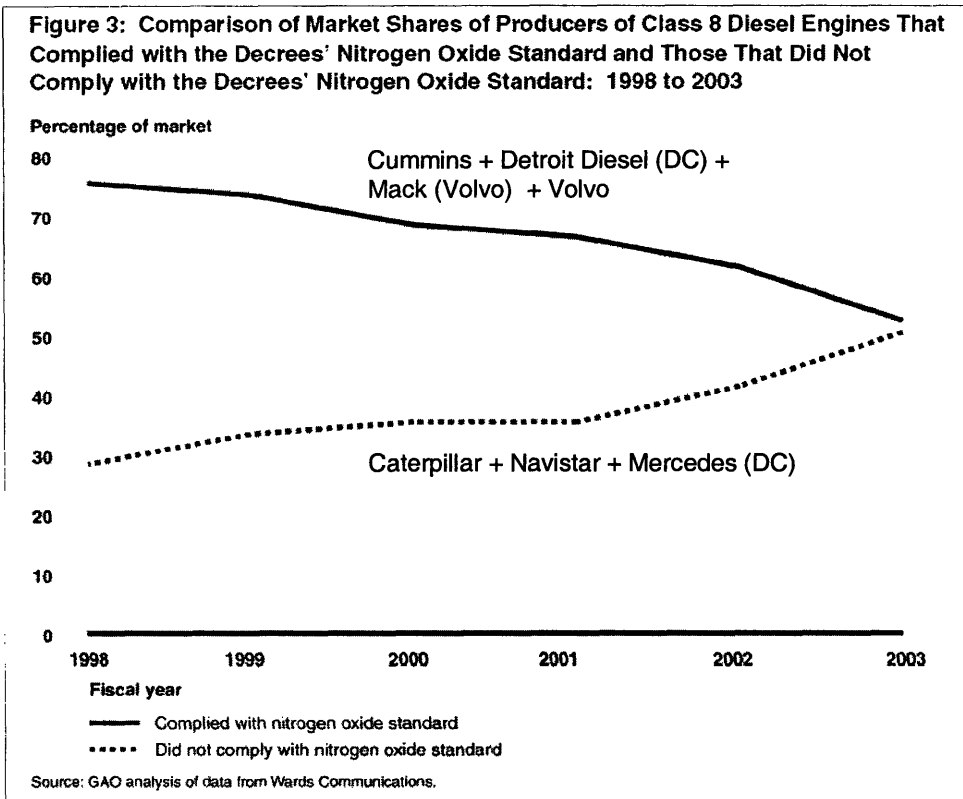
²⁴ Interview with a senior expert in the US heavy-duty engine industry, 2003.

engines (Wolfe and Yagerman 2003). Other manufacturers with fully compliant engines priced their engines \$3,000 to \$5,000 higher to cover the cost of the EGR system and other emission-reducing technology. Therefore, the non-compliant Caterpillar engines were comparable in price to the compliant engines. Perhaps not surprisingly, many truck customers ordering engines after October 2002 chose the older, “proven” technology over the new, relatively unproven technology with an expected fuel economy loss (Mercer 2002).

7.3.9 Better sales on non-compliant engines

The consent decree and accelerated deadline for the MY2004 standards contributed to substantial changes in market share and industry structure. According to sales data gathered by the US Government Accountability Office (GAO), the four manufacturers with compliant engines by the October 2002 deadline – Cummins, Detroit Diesel, Volvo, and Mack (owned by Volvo since 2000) – witnessed a decline in their market share between 1998 and 2003 (GAO 2004). Caterpillar and International, who did not meet the October 2002 deadline, increased market share during that time.

Figure 7-4: Market Share Comparisons from the 2004 GAO Report



Source: US GAO (2004); company names added by author

Caterpillar chose to pay the nonconformance penalties, while Navistar International's separate consent decree did not require it to meet the standard early. After the consent decree, Renault left the US heavy duty engine market altogether. Mercedes-Benz was not party to the consent decree because it did not sell electronically controlled engines to the US prior to 1998. It did not have to comply with the standards until the original 2004 deadline. Taking advantage of truck customers' skepticism toward the new compliant engines, Mercedes began to sell their engines in the US in 1999. The truck manufacturer Freightliner gave customers the choice between a compliant Detroit Diesel engine and a non-compliant Mercedes engine, and eventually made the Mercedes engine its standard heavy-duty engine. Mercedes appealed to customers because of its lower price, lighter weight, and strong performance. Mercedes' market share rose to 10% in 2003 after it entered the market in 1999 (Berg 2003). Ironically, the US companies who met their consent decree requirements on time were penalized in the marketplace, losing

market share to a European entrant (Mercedes), a US late-comer (Caterpillar), and a US manufacturer subject to a less demanding consent decree (Navistar International). The market shares reflect customers' reticence to try a new technology that they perceive as more costly and less reliable than its predecessors, despite reassurances by manufacturers, such as Cummins' Uptime Guarantee. The 3-5% fuel economy penalty associated with the new engines also did not help sales.

7.3.10 International – Different from the rest?

The “defeat device” investigation and consent decree reveal that no engine manufacturer was ahead of existing regulations; rather, they were circumventing them. However, the extent of each company's transgressions and post-consent decree response varied considerably.

International Truck and Engine, held by parent company Navistar International, was found to be in violation of the Clean Air Act, but its engines' relatively lower emissions and progress on cleaner technologies resulted in a lesser penalty compared to its competitors. International is the world's largest manufacturer of mid-range engines (160 – 300 hp) and the third largest heavy truck manufacturer in North America, after Freightliner and PACCAR. It also produces school buses, medium trucks, and aftermarket parts. International was subject to a different consent decree than the other engine manufacturers, whose consent decrees were identical.

Unlike the other manufacturers whose engines operated with a dual-mapping strategy to control emissions, International's control strategy was the same for both the real-life vehicle operation and the test cycle. International's emission control strategy was consistent with pre-1994 regulations and EPA policy on fuel economy dating back to the 1970s. In particular, International's control strategy would only activate at high-speed, steady-state modes of operation normally seen only on interstate highways (i.e., "non-urban" operations). When not at high, steady-state speeds, International's control strategy would not operate. International's engine product line had a lot to do with this different strategy. For example, medium-duty delivery trucks, such as International's, would only infrequently operate on interstate highways between deliveries and, therefore, would only infrequently utilize a control strategy. Their mid-range engines go into medium-duty trucks and buses that predominantly run within local areas. They source their heavy-duty engines for their highway tractor-trailer trucks from Cummins and

Caterpillar. The long distances traveled by highway trucks make fuel economy more important to fleet operators than it would be to medium-duty truck or bus operators. There was less pressure for International to optimize for fuel economy on its mid-range engines.²⁵

International had 78,000 non-compliant engines, 6% of the total non-compliant engines, but their emissions contribution was less than 0.3% of the estimated total emissions from all the “defeat device” engines (EPA 1998b). International was penalized with the smallest penalty - \$2.9 million. Unlike the other companies, it was not required to hire a compliance auditor, fund special environmental projects, or comply with the MY2004 emission deadlines by October 2002 (EPA 1998c). In the consent decree agreement, EPA did specify its anticipation of “New Technology HDDE” (heavy-duty diesel engines) from International after October 1, 2002. During its consent decree negotiations with EPA, International demonstrated its latest emission reduction technology. It promised that any new engine models introduced before 2004 would have reduced levels of NO_x+NMHC, closer to the 2004 standards than the 1998 standards (Herman 2002). Because of International’s advanced future engine plans and the lesser degree of their emission violation, EPA did not require them to meet the MY2004 deadlines.

International’s reputation for early compliance and its advanced engine design for MY2004 helped it achieve a less punitive result in its unique consent decree. International boasted of its record of “proactively improving diesel emissions ahead of government deadlines,” which is supported by an examination of its past technology introductions (Navistar International 1998). Back in 1989, International was the first company to demonstrate a prototype engine meeting the 1994 NO_x and PM standards (PR Newswire 1995; PR Newswire 1997). As early as July 1996, International was the first manufacturer to demonstrate an engine capable of surpassing the proposed MY2004 federal standards. Then in January 1997, it introduced its second prototype engine which was equipped with a passive, self-regenerating trap, which required adding a cerium additive to normal diesel fuel. It emitted 2.0 g/bhp-hr NO_x+NMHC and 0.01 g/bhp-hr PM, significantly less than the 2.5 g/bhp-hr NO_x+NMHC and 0.1 g/bhp-hr PM required by the 2004 regulations, which were finalized in October 1997. International was the only US diesel engine manufacturer to receive unconditional approval for its MY1999 engines (Navistar International 1998).

²⁵ Interviews with senior experts in the diesel vehicle industry, 2006.

Despite efforts by International to differentiate itself from its competitors to the press and public with regards to the engine settlement, journalists, and even the EPA, tended to lump all the engine manufacturers into one large group when reporting the consent decree (Navistar International 1998; PR Newswire 1997). International tried to point to its different consent decree, especially since the company was trying to promote the advantages of low-emissions diesel technology at the same time.²⁶ However, International's "return" for higher performance was in the consent decree agreement itself, not in the preferential treatment by the media. By having lower-emitting engines that its peers (even if those engines were still in violation of the Clean Air Act), International was able to avoid the same penalties, i.e. the acceleration of the MY2004 standards, as the other engine manufacturers. While it was still expected to introduce lower-polluting engines before 2004, it did not have to fully comply with the MY2004 standards until January 2004.

7.3.11 Evaluating the new engines on the road

By mid-2003, it seemed that fleet operators' early fears about unreliability of the new compliant engines were mostly unfounded. According to the trade press, fleet operators were pleased with the reliability and driver acceptance. In general, the fuel economy loss of 3-5% was as predicted by the manufacturers, while a minority of operators reported 7-10% gains in fuel economy with the new engines. This is likely attributable to the deteriorated fuel economy of their previous engines. The biggest sticking point was the \$3000 to \$5000 added to the upfront cost of the engines, which was the first time emission compliance costs were noticeably passed onto the fleets (Hampton 2004; Petty 2003). The technical complexity of the engines, especially the electronic controls, and the increased purchase of extended warranties have also forced truck customers to turn to truck dealerships for major repairs, rather than rely on their own mechanics (Hampton 2004).

As concerns about the new compliant trucks died down and engine manufacturers turned their energy to meeting the next round of emission standards in 2007, an inventor challenged Caterpillar's patents on its ACERT technology. In October 2004, Clyde Bryant, an inventor and chairman of Entec Engine Corporation filed a petition with the US Patent Office, claiming that

²⁶ Interviews with senior experts in the diesel vehicle industry, 2006.

two key patents related to Caterpillar's ACERT technology infringed his 2001 patent. By this time, Caterpillar had touted its ACERT technology as a breakthrough technology, different from other manufacturers' EGR technology. Two of its engineers had even received a national "Inventors of the Year" award from the Intellectual Property Owners Association for ACERT. A US Patent and Trademark Office (USPTO) examiner claimed that the Caterpillar patents, which had been awarded in 2003 and 2004, should be withdrawn. By September 2005, Caterpillar had already sold 200,000 ACERT engines worth billions of dollars, so the USPTO decision opened the door for Bryant to demand royalties from engine sales (ENR 2005; Nesmith 2004; Nesmith 2005).

In late 2003, the largest trucking companies in the US were still actively bringing claims against the EPA about their decision-making process for their MY2004 emission standards, which most engine manufacturers had already met by October 2002. At this point, engine manufacturers had already made substantial investments to meet the standards, so any attempts by the trucking industry to reverse the standards would actually be contrary to the manufacturers' plans.

7.3.12 Engine reprogramming delays

EPA underestimated the role of vehicle owners in the effort to reprogram existing engines to lower NOx emissions. The consent decrees focused on the activities of the manufacturers without accounting for the behavior of vehicle owners. As part of their consent decrees with EPA, engine manufacturers are required to provide "low NOx rebuild kits," which include software upgrades to make MY1993-98 engines with "defeat device" problems compliant with emission standards. When owners bring their trucks to the dealer for an engine rebuild, the dealer must install the low NOx rebuild kit at no added cost to the owner. EPA gave the engine manufacturers firm deadlines with penalties for failing to submit a low NOx rebuild plan, identify a compliance auditor, conduct in-use tests, or submit quarterly progress reports (EPA 1998d). By 2000, most engine manufacturers had the low NOx rebuild kits ready for use. However, EPA did not give a deadline for when the engines had to be rebuilt, assuming that normal engine rebuild occurs at 200,000 to 300,000 miles of service. By 2004, it came to the attention of federal and state regulators that owners and operators were running heavy-duty

diesel engines for 750,000 to 1,000,000 miles without servicing, resulting in more excess NOx emissions than estimated (CARB 2004). By July 2005, 6 years after the consent decree agreement, only 7.2% of eligible engines with defeat devices had their software upgraded. Half of the 4.5 million tons of NOx emission reductions from the consent decree were supposed to come from engine rebuilds, but the low rebuild rate resulted in only 200,000 tons of NOx reduction (Inside Fuels and Vehicles 2005).

Disappointed in the progress of the low NOx software upgrades, the California Air Resources Board (CARB) implemented low NOx software regulation in 2004. CARB established deadlines for upgrades for various model years. Vehicle inspections would identify non-complying vehicles and issue citations with a \$300 penalty. CARB had a target of installing the upgrades on 35% of eligible engines by December 2004, 60% by May 2005, and all the engines by the end of 2006. Owners of specific Caterpillar, Cummins, Volvo, Mack/Renault, or International engines were subject this CARB regulation. Detroit Diesel was held exempt from this new regulation because it had made good progress towards upgrading engines through its voluntary program (CARB 2004; CARB 2005). Truck owners were probably intentionally delaying their engine rebuilds because they feared that the software upgrades would reduce their fuel economy. The Engine Manufacturers Association and four engine manufacturers – Caterpillar, Cummins, Volvo, and Mack/Renault – filed a motion for an injunction against this regulation because it was outside the terms of their consent decrees. The court denied their injunction and the regulation was finalized in March 2005 (CARB 2005).

Other states wrote letters to the EPA requesting regulatory action similar to California's. The lack of response from EPA and Department of Justice regulators prompted state and local regulators to devise their own plans to accelerate low NOx engine rebuilds. Because the timing of rebuilds was not stipulated upfront in the consent decree, EPA had no leverage to change its requirements and force manufacturers to follow an engine rebuild schedule. EPA's failure to account for the owners' slowness to pursue engine rebuilds greatly reduced the air quality benefits expected from the consent decrees.

7.3.13 Consent decree's impact on regulatory reform

Addressing the fuel economy-NOx emissions trade-off

The investigation and the consent decree had the immediate effect of bringing to EPA's attention (1) the importance of fuel economy impacts of increasingly stringent NOx standards and (2) the need to regulate off-cycle emissions. The 1997 and 2000 rulemakings which established the 2004 standard did not analyze the fuel economy impacts of going from 6.0 g/bhp-hr to the 2.0 g/bhp-hr NOx standard because EPA expected manufacturers to optimize fuel consumption while meeting emission requirements. Instead, manufacturers wound up doing so outside the bounds intended by EPA. In response to the consent decree, manufacturers shared their estimates of fuel consumption losses to the EPA (EPA 2002b).

Development of a worldwide harmonized test cycle for heavy-duty engines

The violations of diesel engine manufacturers in the US that resulted in the 1998 consent decrees drew international attention to the importance of procedures that reflected real-life driving conditions. Growing awareness of the ability of onboard diagnostics to circumvent pollution controls compelled the international community to use the UN as a vehicle to address the problem. In June 1997, the UN Economic Commission for Europe's Group of Rapporteurs on Pollution and Energy (GRPE) tasked its ad-hoc working group on worldwide heavy-duty certification procedure (WHDC) to develop a harmonized test cycle that would be representative of real-life engine operation and acceptable for engine certification around the world (UN ECE-GRPE Working Group 2001). The motivations are relatively straightforward – (1) the public benefits from the same high standards in the participating countries, (2) engine manufacturers can more effectively sell their models worldwide if they only have to meet one set of emission requirements, and (3) regulators gain new knowledge about testing and compliance by working within an international community.

The WHDC working group was part of a larger effort to harmonize global vehicle standards. The 1998 global agreement on global technical regulations for wheeled vehicles

established the World Forum for Harmonization of Vehicle Regulations (WP.29). Contracting countries have agreed to promote the harmonization of technical regulations on environmental protection, health, safety, energy efficiency, and anti-theft performance. So far, there have only been global technical standards on door locks and latches and motorcycle emission measurements. However, there are groups within GRPE working on harmonized certification test procedures and off-cycle emission regulations (UNECE 2005).

Starting in October 1999, the heavy-duty certification procedure group began collecting “worldwide” driving pattern data. Even though “worldwide” referred only to the EU, Japan, and the US, the new test cycle was designed to be representative of real-life engine operations. From their database of driving patterns, researchers ultimately developed a reference transient cycle (WHTC) and a reference steady-state mode cycle (WHSC) (Steven 2001).

Concerns about off-cycle emissions and defeat devices were prominent in the discussion, as indicated by the summary notes of the fourth WHDC meeting in June 1998: the Chairman of the WHDC group “reported that a particular effort would be necessary to make the future test procedure safe against cycle by-passing or beating and that results on this matter should also be available before the completion of the project” (UNECE-GRPE Working Group 1999).

Supplemental Emission Test and Not-to-Exceed Limits

A positive outcome from the diesel engine consent decree is the changes in the US certification procedures that make it more difficult to circumvent the emission standards. As a result of the consent decree, engines were subject to two additional testing requirements – a supplemental emission test (SET) and not-to-exceed (NTE) limits. These requirements are designed to prevent manufacturers from circumventing emission standards during steady-state driving or off-cycle conditions. The supplemental emission test (SET) is based on the EU’s 13-mode ESC schedule, also known as the Euro 3 test. It was first used in the EU in 2000 to accompany the Euro 3 standards. The Euro 3 test puts the test engine through 13 different steady-state modes, under various speeds and loads, for 2-minute intervals.

Unlike SET, the NTE limits are not accompanied by a specific test procedure. Instead, there is an “NTE zone” for a range of speed and load combinations where specified values of pollutants, usually 1.3-1.5 times the engine emission standard, cannot be exceeded. It is

supposed to cover steady-state, transient, and ambient conditions that occur in use but may not be captured by the standard US FTP or Euro 3 test procedures. Emissions are measured and averaged over a time period of 30 seconds or more, and then compared to the NTE limit (EPA 2003a).

The Engine Manufacturers Association (EMA) and its member engine manufacturers International and Cummins filed five separate lawsuits against the EPA, charging that the NTE limits were not allowable under the Clean Air Act. They argued that the lack of a specific test procedure and the freedom to test over an infinite number of driving conditions would make compliance impossible. In June 2003, EMA settled with EPA, and engine manufacturers agreed to run an in-use testing program for heavy-duty diesel trucks. This would be the first testing program to use portable emission measurement systems to measure in-use exhaust emissions. The details of the program were proposed in June 2004. Although it will not be fully implemented until 2007, 2005 and 2006 serve as test years. Manufacturers will test fleet or customer-owned trucks at their own cost and submit documentation on their emission performance for EPA review. Instead of the cumbersome traditional procedure of removing engines from trucks for testing, this program tests the complete vehicle under normal driving conditions (EPA 2004b).

7.4 Europe

Given that all the major engine manufacturers in the US were accused of using defeat devices in their engines, it was conceivable that similar practices could occur elsewhere. Although European NO_x standards have not been as stringent as US standards, there has been evidence that engine manufacturers across the Atlantic were also manipulating electronic controls to optimize for fuel savings instead of NO_x emission reduction.

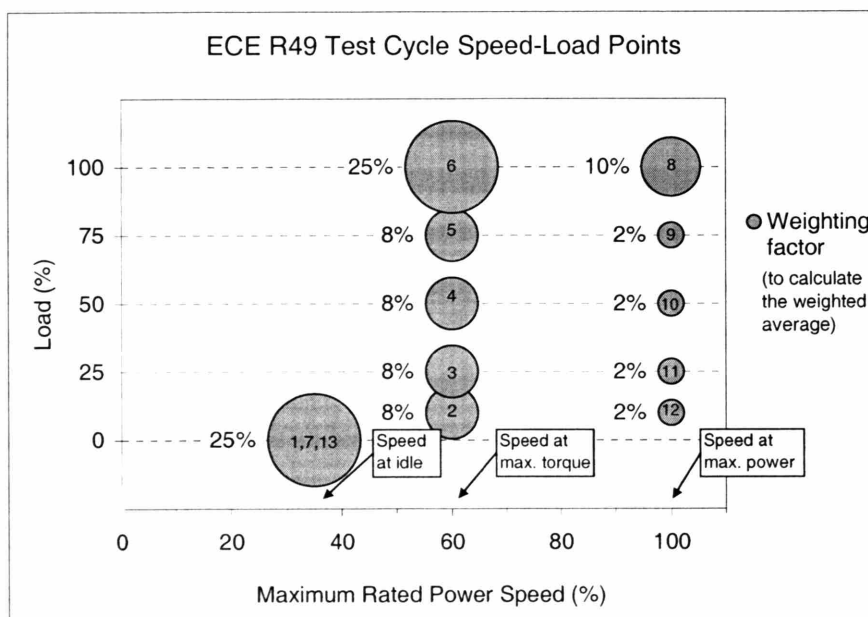
7.4.1 European test cycles

In the 1990s, the European Commission reduced the heavy-duty diesel engine NO_x emission standards from 8.0 g/kWh in 1992 (Euro 1) to 7.0 g/kWh in 1996 (Euro 2), and then to 5.0 g/kWh in 2000 (Euro 3). Electronic injection systems became popularized in the early 1990s.

By the onset of the Euro 2 standards in 1996, manufacturers had the ability to use complex but questionable control strategies to adjust the trade-off between fuel economy and NOx emissions. Prior to sale in the European Union, new engine models must receive type approval (similar to certification in the US) from the European Commission. For Euro 1 and 2 type approval, engines were placed on an engine dynamometer and emissions were measured with the R49 test, a 13-mode steady state test cycle, consisting of 13 combinations of speed and load. The final result is a weighted average of the emissions at the 13 modes, which must be within the emission limits.

Figure 7-5 illustrates the 13 load and speed points in the R49 cycle, with the number order of testing noted in the circles. The size of the circles is proportional to the weights given to each point, which are used to calculate the weighted average. There is noticeable emphasis on testing at the maximum torque and at full load. The emissions are measured for various loads at the maximum torque speed and maximum power speed, and at idle. An unintended consequence of having pre-designated load and speed points is that electronic controls enable the engine to meet NOx emission limits at those 13 points, but then allow the engine to emit more NOx during conditions between those points.

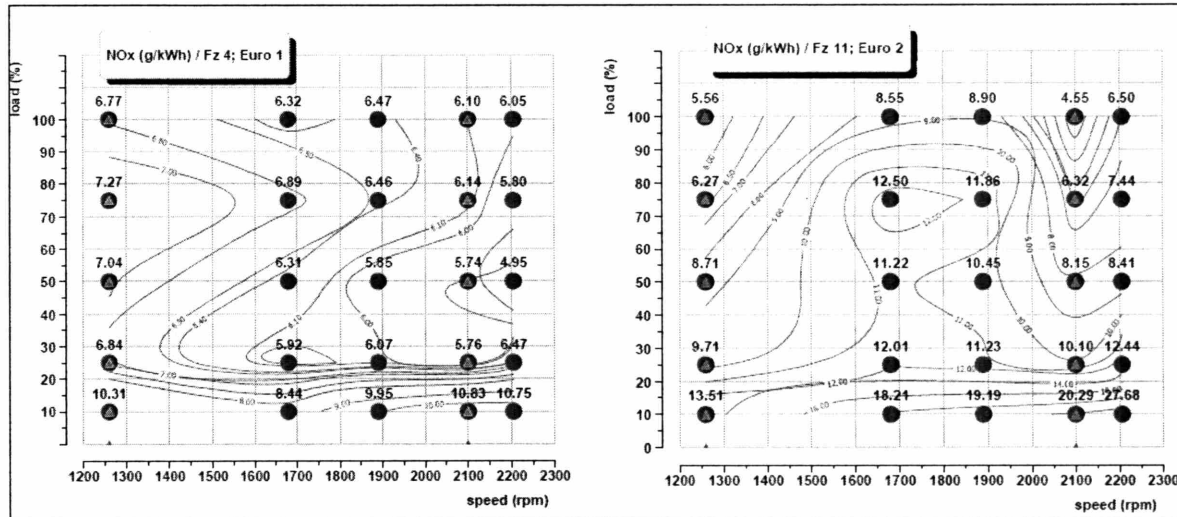
Figure 7-5: ECE R49 Test Cycle



Source: Dieselnets (2005)

In the “Future Diesel” report written by UBA, the German environmental agency, the UBA staff pointed out the ability of electronic controls to optimize for fuel economy between testing points. The report shows the NOx emission measurements of two comparable diesel engines, tested outside the R49 cycle’s testing points. Both are from the same manufacturer and have the same rated power at 230 kW.

Figure 7-6: NOx Characteristic Curves for a Euro 1 Engine and a Euro 2 Engine



Source: Rodt (2003); Original source: RWTUV (2002).

The points with gray triangles at 1,260 and 2,100 rpm represent the speeds at maximum torque at maximum power, which are covered by the R49 test cycle. For the heavily weighted points at 75% and 100% load, the Euro 2 engine’s emission levels are significantly lower than the Euro 1 engine’s, but its emissions at the lower loads are worse. The other 3 R49 test points, at idle speed, are not shown here. Measurements were taken at different loads at 3 other speeds not in the test cycle. The Euro 2 engine actually has higher emissions at all these other points than the Euro 1 engine. Moreover, the Euro 1 engine has a relatively even emission behavior between points, while the Euro 2 engine clearly emits an unexpectedly high amount of NOx between the two key test speeds. By adjusting fuel injection between test points, electronic controls can improve fuel efficiency by a few percent, albeit increasing NOx emissions at the same time. The engine manufacturer clearly intended for the electronic controls to optimize for

higher fuel economy in this off-cycle region. This was not an outcome intended by the regulatory design of the steady-state test cycle.

Because the ECE R49 steady-state test consists of discrete points rather than a transient test like the US heavy-duty cycle, manufacturers selling engines in Europe did not have to use the dual mapping strategy used by the US manufacturers to differentiate between transient urban conditions (like in the US transient FTP cycle) and steady-state highway conditions. They could bypass the cycles by adhering to emission limits only at the specified cycle points.

Senior staff at the UBA in Germany claimed that cycle bypass has been a problem since the introduction of electronic controls for engines. In a study led by transport chief Axel Friedrich, UBA found evidence of type-approved engines with off-cycle emissions double the level permitted under the Euro 2 standards. UBA estimated that the discrepancy resulted in an additional 140,000 tons of NO_x in Germany per year (UBA 2003a). When UBA confronted the European heavy-duty diesel engine manufacturers, the manufacturers admitted to bypassing the cycles, but argued that the regulations left room for legal “freedom of interpretation.” The German auto association, VDA, also denied any wrongdoing, claiming all engines were compliant with emission regulations. The results of the UBA study were reported on the German television program, Monitor, and other media outlets. There was some media coverage in Austria and Switzerland on excess truck emissions as well (UBA 2003b). UBA worked with lawyers to investigate the legality of this practice. Convinced that manufacturers had violated the law, UBA submitted technical information to the Ministry of the Environment, but no action was taken.

Unlike the US EPA, the German UBA does not have enforcement power. It serves a technical advisory function to the Environment Ministry, which is responsible for policy decisions. Although the Environment Ministry is often guided by UBA recommendations, it appears that pressure from other government ministries, such as the Transport and Finance Ministries, allegedly prevented further investigation of engine manufacturers’ questionable practices.²⁷ Whereas the EPA could sue manufacturers for violating the Clean Air Act, the UBA had no legal authority to do the same to the European engine manufacturers.

²⁷ Interview with a German government representative, January 2005.

7.4.2 Transient versus steady-state

Despite the lack of legal action in Europe, the awareness of the off-cycle emission problem in US led to changes in European's type approval and testing procedures. It also highlighted the ongoing debate between the Americans and Europeans/Japanese on the appropriate choice of test cycles.

Up to this time, the US had used transient testing (continuous changes in speed and load) while Europe and Japan had used relatively simpler steady-state tests with fixed time intervals at 13 or 6 different speed-load points. Up until 1998, it seemed likely that Europe and Japan would eventually adopt transient testing as well. The US EPA had assumed that transient testing would more accurately simulate real road driving conditions. However, as demonstrated by the investigation leading up to the consent decrees in 1998, the US FTP test's absence of steady-state highway driving conditions allowed for the circumvention of NO_x controls. Expectations about the inevitable domination of the transient cycle began to shift, and some speculated that steady-state tests could be a viable choice (Automotive Environment Analyst 1998). Yet, evidence of cheating in Europe, though not prosecuted as in the US, showed that the steady-state tests had shortcomings as well.

7.4.3 Manufacturers' response to test cycle discussions

Most major engine manufacturers sell in multiple markets, where they face country-specific certification procedures and standards. They support the adoption of a single harmonized test cycle because it would be more efficient, in terms of cost and ease of obtaining certification. However, manufacturers have disagreed on whether to choose a transient or steady-state cycle. European manufacturers supported a test cycle modeled after the steady-state test cycle used for Euro 1 and Euro 2, using the consent decree as an example of the transient cycle's failings. The steady-state cycle is also a less complex and costly test procedure. In 1998, the head of diesel truck engine design at Mercedes, Michael Schittler, asserted that basing the worldwide test cycle on the 13-mode European cycle would give a more realistic emission performance than the US cycle (Automotive Environment Analyst 1998). Schittler clearly

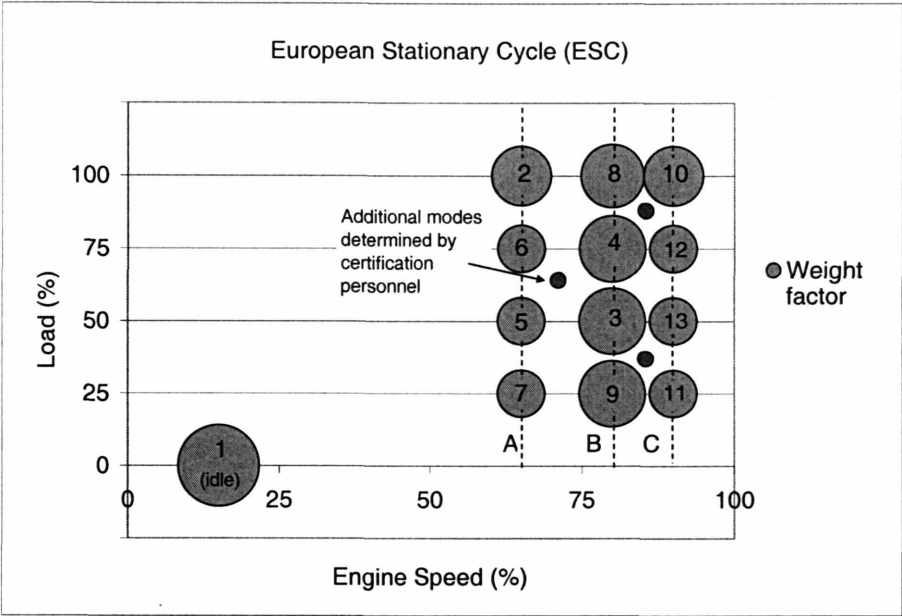
supported persuading the EPA to move away from the transient cycle to something similar to the European cycle (Automotive Environment Analyst 1998). US regulators argued that the transient cycle is more representative of real-world driving. Despite European manufacturers' support for a regulatory shift from steady-state cycles to transient cycles, European and Japanese regulators added transient test cycles in time for the 2000 Euro 3 and 2005 Japanese emission standards, while the EPA adopted the steady-state Euro 3 test as a supplemental procedure. Using multiple test cycles to cover a greater variety of conditions would presumably reduce the opportunities for off-cycle emissions.

7.4.4 New European Transient Cycle

New heavy-duty diesel emission standards and test procedures for Euro 3 were finalized by the European Commission in Directive 1999/96/EC. The directive also proposed Euro 4 and 5 emission standards. As of 2000, two new test cycles – the European Stationary Cycle (ESC) and the European Transient Cycle (ETC) – replaced the steady-state R49 test cycle. For Euro 3, manufacturers could choose either ESC or ETC, but by 2005, their engines would have to be tested with both. Instead of replacing the steady-state cycle with a transient one, European regulatory staff decided to use both.

The new steady-state ESC, shown in Figure 7-7, resembles the R49 test. It still has 13 modes with various timed speed-load combinations, but the engine speeds are based on the maximum net power and no testing occurs at 10% load. The certification personnel may request additional random testing of points lying between the designated test points, as long as they are in the cycle control area. This helps to get avoid the cycle bypass problem caused by pursuing higher efficiency and higher NO_x emissions between test points.

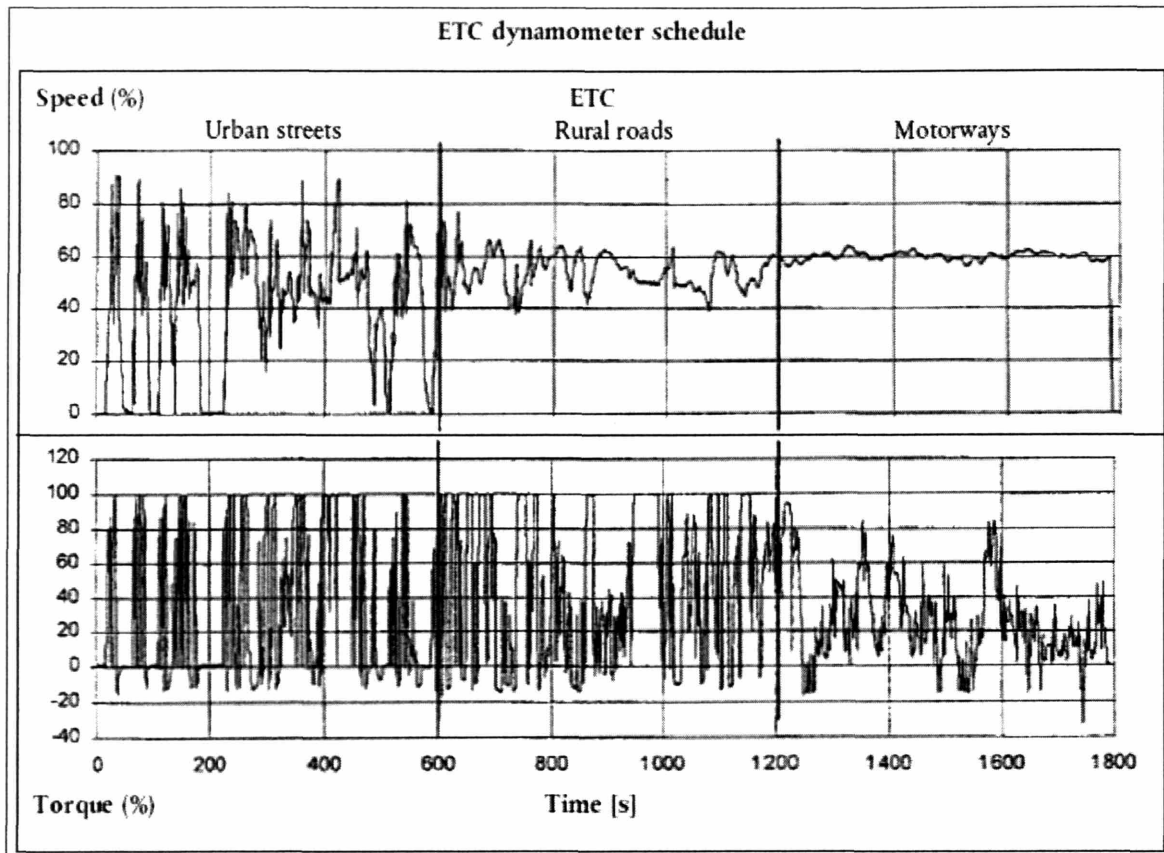
Figure 7-7: New European Stationary Cycle



Source: DieselNet (2005)

The second cycle, ETC, was developed by Germany’s FIGE Institute to reflect real road driving conditions, and includes 3 main segments – urban, rural, and motorway. The urban segment bears some similarity with the US transient FTP cycle, but the rural and motorway segments reflect the type of driving that FTP fails to simulate. By requiring both the steady-state and transient tests, the Commission sought to reduce the opportunities for high off-cycle emissions to occur.

Figure 7-8: European Transient Cycle



Source: Directive 1999/96/EC (EC 2000a)

In April 2001, the Commission directly addressed the defeat device issue in Directive 2001/27/EC:

“Directive 1999/96/EC provided for new emission test cycles and prescriptions to prevent the use of defeat device and/or irrational emissions control strategy. It is now appropriate to strengthen those requirements and to provide a tool for authorities to determine whether engines are using defeat devices and/or irrational emissions control strategies under normal conditions of use to manipulate engine performance at the expense of emissions control.”

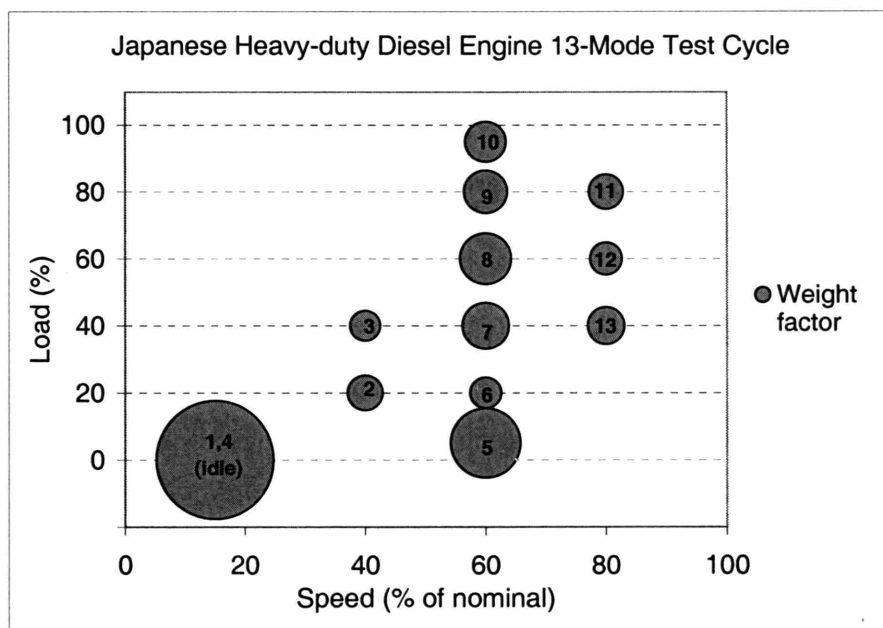
A section in the 2001 directive defined when devices or strategy would be considered a defeat device. It also required manufacturers to provide documentation of any auxiliary control device. Type approval or test authorities could request a NO_x screening test in addition to the ETC test.

7.5 Japan

7.5.1 Japanese test cycles

From 1994 to 2004, Japan relied on a 13-mode steady-state cycle for diesel engine certification (see Figure 7-9). Driving conditions in Japan are characterized by predominantly urban, stop-and-go driving, more so than US and Europe. Therefore, its 13-mode test cycle focuses on low-speed driving, with lower loads and exhaust temperatures.

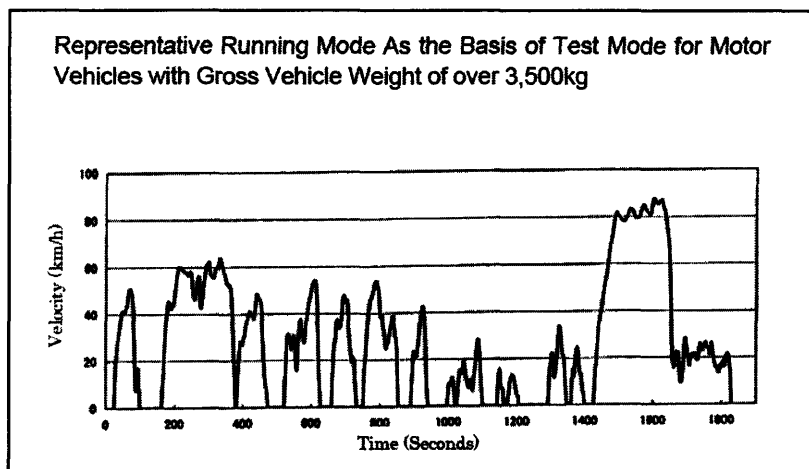
Figure 7-9: Japanese Heavy-duty Diesel Engine 13-Mode Cycle



Source: Dieselnets (2005)

However, as in Europe, the Japanese Ministry of Environment moved from this steady-state cycle to a transient cycle, JE05 (or ED12), effective 2005. The transient cycle tests heavy-duty engines, and is made up of vehicle speed vs. time points. Special software converts these points to the torque-speed-time points needed to test engines on a dynamometer. Although most of the test still emphasizes low-speed city driving, a portion of the cycle, around 1500-1650 seconds, reflects steady-state highway conditions.

Figure 7-10: Japanese JE05 Transient Test Cycle



Source: Japan Central Environment Council (2002)

In the 2002 Fifth Report on the Future Policy for Motor Vehicle Exhaust Emission Reduction, Japan's Central Environment Council gave its reasons for shifting to a transient test cycle. First, the anticipated use of new emission control devices, like diesel particulate filters, necessitated the simulation of exhaust temperature changes, which affects the pollutant removal rate. The steady-state 13-mode test was not capable of assessing how well the new devices were working. The new test would also allow for engine-specific speed and load, unlike the previous practice of using the same speed-load points irrespective of engine size. Since the new 2005 regulations drove this test cycle change, the Council decided to introduce the new cycle at the same time as the new regulations (Japan Central Environment Council 2002).

7.5.2 Regulatory process in Japan in the early 2000s

In 1998, the Central Environment Council issued its Third Report on the Future Policy for Motor Vehicle Exhaust Emission Reduction. This Third Report specifically addressed the reduction of NO_x and PM emissions from diesel-powered vehicles, calling for short-term targets for 2002-2004 and long-term targets for 2007, which would be half the emission levels of the short-term targets. The emission limits were finalized in September 2000 (Japan Central Environment Council 2002). At the same time, the Fourth Report was issued and the deadline

for the long-term targets for both light-duty diesel vehicles and heavy-duty diesel engines was accelerated two years, to 2005, because of an industry-government agreement.

In addition to the Japanese central government's emission standards, the Tokyo metropolitan government and other districts began instituting their own restrictions on in-use diesel vehicles. As mentioned in Chapter 6, the 1992 Automobile NO_x Law allows special regulation of NO_x emissions from vehicles in 196 designated areas in the Tokyo, Saitama, Kanagawa, Osaka and Hyogo Prefectures, which have the worst air quality problems. When the law was revised in 2000 to include PM, it focused primarily on diesel trucks and buses. Under the new Automobile NO_x/PM Law, vehicle owners were required to retrofit or replace their existing vehicles within a specified timeframe. This encourages the purchase of new and cleaner vehicles, giving an incentive to manufacturers introduce new models to the market.

7.5.3 Industry prepares for regulation

Engine manufacturers, recognizing that increasingly stringent engine standards were inevitable in Japan, ramped up their R&D efforts on cleaner diesel technology. Even though one company made some significant early progress on emission control, ultimately all the Japanese manufacturers supported the same target emission levels.

In 1998, Hino Motors, a subsidiary of Toyota Motor Company, was the first Japanese manufacturer to announce the successful development of an effective prototype catalytic converter to reduce NO_x emissions from diesel trucks. Although the prototype reduced NO_x emissions by only 25%, Hino expected to market a commercial version capable of 50% NO_x reduction by 2003-2005. However, Hino overestimated the stringency of Japan's long-term NO_x target, while underestimating the stringency of the long-term PM target. According to its 2001 Environmental Report, the company estimated that the targets would be 0.045 g/kWh PM and 1.69 g/kWh NO_x, which represent a 75% and 50% reduction, respectively, from the short-term 2003 levels. Instead, in 2002, the manufacturers and the government agreed upon long-term targets of 0.027 g/kWh PM and 2.0 g/kWh NO_x, to be met in 2005.

The discrepancy in the expected and actual emission standards stems from the status of progress for NO_x- and PM-reducing technologies. In the early 2000s, particulate filters were shown to be reliable and relatively affordable devices, capable of reducing PM with over 90%

efficiency. Meanwhile, the Automotive NOx/PM law already required that in-use diesel vehicles be equipped with a PM filter or be replaced by a new, cleaner vehicle. The trend towards widespread filter use was clear, so it made sense to base the PM standards for new diesel engines on filter technology. However, reducing NOx is much more costly and difficult, while PM reduction has more dramatic health benefits. The government recognized the trade-off between NOx and PM reduction. Manufacturers likely also lobbied the central government to agree to more lenient NOx standards in exchange for very stringent PM standards and a 2-year accelerated timeline. A March 2002 risk assessment report on the health risk of diesel exhaust particles further convinced the government to prioritize PM reduction over NOx: “Judging from comprehensive knowledge obtained so far, we consider there to be strong indications that DEP possesses cancer-inducing qualities” (Japan Central Environment Council 2002).

Even though Hino may have had earlier success with NOx reduction than its Japanese rivals, ultimately all the manufacturers found themselves under similar pressures to reach the short-term emission standards for 2003. No manufacturer had a clear advantage in meeting the recommendations. However, this did not mean that they had no influence in shaping the stringency of the regulations. Rather than one manufacturer stepping forward with a proposal, all four major Japanese heavy vehicle makers joined together to propose special emission limits.

7.5.4 Cooperative approach to regulations

Japan benefited from a cooperative government-industry relationship in setting and implementing heavy-duty diesel engine standards for the early 2000s. In March 2002, the four major Japanese truck manufacturers – Hino Motors, Mitsubishi Motors, Isuzu Motors, and Nissan Diesel Motor – agreed to adopt industry standards for PM that would be more stringent than the government’s 2003 short-term target of 0.18 g/kWh. The government standard constitutes a 28% reduction over 1997-2002 levels, while industry proposed reducing PM by 70%. In addition to meeting these reductions by 2003, the four manufacturers claimed that they would each budget 20 billion yen (US\$150 million) annually in R&D toward environmental technologies (AFX 2002)²⁸. By the publication of the Fifth Report from the Central Environment Council in April 2002, industry had also agreed to meet the long-term standards by

²⁸ Historic exchange rate from FXTOP.com. In March 2002, 100 yen = \$0.7631.

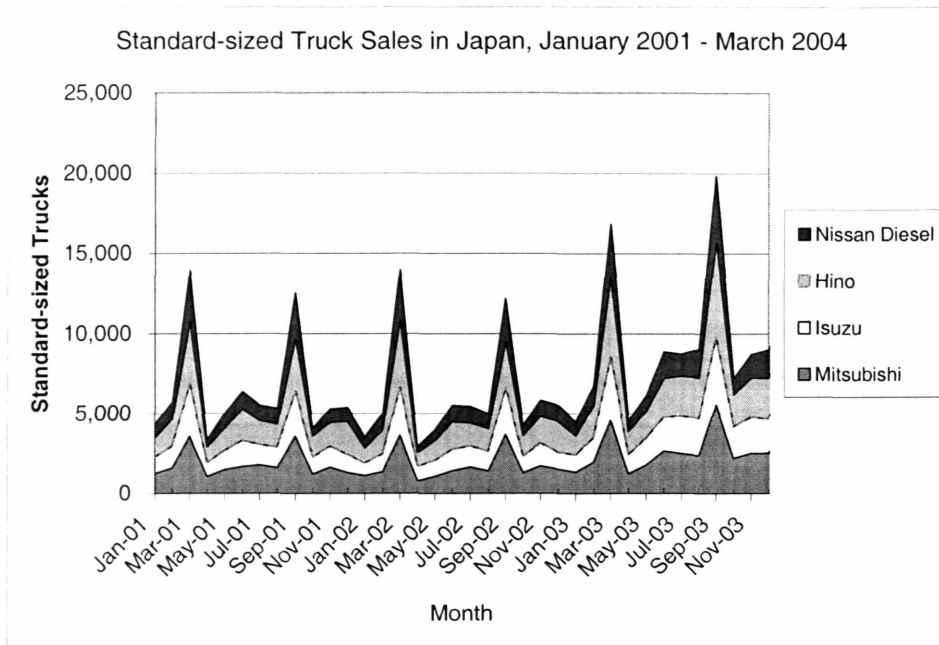
2005. Those standards promised a 56% reduction in NOx and a 89% reduction in PM over the 1997-2002 levels (Japan Central Environment Council 2002).

The Japanese manufacturers' shaping of emission targets gave them the regulatory certainty for substantial technology investment. Once the regulations were finalized, they competed intensely against each other to develop diesel engines capable of meeting the upcoming regulations and maintain good fuel economy. Manufacturers expected that earlier compliance with the new standards would help them gain greater market share. In mid-2002, Isuzu announced that its new Elf truck series met the 2003 emission standards, and was soon followed by announcements by Hino and Mitsubishi, eager to showcase their new trucks (Kyodo 2002). While these emission standards applied only to new vehicles, the local government's Automobile NOx/PM law tackled pollution from in-use vehicles. The law helped to create customer demand for cleaner vehicles and retrofits because it holds the owners responsible for replacing or retrofitting old diesel trucks and buses.

7.5.5 Sales boom for diesel engine and truck manufacturers

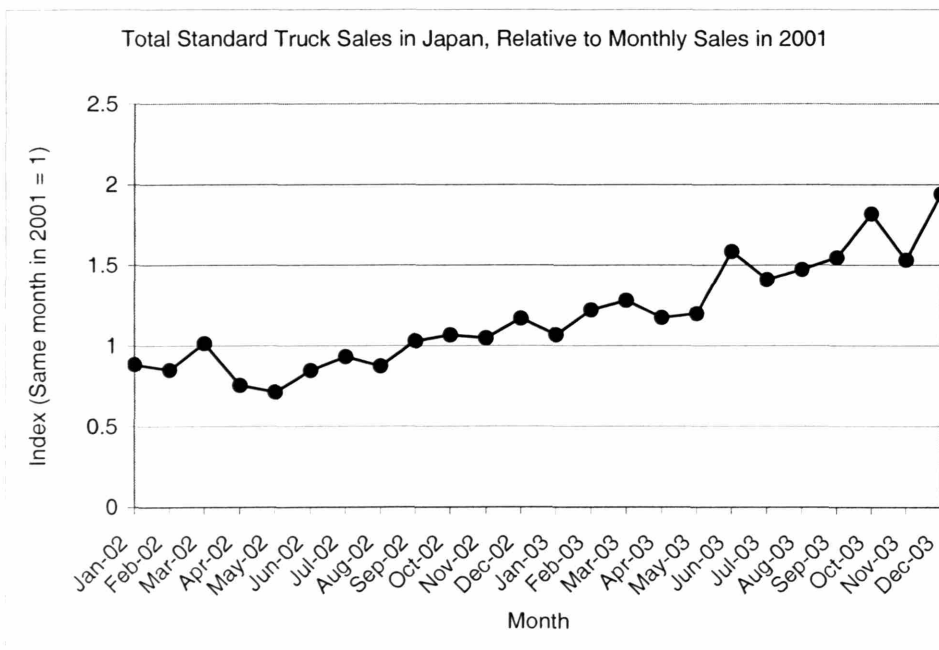
Truck sales in Japan follow a highly cyclical pattern, with purchases peaking in March and September, corresponding to sales pushes at the midpoint and end of the fiscal year. Public data on standard truck sales from the Japan Automobile Manufacturers Association (JAMA) provide a good indication of diesel truck sales patterns in Japan. Japan has three categories of trucks – standard, small, and mini – with standard trucks being the largest in size. They are also the most diesel-dominated: in 2003, 80% of standard trucks were diesel-powered. When comparing standard truck sales in the months of 2003 to the previous 2 years in Figure 7-11, it is clear that standard truck sales increased significantly. Figure 7-12 separates out the monthly cyclical variations in sales by indexing the monthly 2002 and 2003 sales according to 2001 sales figures. Sales picked up significantly in the middle of 2002; by the end of the 2003, sales were almost twice that of 2001, a great boon to the manufacturers.

Figure 7-11: Truck Sales by Manufacturer



Source: JAMA (2004)

Figure 7-12: Total Truck Sales in 2002-2003 Compared to 2001



Source: JAMA (2004)

The sales increase of diesel trucks in 2003 was a direct result of owners' replacing their old diesel trucks and buses with new models before the Automobile NO_x/PM law went into effect in October. Manufacturers hired temporary contact workers and canceled summer holidays to accelerate the production of the new trucks. Individual companies benefited from increased profits, especially since they had been plagued with weak domestic truck demand since the mid-1990s. In particular, Isuzu had suffered four years of consecutive losses until 2003, when the company's April to September 2003 sales were 76.5% higher than the same time in the previous year. In a press release, the company attributed the surge in domestic truck demand to the tightening of emission regulations in 2003 (Channel NewsAsia 2003). Trade articles supported this explanation, but also speculated that the strong demand would fade once people replaced their old vehicles.

7.5.6 Mitsubishi Fuso's defect cover-up obscures clean diesel product

Initially all the truck manufacturers seemed well-prepared to meet the standards and to benefit financially from the sales boom. Despite frequent announcements of new clean diesel progress, no clear technology leaders emerged. In 2004, Mitsubishi had difficulty selling its new models, but not because of emission control problems. Mitsubishi Fuso, its truck and bus division, spent spring 2004 mired in a major corporate scandal and a series of vehicle recalls. As far back as 1996, Mitsubishi Fuso executives had been receiving customer complaints about potential defects. Instead of reporting these cases to the proper Japanese authorities at the Ministry of Land, Infrastructure and Transport, the company covered up the defects, going as far as to falsify documents. A whistleblower's tip-off in 2000 and two fatal accidents related to faulty wheel hubs in 2002 brought government attention to the issue. Following a government investigation, former Mitsubishi Fuso executives were arrested and indicted for criminal negligence in spring 2004. They admitted to neglecting the problem since 1996 (Kyodo 2004). By September 2005, over 100 cases of defect cover-ups had been found, and over 2.5 million vehicles had been recalled, covering almost all the vehicles made by Mitsubishi Fuso in the past 30 years (Yomiuri Shimbun 2005). Granted, many of those vehicles are no longer on the road, but the number of vehicles requiring repair is on the order of hundreds of thousands. The scandal spread to the car division, where defect cover-ups were also found to be widespread.

As Japanese customers lost confidence in Mitsubishi Fuso's safety record and accountability, the company's domestic sales volume suffered. Mitsubishi Fuso's January 2005 domestic truck sales were down 48.1% from the year before, and its market share declined from 29.1% in January 2004 to 19.3% in January 2005. Meanwhile, its three competitors all gained market share. The defect cover-up inhibited Mitsubishi Fuso's ability to sell its new diesel truck models, which were designed to meet the 2004 emission standards for large diesel vehicles.²⁹ Wary of the company's history of defects, the Transport Ministry delayed company's introduction of the new models in order to perform stricter checks on the vehicles (Asia Pulse 2004).

7.5.7 Environmental benefits

One year after the October 2003 law went into effect, Tokyo officials claimed a measurable improvement in air quality. Based on measurements taken at 35 monitoring sites in the metropolitan area, particulate levels have dropped from an average of 42 $\mu\text{g}/\text{m}^3$ to 36 $\mu\text{g}/\text{m}^3$, a 14% drop in 12 months (Asahi Shimbun 2004a).

Despite the air quality improvements, regulatory officials were still finding violations of the law. They have inspected only half of the vehicle fleet required to make retrofits or replacements. Some truck drivers are merely avoiding the inspection officials, biding their time until they get caught. There has also been the problem of vehicles from outside Tokyo illegally entering the metropolitan area without filter devices (Asahi Shimbun 2004a).

7.5.8 Impact on trucking companies

While manufacturers of diesel engines, trucks, and aftertreatment devices reported improved sales from the Automobile NOx/PM law, truck companies have complained about the high costs of installing filter devices or replacing their vehicles. Truckers claim that the retrofits have reduced fuel economy and power. The retrofit costs range from 400,000 to 1.3 million yen

²⁹ Diesel trucks and buses weighing more than 12,000 kg had until September 2004 to comply with the short-term emission standards introduced in 2003.

(US\$3,500-11,300) per truck.³⁰ Although municipalities administered subsidy programs to help cover half the cost, some ran out of money before the 2003 deadline. The rush to meet the October 2003 deadline overwhelmed vehicle suppliers, who delayed the fulfillment of customer orders for new trucks and filters. Because so many trucking companies encountered difficulty installing the emission control equipment, municipal governments promised to delay enforcement and fines until April 2004.

According to the Tokyo Trucking Association, 70% of its member companies were reporting losses (Asahi Shimbun 2004). Over half of the 206 businesses that left the 4,300-member Tokyo Trucking Association in fiscal year 2002-03 cited the new retrofit requirement as their reason for going out of business. This was the largest number of firms leaving the association in its history. Most exiting companies were small businesses, which had the greatest difficulty covering the retrofit costs (Asahi Shimbun 2003; Okamoto and Ishii 2003). With the regulations hurting smaller firms disproportionately more, the industry outcome could be increased average firm size and industry concentration.

7.5.9 A different type of pre-buy

Japan's surge in factory production of engines and trucks leading up to the Automobile NOx/PM Law's October 2003 deadline may seem reminiscent of the 2002 pre-buy in the US. However, in this case, the demand was for new, cleaner engines, not the pre-regulation ones. Japan's experience stands in sharp contrast to the US "pre-buy" of older engines prior to the EPA's accelerated October 2002 deadline. In the US, the EPA regulated the manufacturers only, with no incentives or requirements for customers. In Japan, the central government's 2003 short-term emission standards placed pressure on the manufacturers, while the local governments' restrictions on older diesel vehicles placed pressure on the customers. Despite delays in compliance and enforcement, this two-pronged approach had the effect of motivating technology development and demand for the cleaner technology.

³⁰ Historical rate from FXTOP.com: In September 2003, 100 Japanese yen = \$0.870.

7.5.10 A DPF scandal

Barely a year after the implementation of the Automobile NO_x/PM Law, illegal behavior by Japan's leading diesel particulate manufacturer led many to question the government's diesel emission reduction efforts. Regulations requiring filter retrofits on existing diesel vehicles in Tokyo and other metropolitan area represented a huge opportunity for emission control manufacturers. In addition to restricting the use of high-emitting diesel vehicles, local governments offered subsidies to cover the cost of vehicle retrofits. The regulation-induced and subsidy-supported demand also risked attracting newcomers who did not necessarily have the technical expertise to develop and market filters. To verify a technology's effectiveness, companies had to have their devices certified by the government before they could sell them for vehicle retrofits.

Mitsui & Co., a major Japanese trading company, eyed the lucrative market for diesel particulate filters, and immediately established a filter subsidiary, PUREarth Inc. It used a prototype filter design from British company Johnson Matthey, but ran into quality problems. The actual particle removal rate of the Mitsui filters was only 70-80% of the reduction rate required by the government program. Instead of improving its technology, Mitsui falsified the data submitted to the Tokyo Metropolitan Government. It was the first manufacturer to receive government approval for its filter in April 2002. In November 2004, a Mitsui employee reported the data falsification to his supervisor, and news eventually reached the Tokyo government. That month, Mitsui voluntarily recalled defective particulate filters made by its subsidiary PUREarth Inc. It had already sold 21,500 units of its SOW-301B filter for use in subsidized government programs to retrofit buses and other vehicles. The filters, which sold for 20 billion yen in total, had qualified for more than 8 billion yen (US\$78.2 million) in government subsidies which Mitsui was required to repay (Asahi Shimbun 2004b; Nikkei Weekly 2004). Prior to the revelation about Mitsui's data falsification, the company was Japan's leading DPF manufacturer, with a third of the market share. It had clearly benefited from being the first manufacturer to gain approval for its filters. However, after the scandal, Mitsui quickly exited the DPF business.

Following the Mitsui scandal, media reports began to question whether the government's rush to reduce diesel emissions had led them to overlook the inadequacies of Mitsui's technology, especially when major automakers had been hesitant about filter technology. The Tokyo

Metropolitan Government had been in discussion with Nissan Diesel, which was doing promising work with the Tokyo Metropolitan Research Institute for Environmental Protection on filters. However, in April 2001, Nissan Diesel told the government it did not plan on commercializing the filters. The government turned to the ready-and-willing Mitsui, which began equipping public buses with filters in 2001 (Dieselnet 1997; Okamoto 2004). One Tokyo journalist for Yomiuri Shimbun, Japan's largest newspaper, observed: "Many metropolitan officials feel betrayed, and questions are being raised over whether the government underestimated the risk of leaving the development and manufacture of a technology that even automobile makers found difficult to a trading company, exposing blind spots in the business of environmental cleanup into which the government has sunk so much money" (Okamoto 2004).

7.6 Summary

This chapter demonstrates the importance of testing procedures and enforcement to emission regulations. While standard-setting often attracts the most attention from interest groups and gives companies the opportunity to provide technical input into the regulatory process, the challenges are not over once the standards are finalized. In terms of identifying technology leaders and laggards, a company's competitiveness may often be better understood in the ramp-up to meet the finalized regulations and in the demonstrated performance on the road after the compliance deadline has passed.

The experience of emission regulations in the US, the EU, and Japan in the late 1990s and early 2000s go against the idealistic expectation that first movers in environmental technologies are necessarily technologically superior or do better in the marketplace. In the aftermath of the consent decree, the companies that did comply with the accelerated October 2002 deadline performed more poorly with truck customers in the several months following the deadline. Meanwhile, Caterpillar paid penalties for months of noncompliance and but benefited from increased sales. Mercedes entered the US heavy-duty diesel market after the consent decree, and quickly gained 10% market share. Circumventing NOx controls was widespread among engine manufacturers in Europe as well, but no company was ever held responsible. In Japan, Mitsui, the first company to introduce diesel particulate filters and the market share leader,

turned out to be defrauding the Japanese government with falsified certification data for substandard filters.

Government agencies may lack the enforcement authority or resources to determine whether the implemented regulations are having their intended effect. The test cycle bypass and faulty filter problems were not caught immediately; afterwards, government agencies came under scrutiny for overlooking these violations. The EPA was slow to hold engine manufacturers responsible for defeat devices. Even after the settlement, in which manufacturers agreed to reprogram the software, EPA did not have the authority to force truck owners to bring their engines in for servicing. UBA, the German environmental agency, felt even more powerless than the EPA. It did not have the enforcement power to bring a lawsuit against European engine manufacturers for using defeat devices. Japanese officials acknowledge there are still many diesel trucks without the required retrofits in operation. In their enthusiasm for subsidizing emission improvements, Tokyo officials did not thoroughly scrutinize the performance of Mitsui's filter, which sold for 2 years before it was recalled. Government agencies have tried to prevent repeat occurrences of these problems by improving testing and enforcement procedures.

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CHAPTER 8 – Heavy-duty Diesel Engines, Beyond 2005

8.1 Introduction

The diesel vehicle industry faces a new set of challenges and technology choices to meet the emission regulations in the second half of 2000-2010. The focus on NO_x and PM emissions continues, but the ever decreasing levels will push the technology beyond what is currently possible. Although particulate filters seem assured to be a requirement, there is still pressure to improve reliability, and to reduce cost and the associated fuel penalty.

This second chapter on the regulation of heavy-duty diesel engines mostly focuses on the PM and NO_x regulations that will be implemented between 2007 and 2009. However, because of the time overlap and greater frequency of regulatory change in Japan and Europe, there will be some discussion of the 2005 Japanese standards and the 2005 Euro 4 standards as well. The post-2005 period is particularly interesting because it is considered by heavy-duty engine and truck manufacturers as the first time that they have diverged in their technology paths. In the past, there have been dominant emission reduction strategies collectively adopted by the industry.

In Chapter 7, it was already clear that Caterpillar had opted to pursue its own ACERT technology while the rest of the US heavy-duty engine industry would be pursuing exhaust gas recirculation (EGR) technology. Some Europeans and Japanese manufacturers have embraced urea selective catalyst reduction (SCR) systems as their preferred NO_x reduction strategy while most American companies are opting for non-SCR strategies. The decisions are based largely on individual manufacturers' strengths and government support.

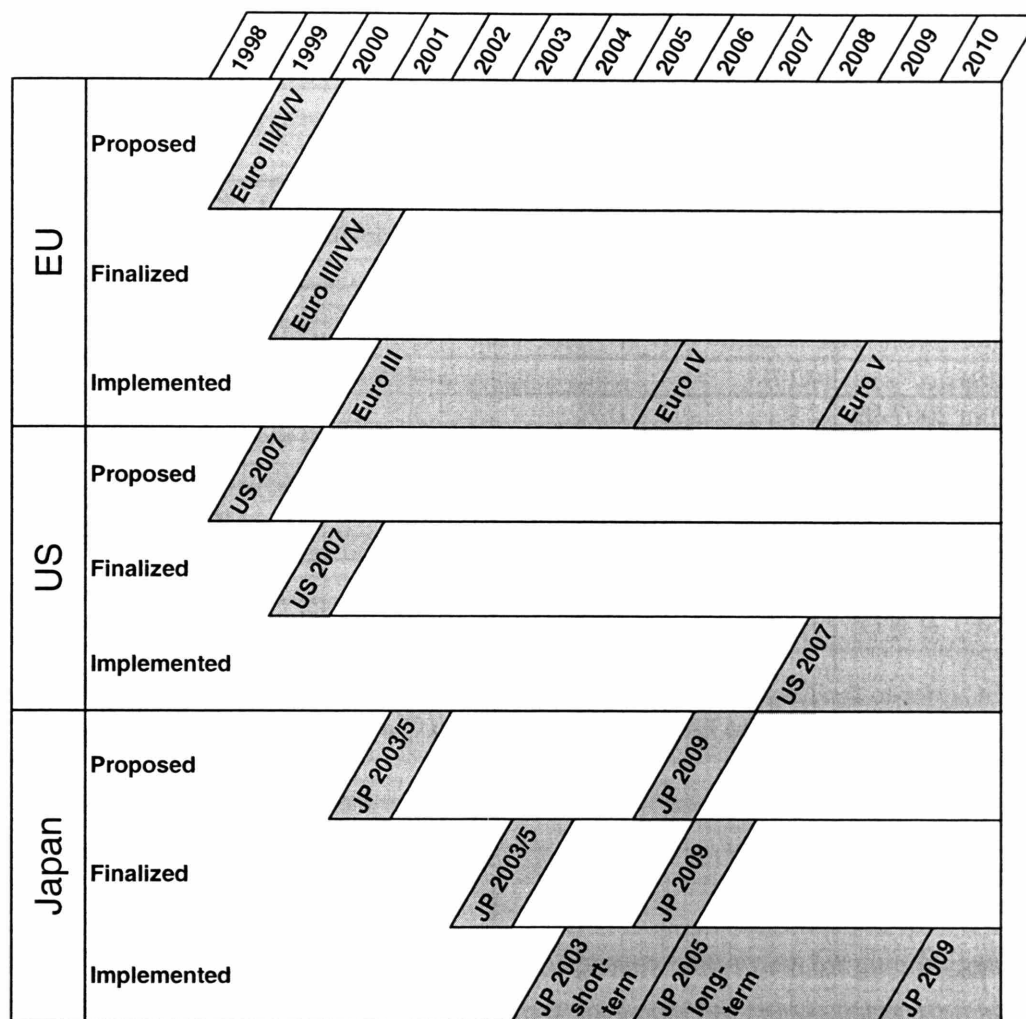
Engine companies cannot push for their new technologies on their own. As emission control systems become more technologically sophisticated, they require supporting infrastructure for higher quality fuels and chemical additives. For example, most filter technology for heavy-duty engines also requires very low sulfur fuel, so widespread implementation of filters is not possible until the appropriate fuel is available. Technology adoption therefore hinges on the oil industry's readiness to market lower sulfur fuel and the government's aptitude in coordinating the timing of clean vehicles and clean fuels.

The industry has become more global, with companies aiming to develop markets in all major industrialized countries and in developing regions as well. In the 1990s, engines purchased in the US were made mainly by US manufacturers. However, after major industry restructuring in the late 1990s and early 2000s, some of those US manufacturers were acquired by European firms. Sweden's Volvo Truck bought the US company Mack Trucks and Germany's DaimlerChrysler acquired the US company Detroit Diesel and gained control of Japan's Mitsubishi Truck. Manufacturers were not just dealing with their home market's regulators, but they were increasingly involved in regulatory discussions with authorities in other markets as well. Countries with strong domestic interests in specific technology paths have helped to facilitate infrastructure development and regulatory requirements to improve the competitiveness of their national champions. Governments have lobbied for favorable regulatory conditions for their domestic companies in outside markets as well.

8.2 Regulatory processes

As seen with light-duty vehicle and previous heavy-duty diesel engine emission standards covered in Chapters 5-7, the US, EU, and Japan do not have overlapping time periods for regulatory standards. Because the US Clean Air Act requires at least 4 years of lead time before heavy-duty vehicle emission standards go into effect, the regulatory process in the US tends to occur much further in advance of the implementation date. For the new engine standards effective in 2007, the US began its regulatory process in mid-1999, culminating in a final rule in December 2000. At that time, the 2004 standards had not yet come into effect. Japan and Europe tend to set their standards in a shorter timeframe, and usually closer to the implementation date. Japan finalized its 2005 heavy-duty vehicle emission standards in 2002. Its 2009 standards were proposed in February 2005, and finalized 2 months later. In Europe, the Euro 3, IV, and V standards, effective 2000, 2005, and 2008, respectively, were proposed together in December 1998 and finalized a year later with the December 1999 Directive 1999/96/EC. These overlapping regulatory periods and multiple deadlines are particularly challenging to manufacturers, especially those with overseas markets.

Figure 8-1: Heavy-duty Diesel Vehicle Emission Timelines



Sources: US EPA, Japan Ministry of the Environment, European Commission 2005.

Table 8-1 shows the emission standards themselves. Because the test procedures and cycles are not harmonized worldwide, the emission standards are not directly comparable. Because of their similar timing, industry experts group together the US 2007 standards, the 2009 Japanese standards, and the 2008 Euro 5 standards (Muller, Olschlegal et al. 2003). However, their relative stringency varies. The Japanese standards are considered more stringent overall than the European standards, but less stringent on NO_x than the US standards (Automotive Environment Analyst 1999; MIRA, PBA et al. 2002). All three regions share extremely

stringent requirements on PM emissions, which effectively require the installation of a diesel particulate filter.

Table 8-1: Overlapping Regulatory Cycles

	US (2007-10)	Japan (2005)	Japan (2009)	Euro 4 (2005)	Euro 5 (2008)
CO	15.5 g/bhp-hr (20.8 g/kWh)	2.22 g/kWh	2.22 g/kWh	1.5 g/kWh on ESC, 4.0 on ETC	1.5 g/kWh on ESC, 4.0 on ETC
HC				0.46	0.46
NMHC	0.14 (0.19)	0.17		0.55 on ETC	0.55 on ETC
NOx	1.2 (1.6) in 2007-09 0.20 (0.27) in 2010	2.0	0.7	3.5	2.0
PM	0.01 (0.013)	0.027	0.01	0.02 on ESC 0.03 on ETC	0.02 on ESC, 0.03 on ETC
Weight	> 8,500 lbs (3860 kg)	> 3500 kg	> 3500 kg	> 3500 kg	> 3500 kg
Test	FTP & SET & NTE (1.5xFTP)	JE05	JE05	ESC, ETC, and ELR	ESC, ETC, and ELR

Note: ETC and ESC refer to the European Transient Cycle and European Stationary Cycle. Sources: US EPA, Japan Ministry of the Environment, European Commission 2005.

8.3 Europe

The regulatory timing for heavy-duty vehicle emission regulations in Europe has been very different from the US and Japan. In December 1998, the EU Environment Ministers had already proposed the Euro 3, 4, and 5 emission limits, which were formally introduced with the 1999 Directive 99/96/EC. Since the Euro 5 standard was being proposed 10 years before its implementation, the NOx standard in particular would be revisited in 2002 to review its feasibility. “The Commission shall, no later than 31st December 2002, consider the available technology with a view to confirming the mandatory NOx standard for 2008 in a report to the European Parliament and to the Council, accompanied, if necessary, by appropriate proposals” (Automotive Environment Analyst 1999; MIRA, PBA et al. 2002). Because the European emission standards had been established so far in advance, industry leaders influenced standard-setting as well as later progress reviews and fiscal incentives.

8.3.1 Countries champion their own technology leaders

Leading up to the 2005 Euro 4 and 2008 Euro 5 standards, various companies have been promoting their own technology strengths. Individual countries have been perceived as championing their domestic companies' technologies, going as far to support the standards that can be met by those technologies. The British catalyst manufacturer, Johnson Matthey, has already been well known in the diesel vehicle retrofit world for its continuously regenerating trap (CRT), a highly effective diesel particulate filter. A very stringent heavy-duty engine PM limit in Europe would give them a huge regulatory-induced demand from truck and bus manufacturers. Prior to the finalization of the Euro 4 standards, British environmental representatives to the European Commission had been accused by engine and vehicle manufacturers of pushing for a very low PM standard, for the benefit of their domestic firm (Automotive Environment Analyst 1999).

A Germany-based consortium of engine and aftertreatment manufacturers, which included DaimlerChrysler, IVECO, MAN, and Siemens, conducted joint research in the 1990s on selective catalyst reduction (SCR) systems. Siemens had developed their SINOx SCR aftertreatment system for stationary engines, and now wanted to develop it for vehicles. Siemens ultimately spun off its SINOx business to the new Argillon GmbH. Beginning in 1992, the consortium set out to develop an SCR system for trucks, with a target of 70% NOx reduction on the ECE R.49 test cycle, and later, the newer European Stationary Cycle (ESC) and European Transient Cycle (ESC) tests. The SINOx system, developed predominately by German companies, has long been a favorite of the German government. The SINOx consortium had influence over Euro 4 and 5 standard-setting, which required the use of aftertreatment devices. Their promotion of SCR technology resulted in regulators' support of SCR as the dominant NOx reduction strategy in Europe.

8.3.2 Technology development

The SINOx consortium first began their collaborative R&D efforts with laboratory testing and then conducted their major on-road testing in 1995-2000. After completing bench

tests and chassis dynamometer tests on SCR systems, the consortium published their results in a 1999 SAE paper (Fritz, Mathes et al. 1999). By this time, the Euro 4/V and US2004 standards were already known. However, the results gave evidence of promising SCR effectiveness, as shown in Table 8-2.

Table 8-2: Test Results from SINOx Consortium’s Laboratory Testing

Comparison of Measured Emissions and Emission Standards in European Steady-state (ESC) and Transient Test Cycles (ETC) (units in g/kWh)					
Test cycle	Condition	NOx	NMHC	CO	PM
ESC (OICA/ ACEA)	before catalyst	8.31	0.23	0.39	0.06
	after catalyst	2.55	0.04	0.54	0.06
	Euro 3	5.0	0.66	2.10	0.10
	Euro 4	3.5	0.46	1.50	0.02
	Euro 5	2.0	0.46	1.50	0.02
ETC (FIGE)	before catalyst	9.25	0.17	2.01	0.11
	after catalyst	1.69	0.04	1.96	0.09
	Euro 3	5.0	0.78	5.45	0.09
	Euro 4	3.5	0.55	4.0	0.03
	Euro 5	2.0	0.55	4.0	0.03

Source: Fritz, Mathes et al. (1999)

Note: Highlighted boxes indicate the emission levels that can be attained by the SiNOx system.

In addition to bench testing and chassis dynamometer testing, the SINOx consortium performed on-road tests in Europe to demonstrate the NOx reduction performance of the urea-SCR systems. The first on-road demonstration project, entitled “Development and Testing of a Diesel Catalyst to Reduce Diesel Exhaust Gas Emissions,” was funded by the Bavarian government. It occurred in 1992-94, and provided a starting place for subsequent test programs (Fritz, Mathes et al. 1999).

The SINOx consortium conducted two sets of on-road demonstration tests starting in 1995 and 1998 to evaluate the SCR system’s NOx reduction performance, durability, and readiness for volume production. Trucks equipped with SINOx systems were driven by actual trucking companies. The scheduled maintenance interval for urea refilling was 31,000 miles, or 50,000 km.

Table 8-3: SiNOx On-road Tests

	1995-1998	1998-2000
Goal	Evaluate SCR's effectiveness and prove durability	Demonstrate durability and readiness for serial production
Engine type	12-L MAN D2866 LF	12-L Mercedes OM 501 LA 12-L MAN D2866 LF
Trucks	8 MAN trucks	10 DaimlerChrysler trucks 3 MAN trucks
Trucking companies	3	4
Reports issued	First interim report: 8/96 Second interim report: 8/97 Final report: 3/98	

Source: Fritz, Mathes et al. (1999)

TÜV Institute of Germany measured on-road emissions with a mobile measuring cell. Tests demonstrated an average NOx reduction of 65%, even after 80,000 to 111,000 miles of operation (Fritz, Mathes et al. 1999). Based on program results, the urea SCR system would be capable of meeting the 2005 Euro 4 and US MY2004 NOx standards. It was short of reaching the Euro 5 requirements, but it was expected that further improvements would make the standard attainable by 2008. Industry sources claim that the SiNOx consortium's program results influenced the Euro 4 NOx standard because it demonstrated a feasible pathway for increased stringency. The next table summarizes the programs.

8.3.3 Europe's enthusiasm for urea SCR

European governments and manufacturers prefer urea SCR systems for NOx reduction. In a 2002 EC-sponsored study evaluating future emission control technologies, SCR was expected to be the universal technology to meet Euro 5 requirements. EGR was deemed a "short-lived interim technology." The study recognized that choosing one technology path for Euro 4 might preclude the competing technology for Euro 5. For example, if manufacturers select an EGR system for Euro 4, they may prefer to incrementally improve that technology for Euro 5 rather than pursue an entirely new technology. Meanwhile, manufacturers would feel committed to SCR if they already had made a heavy investment in a urea infrastructure (MIRA, PBA et al. 2002).

Fuel savings is a very important priority of the truck and bus industry. Instead of having the fuel consumption penalty associated with EGR (approximately 3%) and NO_x adsorber technologies, SCR offers a 3-5% fuel economy benefit. With an SCR system, the engine's electronic controls optimize for fuel economy while still reducing NO_x emissions by approximately 65%, sufficient to meet the 2005 Euro 4 standards. A closed-loop system, which uses feedback from NO_x sensors, is capable of reducing NO_x emissions by over 85%, which would be sufficient to meet the upcoming 2008 Euro 5 NO_x standards (Muller, Olschlegel et al. 2003). The high cost of fuel in Europe and the lower cost of the urea additive, which comprises 3-5% of the fuel volume, also translate to fuel savings with the SCR system.

8.3.4 Industry dynamics

ACEA, European Automobile Manufacturers Association, representing 13 European vehicle manufacturers, has placed their support behind SCR technology. In 2003, ACEA issued a public statement of the industry's decision to introduce SCR technology starting in 2005, accompanied by a new production and distribution infrastructure for AdBlue, a commercial 32.5% urea-based solution (ACEA 2003). In 2004, DAF, IVECO, Mercedes-Benz, Renault Trucks and Volvo Trucks, comprising 80% of the European truck market, publicly announced their commitment to SCR technology to meet Euro 4 and 5 standards (PR Newswire Europe 2004). Not surprisingly, DAF, IVECO, and Mercedes-Benz were participants in the German consortium of companies conducting R&D and testing of SCR technology for vehicle applications since 1992.

Not all the companies are committing to SCR. MAN and Scania, once supportive of the SCR pathway, decided to rely mainly on EGR for NO_x reduction instead (Barnett 2005). Commercial Motor, a UK industry trade journal, reported on a comparison of operation costs for EGR- v. SCR-equipped engines in Germany. A test compared three equivalently sized Euro 4-compliant trucks from Mercedes-Benz, MAN and Scania. The Mercedes-Benz truck had an SCR system, while the other two had EGR systems. Although the Mercedes-Benz truck had a 0.2 mpg fuel advantage over the Scania truck and 0.6 mpg over the MAN truck, factoring AdBlue cost made the Scania slightly more cost competitive over the Mercedes-Benz (by 0.06

pence/km). In the end, the comparison results demonstrate that the current operating cost differences between the two technologies may be negligible (Barnett 2005).

The different technology choices led to a rift in ACEA. Mercedes-Benz has always been SCR's biggest advocate. It tried to persuade ACEA to issue a public statement in favor of SCR in 2004, but opposition by member companies MAN and Scania blocked this move. Instead, executives from the companies have resorted to publicly criticizing the other companies' technologies. DaimlerChrysler has touted SCR's cost and fuel economy benefits over EGR, but MAN and Scania contend that SCR is no better than EGR (Semple 2004). MAN's chairman, Hakan Samuelsson, has even appealed for increased regulatory scrutiny of SCR technology. He urged the European Commission to establish more specific regulatory guidelines for SCR, such as requirements for on-road monitoring and proper urea fueling (Semple 2004). Coming from a company with a competing technology, this appears to be a lobbying effort to create regulatory barriers for MAN's competitors. However, the end-user compliance concerns are valid, and have been flagged by regulators and manufacturers during the developmental phases of the technology.

8.3.5 Urea infrastructure

With the manufacturers' tentative commitment to introduce SCR-equipped trucks starting in 2005, the availability of AdBlue infrastructure is crucial. AdBlue production and distribution has coevolved with the development of SCR technology. Because of the lack of oil industry interest in supplying and distributing urea, the chemicals industry has moved into the market. As of 2005, urea suppliers have made AdBlue available in six European countries. They have worked together with oil companies to allow for AdBlue sales at retail fuel stations.

After the October 2005 deadline passed for Euro 4 compliance, operational issues entered the limelight. Currently, there is no method of detecting whether the urea tanks are properly refilled. AdBlue sensors for SCR engines are not a requirement until 2009, so truck operators may fill tanks with water and go undetected. Rental companies report preferring EGR over SCR because they do not want to worry whether the different drivers will have access to AdBlue (Shiers 2005).

8.3.6 Government policy supporting SCR and urea infrastructure

National governments in several European countries have offered monetary incentives to truck operators to use SCR systems. For example, Germany began a new road tolling scheme effective January 2005, as shown in Table 8-4. The rates vary with the emission standard attained. Euro 4 and 5-compliant trucks pay only 10 cents per km in road tolls, 2 cents less than Euro 3 trucks. The 10 cents per km rate lasts until October 2009 for Euro 5 trucks, 3 years longer than for Euro 4 trucks. The Netherlands also offers more favorable depreciation rates for compliant vehicles.(PR Newswire Europe 2004)

Table 8-4: Emission Categories for the German Autobahn Tax

(Applies to vehicles with 4 or more axles)

Emission standard	Jan. 1, 2005 – Sept. 30, 2006	Oct. 1, 2006 – Sept. 30, 2009	After Oct. 1, 2009
Euro 1	0.14€ / km	0.14€ / km	0.14€ / km
Euro 2	0.12	0.14	0.14
Euro 3	0.12	0.12	0.14
Euro 4	0.10	0.12	0.12
Euro 5	0.10	0.10	0.12

Source: Toll Collect (2006)

Following the success of the SINOx consortium’s on-road demonstration program, Mercedes-Benz and MAN had anticipated offering the SINOx system on heavy-duty trucks for MY2000 (Brodrick, Farsh-chi et al. 1999). Ultimately, early mover Mercedes did not introduce its Euro 5-compliant, SCR-equipped trucks until 2004 (Motor Transport 2004). It was motivated to do so by the fiscal incentive provided by the German road tolling scheme.

8.3.7 Transferability of European results to US results

The consortium testing programs were conducted with more than the European market in mind. In laboratory and on-road tests, they also measured emissions of vehicles running on the US FTP cycle, showing their intention to introduce the urea SCR system to the US market

(Amon and Keefe 2001). Measurements conducted in 1995-96, showed that the SCR system reduced emission levels to 1.22 g/bhp-hr NO_x and 0.062 g/bhp-hr PM, well below the US 2004 standards of 2.0 g/bhp-hr NO_x and 0.10 g/bhp-hr PM (Fritz, Mathes et al. 1999). The US demonstration programs reflected the European manufacturers' interest in demonstrating SCR feasibility in the US.

8.4 United States

In May 1999, the US EPA gave advance notice of its intention to propose new rules for heavy-duty vehicle and engine emissions and diesel fuel (EPA 1999). This was the first time that EPA treated engines, aftertreatment, and fuel as "one system." A year after the advance notice, the US EPA published its proposed new emission and fuel requirements in June 2000. That summer, EPA held several public hearings, followed by a 45-day comment period. EPA staff also released its Regulatory Impact Analysis in December 2000, which provided the technical and public health basis and economical analysis for the new standards.

Although much of the debate centered on the diesel fuel sulfur levels, which will be discussed in the next chapter, the heavy-duty diesel emission standards were a contentious subject as well. Although the engine manufacturers uniformly supported 15 ppm or lower diesel fuel sulfur levels as key to effective aftertreatment, they considered the new emission standards infeasible. They felt the NO_x reduction technologies were not developed enough to reach the standard set by the EPA.

The PM standard of 0.01 g/bhp-hr will be effective immediately in 2007, while the new NO_x and NMHC levels will be phased in between 2007 and 2010 (see Table 8-1). CO levels remain unchanged from the 2004 standards. As was the case in previous regulatory periods, the NO_x and PM standards are the most challenging for the diesel engine manufacturers to meet.

8.4.1 Regulatory input into the 2007 emission standards

Although the EPA has the authority to propose technology-forcing emission standards which cannot yet be met with existing technology, it values the demonstration of technical and economic feasibility in its proposals. The effectiveness of any regulation is dependent on the manufacturers' ability to meet it in a timely, cost-effective manner. EPA is sensitive to the national economy's dependence on heavy-duty diesel vehicles for freight and passenger transport, arguably more so than for light-duty vehicles. Therefore, while the regulations do not prescribe a particular technology, the regulatory officials did have in mind technologies that they expected to be available in the near future to meet the standards. In EPA's Regulatory Impact Analysis (RIA) of the 2007 Heavy-Duty Highway Final Rule, the EPA staff evaluated the technological progress of emission reductions for heavy-duty diesel engines. In Chapter 3 of the RIA, they made clear their preferred PM and NO_x reduction technologies:

On PM: "Because of the significant PM reductions that they enable and their proven durability on low sulfur diesel fuel, we believe the CDPF (catalyzed diesel particulate filter) will be the control technology of choice for the future control of diesel PM emissions."

On NO_x: "While other technologies exist that have the potential to provide significant emission reductions, such as selective catalytic reduction systems for NO_x control, we believe that the NO_x adsorber will likely be the only broadly applicable technology choice by the makers of engines and vehicles for the national fleet in the 2007-2010 time frame."

EPA expected continued and improved use of cooled EGR to reduce NO_x emissions. EGR works by recirculating a portion of the exhaust gas to the intake manifold. This dilutes the fresh intake air and reduces oxygen, thereby decreasing NO_x formation. Cooling the exhaust gas prior to mixing with the intake air can reduce combustion temperatures and contribute to reducing NO_x formation. Most US heavy-duty engine manufacturers had been using cooled

EGR for their MY2004 engines, many of which were introduced early in October 2002 because of the consent decree.

8.4.2 CDPF as a PM control technology

EPA was very confident in the capability of catalyzed diesel particulate filters (CDPF) to meet the 0.01 g/kWh PM standard. In a CDPF, a ceramic or metallic filter collects PM in the engine exhaust. To prevent the filter from becoming clogged with particles, the filter continuously regenerates, or “burns off” the PM with the help of precious metal catalysts, which ensures that particles are oxidized. CDPFs had been installed on heavy-duty diesel buses and municipal trucks since the 1990s, and on diesel passenger cars in Europe since 2003. However, they require very low fuel sulfur levels to be effective. In regions without widespread availability of lower sulfur diesel fuel, CDPF-equipped vehicles require a dedicated and more costly fuel source, limiting their adoption to public fleets.

EPA cited numerous studies and pilot programs that evaluated the effectiveness of CDPFs in the field. Retrofit applications in the UK, Sweden, Finland, and Denmark showed the CDPFs to be effective, as long as sulfur levels were very low (e.g. 10 ppm). In addition to citing the results of these field studies, EPA also obtained information from industry representatives and their trade associations.

8.4.3 Input from emission control manufacturers

Not surprisingly, emission control manufacturers who made catalyzed diesel particulate filters gave substantial input to the EPA, in the form of industry publications about the filter effectiveness and personal interviews and letters. They have a clear financial stake in supporting regulations that would increase demand for their aftertreatment devices. Johnson Matthey, a leading catalyst manufacturer, was the first to develop a continuously regenerating trap (CRT), a type of CDPF that has been considered the most practical option (Automotive Environment

Analyst 1999). The EPA's RIA frequently refers to the company's information on field tests and demonstration programs. Johnson Matthey was the CDPF manufacturer for many of the field programs conducted in Europe, as well as the CDPF supplier (along with main competitor Engelhard) for the ARCO EC-D program in California (EPA 2000b).

Despite emission control manufacturers' market interest in regulatory stringency, they strive to be information providers rather than policy advocates. In a personal interview with a senior expert in the diesel emission control industry, he expressed that his role was to provide regulators with information about the technical capabilities for his company's products, not to push for new regulations. Based on his 40-plus years of experience in the catalyst industry, he thought it very rare that an emission control equipment manufacturer would individually force new regulations into place, rather preferring to work with other emission control manufacturers through trade organizations to influence the regulatory process.³¹ Even if manufacturers are not aggressively pushing for regulations, their input invariably has impact on the ultimate outcome because EPA solicits their technical and cost data. The emission control industry tends to be more optimistic about technology than the vehicle or engine manufacturers. However, if it casts doubts about the technical or cost feasibility of proposed regulations, EPA may reconsider the stringency or timing. On the other hand, an enthusiastic endorsement of the technology's readiness for new regulations, which EPA received from emission control manufacturers for the 2007 HD Rule, would strengthen EPA's commitment to its proposal.

8.4.4 Using other countries' experience

In addition to citing the field tests of retrofitted vehicles conducted in Europe, the EPA turned to the EU, whose 2005 Euro 4 standards would require the use of particulate filters. In order to meet Euro 4, manufacturers had already begun field testing with CDPFs, so the EPA could use the EU as an example of CDPFs being used to meet regulatory requirements (EPA 2000b).

Since the Euro 5 standard for 2008 was already known at this time, European manufacturers definitely had an interest in getting the US regulations as close to the European

³¹ Interview with a senior expert in the diesel industry, August 2005.

ones as possible. In its comments to the EPA about the HD 2007 Rule, DaimlerChrysler felt that the US should use Euro 5 as a basis for US regulations. Having similar sets of standards makes certification and field testing much easier for international manufacturers, but EPA defended its decision to call for regulations significantly more stringent than Europe's (EPA 2000a).

8.4.5 NOx adsorber catalysts as a NOx control technology

When evaluating NOx control technologies, EPA considered lean NOx catalysts, NOx adsorbers, selective catalytic reduction (SCR), and non-thermal plasma. EPA still viewed the NOx adsorber as the most promising of the NOx reduction strategies. NOx adsorbers are an extension of the three-way catalyst developed for gasoline vehicles. While gasoline vehicles run very close to the stoichiometric air-fuel ratio, diesel vehicles run in oxygen-rich conditions.³² Rather than achieving a balance between the oxidizing potential of the exhaust's NO and O₂ and the reducing potential of the HC and CO, a catalyst-equipped diesel produces very low HC and CO but high NOx emissions. As a result, a NOx adsorber must contain additional storage materials on the catalyst surface to absorb the excess NOx as metallic nitrate during the oxygen-rich, or lean conditions. Periodically, the engine must switch to stoichiometric or fuel-rich conditions such that the metallic nitrate releases excess NOx, which is then reduced by CO and HC (EPA 2000b).

Unlike CDPFs, there has been greater uncertainty about the future development and viability of NOx adsorber technology. CDPFs had been on the market and commercially available since the mid-1990s for heavy-duty diesel vehicle applications. Their main technological hurdle was the availability of ultra-low sulfur diesel fuel, which will be overcome by the new 2006 sulfur limits. Meanwhile, the NOx adsorber is still at the early development stages. At the time of the December 2000 RIA, NOx adsorbers had been used commercially for less than 5 years, and limited to stationary source applications and lean burn gasoline vehicles sold by Toyota and Honda.

³² In a gasoline engine, the ratio of air to fuel (A/F ratio) in the air-fuel mixture is very close to the stoichiometric ratio of 14.7 to 1. For every 14.7 units of air, 1 unit of gasoline will be burned. For proper operation of the three-way catalyst, the A/F mixture must stay very close to this ratio, and an oxygen sensor detects whether there is adequate oxygen for the catalyst to work. A diesel engine has a much higher air-to-fuel ratio, even as high as 60:1 if idling with no load.

EPA also looked to progress in NOx adsorber use in passenger cars. By 2000, Toyota had already announced that it was planning to introduce a diesel passenger car equipped with a CDPF and a NOx adsorber in 2003. According to Toyota, its Diesel Particulate-NOx Reduction (DPNR) system could reduce PM and NOx emissions by 80% for a useful life of 50,000 miles. Although this is less than half the useful life required by the US light-duty regulations and far from the US heavy-duty diesel engine requirement of 435,000 miles, EPA viewed DPNR as very promising. EPA also noted the progress of DaimlerChrysler and Volkswagen on NOx adsorber technology to meet Euro 4 diesel passenger car standards. Despite some promising results, the two German companies ultimately relied on less costly in-cylinder engine modifications to meet the Euro 4 standards.

Although cooled EGR had been sufficient to meet MY2004 requirements, engine manufacturers knew they would have to pursue more advanced technologies to meet future standards. They were already conducting tests with NOx adsorber-equipped engines. According to the EPA's RIA, Cummins had presented its success with a NOx adsorber catalyst in two recent industry presentations. The company reported an 80% NOx reduction over the Supplemental Steady State test and a 98% NOx reduction over the heavy-duty transient FTP (EPA 2000b). In making the argument that the proposed NOx standard of 0.20 g/bhp-hr is attainable with a NOx standard, EPA specifically refers to Cummins' results: "One HDDE manufacturer has also demonstrated greater than a 98 percent NOx reduction over the HD FTP using a NOx adsorber" (EPA Docket A-99-06 II-E).

The Department of Energy worked with industry in a public-private partnership called the Advanced Petroleum Based Fuel (APBF) program. Part of the program included research at DOE national labs on NOx adsorbers for light-duty and heavy-duty applications. The tests showed NOx emission reductions of 90% or higher, but the NOx adsorber was easily poisoned by sulfur in fuel (EPA 2000b).

The emission control industry's trade association, the Manufacturers of Emission Control Association (MECA), was eager to demonstrate the capabilities of NOx adsorber technology. Some of its members would eventually be the ones to manufacture and market NOx adsorbers. MECA provided four different catalyst systems for the EPA to test in its National Vehicle and Fuel Emission Laboratory (NVFEL). The catalysts reduced NOx emissions by more than 90% on the Euro 3 steady-state test cycle. Under "road-load" conditions, the NOx adsorber was able

to reduce NOx emissions from an engine-out emission level of 5 g/bhp-hr down to below 0.1 g/bhp-hr. The EPA placed a lot of credence in these tests, using the lab results as its main justification for the NOx standard:

“We have demonstrated in our laboratory that a NOx adsorber can produce greater than 90 percent reduction in NOx emissions over the hot start HDDE transient FTP. The results of this test program lead us to believe NOx adsorbers will be capable of meeting the Phase 2 FTP NOx emission standard of 0.20 g/bhp-hr” (EPA 2000b).

Even though EPA recognized the challenges related to the cold start FTP, durability, and cost, it anticipated that given several years of lead time and various design options, industry would make the advancements necessary to meet the standard. In its submissions to EPA, Johnson Matthey and MECA “conclude[d] that there are no significant barriers to the commercialization of either catalyst based diesel particulate filters or NOx adsorber technology” (EPA 2000a). Engelhard, another major emission control manufacturer, also believed that NOx adsorber development was on schedule to meet the 2007 regulations (EPA 2000a).

8.4.6 Response of engine manufacturers to 2007 HD emission standards

The engine manufacturers, as represented by the Engine Manufacturers Association, expressed their concern about the timeline and stringency of the HD 2007 standards. They supported a delay to 2010 or a revision of the standards. Even though EPA used Cummins’ early results on NOx adsorbers to support its regulatory decision, Cummins was by no means supportive of the proposed standards. Regulators’ interpretation of Cummins’ technical input was actually counter to the company’s regulatory position. Success at early stages of R&D did not eliminate substantial uncertainty, especially about commercial feasibility. In its numerous comments to EPA on the 2007 HD Rule, Cummins, along with other engine manufacturers, called for the delay or revision of the standards and criticized many aspects of the regulation (EPA 2000a). Cummins, Caterpillar, Mack, Detroit Diesel, and Volvo, engine companies which had also been parties to the 1998 consent decree, offered an alternate proposal. They offered a

more gradual phase-in approach compared to the EPA’s proposal for a 2007 deadline for the 0.01 g/bhp-hr PM standard and a 2007-10 phase-in for the 0.20 g/bhp-hr NOx standard.

Table 8-5: Alternate Proposal from “Consent Decree” Engine Manufacturers

Timeframe	PM standard	NOx standard
2007-2009	0.03 g/bhp-hr	1.5 g/bhp-hr
2010-2012	0.03	0.5
2013 and beyond	0.01	0.2

Source: EPA (2000).

They argued that they were at a competitive disadvantage compared to companies like International and Mercedes, which did not have to meet the supplemental emission requirements (NTE and SET). The consent decree companies claimed that after the consent decree requirements were over in October 2004, they would be “forced to reduce the effectiveness of their emission control systems in order to compete with non-CD [consent decree] companies which must only meet the Phase 1 [2004] FTP standards” (EPA 2000a). However, if their alternate proposal were adopted, they offered to voluntarily meet the supplemental emission tests in the “gap years” of 2005 and 2006, so as not to create a lapse in emission control.

8.4.7 Optimism from industry

International Truck and Engine Corporation

It is not a surprise that engine manufacturers would oppose the proposed emission standards. They faced substantial technological hurdles and costs of complying with the new standards. However, not all the companies had the same level of opposition to the standards. Even though International generally sided with the rest of the engine manufacturers in critiquing the new standards, it offered some glimpses into its own technological progress in its comments to EPA. International referred to its “Green Diesel Technology,” which was already capable of meeting the proposed 2007 NMHC and PM standards in 2001. As discussed in Chapter 5, it had already demonstrated the technology to the EPA and CARB in a public event in Washington, D.C., strategically timed to coincide with the EPA’s Tier 2 emission hearings. Although its

public presentation of a Green Diesel school bus was intended to persuade regulators to adopt very low fuel sulfur levels, necessary for the technology's effectiveness, it undoubtedly assured regulators that very clean diesel engines were feasible. International planned to commercialize the technology for buses where ultra-low diesel fuel (<15ppm) was available (EPA 2000a).

EPA even went as far to cite International's success with CDPFs on school buses as a demonstration of the feasibility of the PM standard: "Given International's commitment to produce a CDPF equipped diesel bus in markets where 15 ppm can be made available, makes us confident that CDPFs will regenerate reliably when operated on the mandated fuel under this program which is expected to have an in-use average level between seven and 10 ppm" (EPA 2000a). Compared to other US manufacturers, International was generally supportive of the proposed 2007 emission standards, because the company already had technology prepared to meet the new levels. Also, International has a strong presence in school buses, which became a rallying point for citizen and environmental groups seeking to protect children from diesel emissions.

Competition from compressed natural gas (CNG) buses in the school bus market was a key motivation behind International's early introduction of 2007-compliant diesel school buses. In the 1990s, International had made a conscious decision to not produce alternative fuel engines, after early evaluations showed their poor performance relative to diesel engines.³³ Their exclusive commitment to diesel technology meant that mounting criticism of diesel exhaust could seriously hurt their bottom line. EPA and CARB were already considering mandates that all transit and school buses run on CNG. International had to convince the public and more specifically, municipalities, school districts, and regulators that diesel buses could be very low-emitting and benefit from the preexisting fuel and maintenance infrastructure. In its public relations and marketing material, International compared the emission levels of its Green Diesel bus and a typical CNG bus. Although the Green Diesel bus has higher NO_x emissions than CNG (2.2 g/bhp-hr vs. 1.2 g/bhp-hr), it has lower PM and HC emissions. International also made an argument for diesel's cost and performance superiority over alternative fuels, including CNG, methanol, ethanol, and liquefied natural gas (International Truck and Engine 2004). International's focus on protecting their existing market may have constituted a defensive strategy, but their behavior had the effect of reducing diesel school bus emissions in advance of

³³ Interviews with senior experts in the diesel vehicle industry, 2006.

regulation and making the case for clean diesel. Sales have still been limited by the availability of funding for new school buses. From 2001 to 2006, International sold 200 Green Diesel buses, mostly in California, where CARB has offered subsidies to replace old buses (International Truck and Engine 2006).

Toyota and its DPNR

Toyota's DPNR system had a far-reaching, cross-industry impact. Although it was developed for light-duty vehicles in Europe, DPNR drew the interest of EPA while it was setting heavy-duty standards. EPA extrapolated Toyota's ability to integrate the CDPF with the NO_x adsorber to heavy-duty applications. The RIA frequently mentions Toyota's technology based on Toyota's press releases on DPNR from summer 2000 and an in-person meeting between Toyota representatives and EPA's Todd Sherwood in October 2000 (EPA 2000b). Ironically, Toyota had not actively submitted technical documentation on DPNR to the EPA for its RIA or to the comment period. Instead, EPA relied primarily on Toyota's press releases. In response to comments by engine manufacturers and oil companies doubting the technical feasibility of the NO_x standard, EPA cited Toyota's success with DPNR (EPA 2000a).

8.4.8 Urea SCR as a competing technology

When EPA proposed its 2007 HD standards, it showed its clear preference of the NO_x adsorber as the dominant NO_x reduction technology. On the other side of the Atlantic, European manufacturers were favoring the use of selective reduction catalysts (SCR), which requires urea as a fuel additive. SCR systems provide fuel economy benefits while reducing NO_x levels by up to 90% (Muller, Olschlegal et al. 2003). EPA had been reluctant to consider urea SCR technology as a practical option. It was concerned that truck owners would fail to refill their urea tank, leading to high NO_x emission levels, as if there were no NO_x control technology at all: "We do not believe that there are acceptable means to ensure widespread compliance under an SCR program where an entirely new fluid needed to be added in order to ensure proper

emission control system function” (EPA 2000a). EPA recognized that the technology worked well, but was skeptical about truckers’ interaction with the technology, whereas the NO_x adsorber was a “passive” technology that did not require any changes in truckers’ behavior.

Although EPA insists that its regulations are performance-based and technology-neutral, it had expressed concern about SCR technology as early as 2001, during the 2007 HD rulemaking. It has cited the lack of national urea infrastructure and end-user compliance as major challenges to implementing SCR technology (EPA 2004b). Both regulators and manufacturers have identified the following as issues to be addressed in order for SCR to be viable in the US market:

- Closed-loop performance feedback: Without feedback, a malfunctioning SCR system may not properly convert the NO_x. On-board NO_x sensors at the outlet of the SCR catalyst have been proposed as one solution, but improving NO_x sensor durability is still in progress.
- System tampering or negligence: The added cost of urea may provide a financial incentive for truck operators to tamper with the SCR system. An operator may intentionally or accidentally fail to refill the urea tank, refill it with a substandard ammonia-water mixture, or otherwise tamper with the urea injection system.
- Fault accommodation: Once a fault is detected, there must be a system in place to give operators an incentive to take their vehicle in for repair. For example, in the event of low urea tank levels, a warning light may switch on, and at very low levels, the engine may not be able to restart.
- Lack of urea infrastructure: Because of the frequency in which the urea tank must be refilled (approximately every 31,000 miles), urea filling pumps must be established at diesel retail stations.

(EPA 2004b; Nebergall, Hagen et al. 2005)

The legal requirements of the HD engine rule also presented an obstacle for the system. It requires that a vehicle’s emission control system be maintenance-free for 150,000 miles. However, based on the European demonstration programs, a typical SCR system has a 31,000-mile scheduled maintenance interval. Companies must seek guidance from EPA on this issue before they can market SCR-equipped vehicles. Although its concerns about SCR technology

persist, the EPA has been less skeptical in the past few years, as SCR catalyst vendors and engine and truck manufacturers have approached the Agency about ways to address its concerns.³⁴

8.4.9 Petroleum industry support of SCR

The interdependency between vehicles and fuels has led to tension between the oil and auto/engine industries, as both sides try to convince regulators that the other is better equipped to tackle emission reduction. The oil industry claims that vehicle and aftertreatment manufacturers have plenty of room to improve their technologies; automobile and engine industries argue that their more advanced technologies are constrained by the poor quality of fuel. Ultimately, the combination of clean fuels and clean vehicles, requiring investment from both sides, is necessary to meet the EPA's proposed emission standards. The industries' differing attitudes toward SCR technology is a perfect example of their disagreement about the distribution of the regulatory burden.

NO_x adsorbers require very low fuel sulfur levels compared to urea SCR technology. Because of the high investment costs associated with desulphurization, the oil industry was enthusiastic about urea SCR. The NO_x adsorber requires sulfur levels below 15 ppm, but SCR has been shown to operate well with fuel with higher than 50 ppm sulfur content. The American Petroleum Institute (API), the US oil industry trade association, had been advocating a 50 ppm sulfur standard to the EPA. It went as far as to fund a third-party study by Engine Fuel and Emissions Engineering (EF&EE) to support its claim that SCR has significantly lower life cycle costs than NO_x adsorbers and tolerates higher sulfur levels (EPA 2000a). Oil companies viewed a combined CDPF and SCR system as a more "proven" technology than the EPA's preferred CDPF and NO_x adsorber combination.

US engine manufacturers treated urea SCR as a promising technology but had their reservations about its readiness for 2007. According engine manufacturers, urea suppliers will only find the market attractive if the entire US industry uses urea SCR, just as the majority of European manufacturers are opting for urea. They also disagreed with API's assertion that urea

³⁴ Interview with Margo Oge, Director, US EPA Office of Transportation and Air Quality, December 8, 2005.

SCR would work with higher levels of sulfur because the accompanying oxidation catalysts would still require very low sulfur levels (EPA 2000a). Even environmental groups and local/state regulatory agencies like the Natural Resources Defense Council and STAPPA/ALAPCO expressed their reservations about urea SCR because of the necessary urea infrastructure and possibility of missed refueling by truckers (EPA 2000a).

8.4.10 European manufacturers try to promote urea SCR in the US

While gaining support from the European Commission after using the SINOx system in European demonstration projects, the SINOx consortium had yet to win over American regulators. DaimlerChrysler took the lead in encouraging the EPA to consider urea SCR for a NOx control technology, considering it superior to NOx adsorber technology. As the champion for SCR, the company also cast doubt about the effectiveness of cooled EGR for 2007 (EPA 2000a). They were already developing these for trucks in Europe to meet the 2008 Euro 5 standards, and expanding to the US market would allow them to increase sales volume and lower per unit costs.

The SINOx consortium participated in test projects in the US, as a way to show US regulators and other companies the feasibility of SCR systems. It had started testing the system for vehicle applications in 1992. The Siemens SINOx system seemed ready for commercialization by 1998, and the European diesel truck manufacturers were eager to use it as their primary NOx reduction technology. However, the US response to urea SCR systems was far more tepid. To demonstrate the technology's performance and durability, several demonstration projects were initiated in the US, many of them with participation from companies with ties to the European consortium.

ITS-Davis Project - Demonstrating the SINOx technology on the West Coast

The Institute of Transportation Studies at the University of California, Davis (ITS-Davis) brought together Siemens-Westinghouse, Detroit Diesel Corporation, Freightliner Corporation, and Valley Material Transport for the SINOx demonstration program. Detroit Diesel and

Freightliner are both part of DaimlerChrysler, the largest promoter of urea SCR technology. The program would test emissions and fuel economy from 10 new Class 8 heavy-duty diesel vehicles, equipped with SINOx, operating in California. The program also included investigation of truckers' acceptance, infrastructure needs, technical feasibility, and cost-effectiveness. These additional components addressed regulatory agencies' concerns about urea infrastructure and truckers' failure to refill the urea tank. Part of the program was funded by air pollution control districts in the San Joaquin Valley and Sacramento and the California Air Resources Board (CARB), demonstrating the growing US interest in the technology (Brodrick, Farsh-chi et al. 1999).

Mack SCR Project - Demonstrating SINOx technology on the East Coast

The consortium companies initiated a testing program with Mack Trucks and NESCAUM in the US in 2000. Funding for the project came out of Mack Trucks' commitment to fund an SCR project through the 1998 consent decree agreement. At the Southwest Research Institute (SwRI) in 2002, participants measured the emissions from heavy-duty 12-L Mack engines with two emission control system configurations on a transient test cell. One configuration had an Argillon SINOx SCR catalyst only, and the other had the SINOx system and an Engelhard DPX diesel particulate filter (DPF). The engines were run on both the US transient FTP cycle and the European steady-state cycle (ESC). The combined DPF and SCR system reduces PM by 89%, such that emission levels are below the 0.01 g/bhp-hr PM standard. NOx is reduced by 82%, to 1.06 g/bhp-hr, still considerably higher than the 0.20 g/bhp-hr limit, but capable of meeting the 2007-09 NOx phase-in average of 1.2 g/bhp-hr allowed by the US HD rule's regulatory flexibility (Scarnegie, Miller et al. 2003).

The field test phase of this project involved 2 years of monitoring 10 Mack trucks in commercial use. Of the 8 tractor-trailer highway trucks used by the United Parcel Service (UPS), 5 had SCR only and 3 had DPF and SCR. Two urban refuse trucks used by the New York Department of Sanitation had DPF and SCR. The trucks began operating in mid-2002. Two of the UPS trucks and one of the refuse trucks were emission-tested with the West Virginia University Translabs after 1 and 2 years of operation (Block, Clark et al. 2005). Based on those three trucks, the Mack SCR Project team measured a 79-95% NOx reduction after 1 year and

81%-91% after 2 years. The team emphasized that the tests were conducted on fuel with regular sulfur levels (e.g. 350 ppm), which did not affect the performance of the SCR system. Other NO_x reduction strategies such as NO_x traps require very low fuel sulfur levels (Block, Clark et al. 2005).

There are other limited demonstration projects involving SCR systems. For example, Extengine Transport Systems, a company recently established in 2001, was the first to commercially offer a mobile retrofit SCR system. A 2003 CARB-verified test showed that the ADEC system reduced NO_x by 90% and PM by 95%. Because of system's impressive emission reduction performance, Europe's largest transit operator and Japanese firms have sought out the Extengine for diesel retrofits. In the US, ADEC has been used by the City of Houston and the Santa Clara Valley Transit Authority for municipal vehicles (PR Newswire 2003). Extengine's second generation device, ADEC II, incorporates self-calibration via NO_x sensors to adjust the quantity of urea injected (Extengine 2005). Although Extengine's system is not yet used in new vehicles, success with fleet-based retrofits may lead to greater SCR acceptance in the US.

8.4.11 SCR in the US for 2010?

Although R&D in NO_x adsorbers and urea SCR continues, none of the engine and vehicle manufacturers plan to apply those two technologies broadly to meet the 2007 standards (EPA 2004b). They will improve their 2004 technology – ACERT for Caterpillar and EGR for the rest. The manufacturers plan to use the two-step compliance flexibility in the regulations to meet an average 1.2 g/bhp-hr NO_x standard in 2007-09, and then meet the 0.20 g/bhp-hr standard by 2010.

Some American engine and truck manufacturers have shown increasing interest in urea SCR systems for new vehicles. SCR systems are not yet able to meet the 0.2 g/bhp-hr NO_x standard required by the US 2007 HD Rule, but researchers in industry and at national labs are working on configurations to meet the NO_x standard by 2010, when the new standard must be fully implemented. Researchers at the Southwest Research Institute (SwRI) tested a combined SCR, EGR, and DPF system under the auspices of the US Department of Energy's Advanced

Petroleum-Based fuels (APBF) program. The system could only achieve 0.15-0.37 g/bhp-hr NO_x with a fresh catalyst and 0.38-0.48 g/bhp-hr with an aged catalyst. However, the SwRI considered the technology promising enough for meeting 2010 levels (Khair and Sharp 2004). According to representatives in industry and EPA, EPA has been more receptive to SCR technology in the past few years because manufacturers have been working actively with the Agency to address concerns about urea infrastructure and end-user compliance. Some industry and regulatory experts believe that there will be greater commonality in the 2010-2012 timeframe, where the US and Europe will both have SCR systems.³⁵

8.5 Japan

New long-term emission regulations in Japan went into effect in October 2005. The new PM and NO_x standards, 2.0 g/kWh NO_x and 0.027 g/kWh PM, require technological improvements beyond engine-only modifications, which had been sufficient to meet national regulations in the past. Like in the US and Europe, engine and truck manufacturers found themselves with the choice between EGR and SCR.

Like the Europeans, the four major Japanese heavy-duty vehicle manufacturers are divided on their technology pathways. Hino Motors and Isuzu Motors have focused on improving existing EGR and DPF technologies, the technology route taken by US heavy-duty engine manufacturers (Asahi Shimbun 2004c). As mentioned in Chapters 6 and 7, Hino Motors had already developed its DPNR (diesel particulate-NO_x reduction) system, which includes a diesel particulate filter and NO_x adsorber catalyst. It improved on their DPNR system to meet the 2005 regulations. Meanwhile, the two other major manufacturers, Nissan Diesel and Mitsubishi Fuso, have committed to SCR. Nissan Diesel took the lead on developing SCR technology for the Japanese market. It faced challenges from the technology itself and the required urea refilling infrastructure.

³⁵ Interview with Margo Oge, Director, US EPA Office of Transportation and Air Quality, December 8, 2005.

8.5.1 Nissan Diesel adopts SCR on its own

In addition to sharing the SCR technology challenges of the European manufacturers, Nissan Diesel had to deal with the problem of poor SCR performance at low temperatures. Compared to the US and European test cycles, the Japanese JE05 test cycle emphasizes low loads and low speeds, characteristic of urban driving in Japan. This results in lower exhaust temperatures, which lower NO_x conversion rates in the SCR catalyst. To remedy the low-temperature problem, the Nissan Diesel system includes a diesel oxidation catalyst upstream of the SCR catalyst and cooled EGR. Engine controls are optimized for reducing PM, and then NO_x is reduced by the SCR catalyst, eliminating the need for a DPF.

In November 2004, Nissan Diesel introduced Japan's first commercial urea-SCR system on a Quon heavy-duty truck. Its Final Low Emission New Diesel System (FLEDS) met the long-term 2005 standard one year ahead of schedule. The system uses AdBlue, a 32.5% urea solution with the same specifications as the AdBlue product in Europe. The SCR system has an average NO_x conversion rate of 70%. Nissan Diesel estimates that the SCR system has a 6.5% better fuel economy than a high EGR and DPF system. If the urea costs are factored into the comparison, SCR is 4% better in terms of fuel consumption (Hirata, Masaki et al. 2005).

In 2004, Nissan Diesel was the only major Japanese manufacturer planning to use SCR on trucks, so it had to coordinate a urea distribution system on its own. By June 2005, it arranged for AdBlue to be available at 7 main in-tank bases, 1,080 truck stops, and 192 Nissan Diesel service centers throughout Japan (Hirata, Masaki et al. 2005). Unlike the US or Europe, Japan is a relatively compact area, where it is easier to establish a urea distribution network. About 80% of medium and heavy-duty truck drivers obtain fuel from their own fuel tank or truck station, so Nissan Diesel focused on equipping those tanks and stations with AdBlue rather than the more difficult task of ensuring supply at retail stations.

Nissan Diesel benefited from being a year early to introduce an SCR-equipped vehicle compliant with the 2005 standards. Other manufacturers had the opportunity to observe the Quon trucks' performance and urea distribution network and decide whether to adopt Nissan Diesel's strategy as well. Mitsubishi Fuso agreed to team up with Nissan Diesel to share emission reduction technology in June 2005, just a few months before the October 2005 deadline. Already struggling financially because of its recent defect scandal, Mitsubishi Fuso licensed

Nissan Diesel's SCR technology so that it would not have to develop its own system (Jiji Press 2005c; Kyodo 2005b). Mitsubishi Fuso also licensed the urea production technology from Nissan Chemical Industries, another financial boon for the Nissan Group (Asia Pulse 2004).

A potential problem with Nissan Diesel's SCR-equipped trucks is its system's low incentive for drivers to refill their tanks with urea. The only "penalty" for non-compliance, such as an empty urea tank level or substandard urea solution, is a warning light on the instrument panel. If the driver knows that the urea tank does not affect the driving performance of the vehicle, he or she will probably ignore the warning (Hirata, Masaki et al. 2005).

8.5.2 Japan's clean engine technologies transferred overseas

The Japanese long-term diesel emission and low sulfur fuel regulation was originally set for 2007, but an agreement with the auto and oil industries accelerated the deadline to 2005. This provided a significant competitive advantage to Japanese vehicle manufacturers, whose earlier R&D efforts and successes allowed them to license their technology to other manufacturers. As of 2005, Japan had the most stringent vehicle emission standards, not to be surpassed by the US until 2007 or by the EU until 2008. Isuzu Motors and Hino Motors, which mostly used EGR and DPF technology, had deals to supply their engines to other manufacturers. Isuzu will supply 6.6-liter V-8 engines to DMAX, its US-based joint venture with General Motors, for school buses, cargo vans, and pick-up trucks in the US. Annual production at the DMAX plant increased by 10% in 2004-2005, and is expected to grow with climbing US demand for diesel-powered vehicles. Hino will supply engines to Nissan Diesel and other companies, increasing its diesel engine sales to other manufacturers by 160% from FY2004 to FY2007 (Asia Pulse 2005b).

8.5.3 Japanese government offers incentives for diesel vehicle turnover

To encourage consumers to replace their older vehicles and purchase compliant vehicles under the Automobile NO_x/PM Law, the government offered reductions in the vehicle acquisition tax. New diesel trucks and buses compliant with the 2005 emission regulations would receive a 2% reduction in the acquisition tax between April 2004 and September 2005,

and a 1% reduction between October 2005 and March 2006. Reductions were slightly higher if consumers demonstrated that their new vehicles were purchased to replace older vehicles (JAMA 2005). Older diesel vehicles were taxed more heavily. For example, diesel vehicles on the road for 11 years or longer had to pay a 10% surcharge (JAMA 2005).

8.6 Summary

Manufacturers and national governments have strong interests in supporting particular NOx and PM reduction technologies to meet engine emission standards in 2005 and beyond. In addition to seeking to wield influence on their own country or region's regulatory processes, manufacturers have tried to expand their influence in other countries' regulatory regimes. Public-private research projects and technology demonstration projects have been popular instruments to persuade regulators of a technology's high performance. On several occasions, national governments have unabashedly supported regulations benefiting their domestic industries.

Technical, economic, and political considerations are major drivers of technology paths, but user responses to the technology cannot be neglected. For example, EGR and NOx adsorbers are passive technologies requiring no behavioral changes by the vehicle operator, while SCR gives the operator new responsibility for refilling the urea tank. Europe and the US have thus far chosen divergent technology paths for NOx reduction – urea SCR in Europe and predominately EGR in the US. Although it is possible that one technology will ultimately prove superior, the Japanese situation demonstrates that EGR and SCR can coexist within the same market and regulatory system.

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CHAPTER 9 – Ultra-low Sulfur Diesel Fuel

9.1 Introduction

There are clear air quality benefits to adopting ultra-low sulfur diesel fuel, typically designated as 50 ppm or lower, but the cost of upgrading refineries for greater desulphurization poses a significant barrier to the oil industry.³⁶ This chapter demonstrates how first-mover countries such as Sweden, Finland, and the UK have used fiscal incentives to encourage oil companies to produce clean, low-sulfur fuels early. Their transition to ultra-low sulfur diesel has been rapid, whereas in the US, in the absence of tax incentives, oil refineries are likely to wait until the mandated regulatory deadline. In addition to enabling cleaner vehicle technologies, early adoption often gives domestic companies a competitive edge in other markets. Even in regions without tax incentives or subsidies, some companies voluntarily have sold ultra-low sulfur diesel ahead of regulatory requirements, to protect or expand their market share. The limited sales and contracts with municipal fleets have helped them prepare for anticipated regulation. Countries and regions with earlier adoption also benefit from improved air quality and more competitive domestic companies. The early-mover countries and companies are in the position to actively lobby other governments to adopt similar policies, which further increases the value of their proactive decision.

The availability of ultra-low sulfur diesel gives automobile and engine manufacturers the assurance that their sensitive aftertreatment equipment will not be contaminated by sulfur. Because poor fuel quality is no longer an obstacle to new technology, the cleaner fuel spurs production of cleaner diesel vehicles and bus or truck retrofits. However, with more countries adopting more stringent clean fuel standards, demand for ultra-low sulfur diesel is already beginning to outstrip supply, leading to price jumps for low-sulfur crude feedstock and the shift of cheaper, high-sulfur crude to developing countries.

³⁶ In Europe and Japan, diesel fuel with 50 ppm sulfur is considered ultra-low sulfur diesel; in the US, the term is used for diesel fuel with 15 ppm sulfur.

9.1.1 Benefits and costs of fuel sulfur reduction

Lowering the level of sulfur in petroleum-based fuels offers direct and indirect benefits to air quality. Less sulfur means fewer fine particulates, which contribute to respiratory ailments and cancer, and fewer sulfur oxides, which contribute to acid rain. Lower sulfur fuel also improves the effectiveness of emission control equipment. For example, the catalysts used to convert pollutants into less harmful substances can be irreversibly contaminated by fuels with sulfur levels as low as 50 ppm. Compared to standard diesel fuel with an average sulfur level of 350 ppm), using 15 ppm sulfur diesel alone can reduce particulate emissions by 10% and sulfur dioxide emissions by 90%. Coupling it with a catalyzed diesel particulate filter can reduce particulate, hydrocarbon, and carbon monoxide emissions by 90% (BP 2005). Some nitrogen oxide (NO_x) reduction technologies under development, like NO_x adsorbers, have the potential to reduce NO_x by up to 90%, but NO_x conversion efficiency drops significantly as fuel sulfur levels go above 5 ppm (MECA 2000).

Engine and auto manufacturers have a clear incentive to promote lower-sulfur fuels. Lower sulfur levels give them more options in emission control strategies, instead of restricting them to sulfur-resistant technologies. While the oil industry acknowledges the benefits of lower sulfur fuels, the high costs for the refineries have been a deterrent to desulfurization. Oil companies are concerned about the large investment costs and the impact on retail prices. The American Petroleum Industry (API) and Europa, the trade associations representing oil companies in the US and EU, supported a more gradual introduction of the fuels, with longer deadlines and smaller reductions. They questioned the air quality benefits of sulfur levels below 50 ppm, asserting that the high costs did not justify the benefits and that more studies should be done (Automotive Environment Analyst 1998b; EUROPIA/CONCAWE 2000). At the heart of this debate was deciding which industry would bear the brunt of the pollution control costs – the oil industry wanted the auto industry to clean up its engines and the auto industry wanted the oil industry to clean up its fuels.

Mandating very stringent NO_x and PM standards without having requirements for very low sulfur diesel fuel can be counterproductive. It is very costly for vehicle and aftertreatment manufacturers to design emission control equipment to withstand high sulfur levels. This delays

the marketing of affordable clean diesel vehicles. For example, some companies like Toyota and Johnson Matthey, which had very effective emission-reducing technology, did not have a market for their products because the accompanying ultra-low sulfur diesel was not available. Therefore, it is very important to coordinate the timing of fuel availability and new NOx and PM standards.

In the EU, Japan, and the US, the timing of the fuel sulfur reductions has been very different. The EU has mandated more frequent but more gradual reductions, while the US has opted for more dramatic reductions over longer time intervals. The earlier availability of low sulfur diesel in Europe and Japan, driven by tax incentives from the government, has facilitated the sales of aftertreatment-equipped diesel vehicles capable of meeting emission standards. In the US, early adoption of ultra-low sulfur diesel and aftertreatment devices has been driven more by local pressures than federal action.

Table 9-1: Highway Diesel Fuel Sulfur Levels

Year	EU	Japan	US
1992	3000	5000	5000
1993		2000	500
1994	2000		
1995			
1996	500		
1997		500	
1998			
1999			
2000	350		
2001			
2002			
2003			
2004			
2005	50 (all)	50	
2006	/ 10		15
2007	(avail)	10	
2008			
2009	10 (all)		

Sources: EIA-DOE (2006a)

The cost of reducing sulfur levels in diesel fuels gets increasingly more expensive as refiners move towards lower sulfur levels. For example, a 2000 EUROPIA/CONWAVE study

estimated that the cost in the EU of going from 50 ppm to 10 ppm is almost three times as costly as going from 50 ppm to 30 ppm, on an NPV basis³⁷ (EUROPIA/CONCAWE 2000). Table 9-2 below illustrates the cost estimates for sulfur reduction in diesel fuel. The figures represent long-term cost estimates averaged over 10-15 year timeframes, meaning that the price premiums for ultra-low sulfur diesel immediately following adoption could be much higher.

Table 9-2: Estimated Costs of Sulfur Reduction in Diesel Fuels.

Product transition	Cost estimates ³⁸	Sources
Japan: 500 to 50 ppm	2 yen/liter long-term (~7 cents/gal in US dollars)	Petroleum Council (2000)
Japan: 500 to 50 ppm	20 yen/liter short-term (~ 70 cents/gal in US dollars)	Petroleum Association Japan (2001)
US: 500 to 15 ppm	5.4-6.8 cents/gal for refining plus 1.1 cents/gal for distribution	EIA-DOE (2001)
EU: 50 to 10 ppm*	0.29-0.61 cents/liter (~1-2 cents/gal in US dollars)	Directorate-General Environment (2001)
EU: 50 to 10 ppm	0.3-0.6 cents/liter in Northern Europe (~1-2 cents/gal in US dollars) 0.6-0.9 cents/liter in Southern Europe (~2-3 cents/gal in US dollars)	Birch and Ulivieri (2000)

*Note: Cost figures for EU transition from 350 ppm to 50 ppm were not found.

Table 9-3: Regulatory Timing for Fuel Sulfur Levels Below 500ppm

	Euro 3 (350ppm)	Euro 4 (50ppm)	Euro 5 (10ppm)	Japan (50ppm)	Japan (10ppm)	US (15ppm)
Proposed	1998	1998	1998	1999	2003	1998
Finalized	1998	2003	2003	2000	2003	1999
Effective	2000	2005	2005 (available) 2009 (all)	2005	2008	Mid-2006

Sources: EC (1998; 2003), EPA (1999), Japan Central Environment Council (2000; 2003).

³⁷ To go from 50 ppm to 30 ppm in diesel fuel sulphur content, the NPV of refinery capital and operating costs over 15 years is 2.4 GEuro, while to go from 50 ppm to 10 ppm, it is 6.7 GEuro (1 GEuro = 1 billion euros).

³⁸ Historic exchange rates from FXTOP.com. In November 2000, 1 Japanese yen = US\$0.0092; in November 2000, 1 Euro = US\$1.17; in September 2001, 1 Euro = US\$1.10.

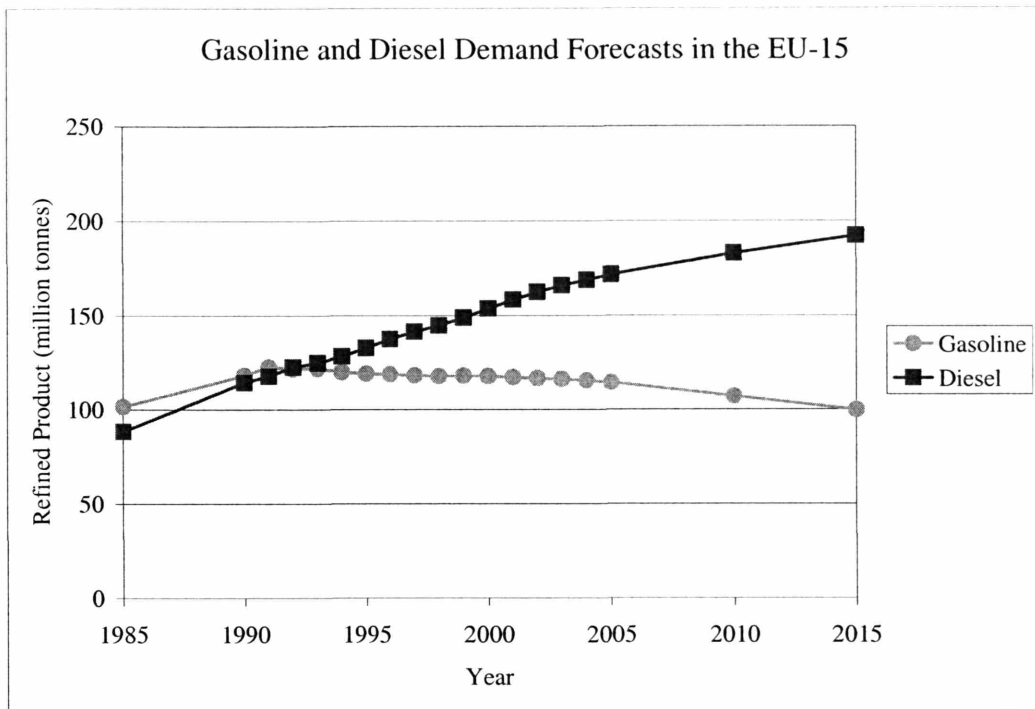
The next sections consider the regulatory processes and industry action leading up to lower diesel sulfur requirements in EU, US, and Japan, focusing on levels below 500 ppm. The regulatory processes began in the late 1990s, and the lower levels began implementation in the 2000s.

9.2 Europe

The European Commission sets specifications for fuel quality in the European Communities. While all EU countries must meet the same standards, individual countries are allowed to adopt tax incentives to encourage early adoption of future standards. They cannot mandate that companies provide a certain type of fuel unless specified by the EU. In 1993, the EU still had a diesel sulfur standard of 3000 ppm. Since then, it has been lowered to 2000 ppm in 1994, 500 ppm in 1996, and then 350 ppm in 2000. The growing popularity of diesel passenger cars since the early 1990s has led to an increasing demand for diesel fuel and greater appreciation for fuel properties that can enhance diesel vehicle performance. Industry experts have forecasted continuing demand growth for diesel fuel, and a decline in gasoline demand. The imbalance between diesel and gasoline demand has led some to question the preferential tax treatment that diesel fuel has received in the EU. In almost all EU countries, diesel is taxed substantially less than gasoline because of its use in the freight transport sector and its better fuel economy and lower CO₂ emissions. Figure 9-1 shows the two very different demand trends, which began to diverge at the same time that the popularity of diesel cars began to surge.

The imbalance between diesel and gasoline demand has led some to question the preferential tax treatment that diesel fuel has received in the EU. In almost all EU countries, diesel is taxed substantially less than gasoline because of its use in the freight transport sector and its better fuel economy and lower CO₂ emissions.

Figure 9-1: Diesel Demand Grows as Gasoline Demand Falls



Source: (Birch and Ulivieri 2000)

9.2.1 Sweden leads in lower sulfur fuels

Sweden was the first country in Europe to have very low sulfur levels for its diesel fuels. It was motivated by health and environmental concerns about diesel emissions in urban areas. As early as 1989, the Swedish government, interested in the effect of diesel fuel quality on emissions, asked its Swedish Environmental Protection Agency (Swedish EPA) to conduct a study and make a proposal regarding diesel fuel specifications. The research study found a quantifiable relationship between diesel fuel quality, the emissions' chemical composition, and their biological effects (Egebäck and Westerholm 1992). As a result, the Swedish government supported diesel fuel specifications that included 10 ppm maximum sulfur content, 5% maximum aromatics content, a minimum cetane index of 50. Lower sulfur content and lower aromatics reduces PM emissions, while a higher cetane index improves combustion.

In 1991, the Swedish government introduced financial incentives in the form of tax differentiation to encourage refiners to distribute the Environmental Class I diesel, or “city diesel,” with these specifications. It established 3 classes of diesel fuel – Class I, II, and III. At that time, the standard diesel fuel’s sulfur limit was 2000 ppm, which went down to 500 ppm in 1996. The maximum sulfur content of Class I, II, and III fuel was 10 ppm, 50 ppm, and 500 ppm, respectively. To keep the new tax policy revenue neutral, the government increased taxes on the lower quality fuels.

Table 9-4: Swedish Tax Differentiation

Units in ECU/liter and in 1990/91 US dollars/gallon in parentheses³⁹

Environmental Class	1990	1991
Class I		0.107 (0.501)
Class II		0.131 (0.631)
Class III (standard)	0.127 (0.611)	0.148 (0.693)

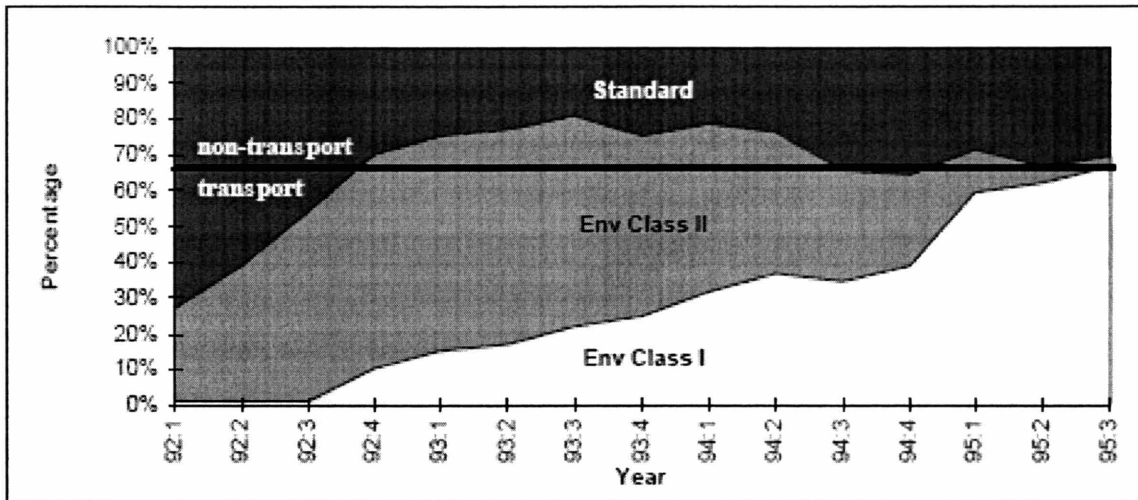
Source: Arthur D. Little (1998)

The Swedish government increased the tax differentiation in 1992 so that in 1992-93, Class III was 0.053 ECU/liter (US\$0.26/gallon) more than Class I, and in 1994, 0.060 ECU/liter (US\$0.27/gallon) more (Arthur D. Little 1998).⁴⁰ “City diesel” was originally designed to be used in urban areas, while the lower quality Class II and III fuels would be used outside cities and for home heating. However, by 1995, the market share of “city diesel” was already approaching 100% of road transport fuels. By 1996, “city diesel” had 85% of Sweden’s total diesel fuel market (EC 1995; Olivastri and Williamson 2000). Figure 9-2 shows that the Class I fuel penetrated the market in just 3 years.

³⁹ The ECU, or the European Currency Unit, was the predecessor to the euro. In 1999, the ECU was set equal to one euro. Historical exchange rates from FXTOP.com: In 1990, 1 ECU = US\$1.27; in 1991, 1 ECU = US\$1.24.

⁴⁰ Historical exchange rates from FXTOP.com: In 1992, 1 ECU = US\$1.30; in 1994, 1 ECU = US\$1.20.

Figure 9-2: Switching to Environmental Class I in the Swedish Diesel Fuel Market



Source: EC (1995)

The tax differential provided financial incentives to both consumers and refineries. By lowering the price of cleaner fuel formulations, it eliminated the cost advantage of the more polluting fuels and encouraged consumers to switch to the cleaner formulations. Because cleaner formulations cost more for refineries to produce, the tax differential ensured the refineries of consumer demand for the low sulfur product and helped to cover the added cost of refinery upgrades. Prior to the introduction of the tax differentiation, Swedish refineries did not exert any leadership to produce cleaner fuels (Arthur D. Little 1998). At this time, no other country had a comparable initiative, so industry had no precedent to follow and was uncertain about clean fuel demand. Not until the tax advantages were certain did the industry make the investments.

9.2.2 Finland follows Sweden's example

In July 1993, the Finnish government introduced a tax differential to promote diesel fuel with 50 ppm sulfur, 20% aromatics, and a 47 cetane index, which was equivalent to the Swedish Environmental Class II. This low-sulfur diesel was taxed 0.15 FIM/liter (\$0.10/gallon in 1993

US dollars)⁴¹ less than the regular diesel with 500 ppm sulfur (Olivastri and Williamson 2000). The tax differential was designed to be revenue-neutral, so higher sulfur fuel was taxed higher than before. Finnish refiners invested 365 million ECU (approximately US\$400 million) to produce low-sulfur diesel. In the first year of the Finnish low sulfur diesel initiative, 70% of diesel fuel was low sulfur diesel. By 1996, 85% of diesel fuel sold in Finland had a sulfur level below 50 ppm (Arthur D. Little 1998).

Unlike the Swedish refineries, which only responded to the demand for lower sulfur fuels after the government's tax differentiation, the Finnish refineries were more proactive. By 1993, they had already observed the Sweden's early success with cleaner fuels, and anticipated the Finnish government following Sweden's example. Finnish refiners began making clean fuel investments before the introduction of tax differentiation in Finland. They were confident enough in existing Swedish demand and expected Finnish demand for lower sulfur fuels. Deregulation of fuel markets also made Finnish refineries more receptive to producing and selling special, value-added products (Arthur D. Little 1998). According to an international fuels expert, the Swedish and Finnish governments' adoption of cleaner fuels was partially motivated by a desire to protect local refineries from the Russian oil industry. In the early to mid-1990s, Russia began to upgrade its aging and inefficient oil industry, seeking to expand its business from supplying crude oil to refining petroleum products, including high octane, lead-free gasoline and low sulfur diesel (FT Energy 1994).

9.2.3 Environmental benefits to Sweden and Finland

The environmental benefits of the adoption of city diesel were two-fold. First, it directly reduced emissions of SO₂, NO_x, polycyclic aromatic hydrocarbons (PAH), and PM. A study by consulting firm Arthur D. Little estimated the following emission changes when switching to cleaner fuel from the normal ungraded fuel in Sweden and Finland:

⁴¹ 0.15 FIM/liter is approximately equivalent to \$0.026/liter in 1993 US dollars. In July 1, 1993, 1 FIM = 0.176 USD (FTXOP 2001).

Table 9-5: Estimated Emission Changes from Switching to Cleaner Fuels in Finland and Sweden

Pollutant	Finnish Reformulated (50 ppm sulfur)	Sweden Class I (10ppm sulfur)	Sweden Class II (50ppm sulfur)
CO	-6 to 2%	-6 to 8%	9%
HC	-20% to 12%	2 to 18%	-10% to 24%
NOx	-12% to -5%	-11% to -5%	-9% to -4%
PM	-25% to -10%	-30% to -10%	-12% to -4%
PAH	-54%	-75%	-36%
SO ₂	-96%	-99%	-95%

Source: Arthur D. Little (1998)

Note: Negative values denote reductions while positive values denote increases.

Although there are estimates on emission reductions from switching to cleaner fuels, there were no specific quantitative data on the national air quality and health benefits of switching to low sulfur fuel in Sweden and Finland (Arthur D. Little 1998). The Arthur D. Little estimates only calculate the impact of the fuel change only, not accounting for any emission control equipment that could then be added because of the higher fuel quality.

The second major environmental benefit was that the widespread availability of Class I diesel fuel enabled new, cleaner diesel technologies and retrofits of existing vehicles. For the public to realize these benefits, the burden was on the vehicle and aftertreatment industry to market vehicles and devices with larger emission reduction capability, and for customers to purchase these new technologies. By 1996, over 1,000 trucks and buses in Scandinavia had been retrofitted with aftertreatment devices that required fuel sulfur levels below 50 ppm (Arthur D. Little 1998). The widespread availability of 10 ppm sulfur diesel in Sweden allowed the largest cities in Sweden to establish “Environmental Zones” starting in 1996. Older, high-polluting diesel trucks and buses would not be allowed into the city centers without having an approved retrofit device capable of reducing PM by 80% and HC by 60%. After the program’s first 3 years, 3,000 vehicles had been retrofitted with aftertreatment systems. In 2002, the requirements became more stringent: HC had to be reduced by 80% and NOx by 30% (Dieselnet 2002)

9.2.4 Business opportunity for Greenergy International

Business opportunities arose from the early introduction of cleaner fuels. The UK-based low-sulfur fuel supplier Greenergy International started in 1992, marketing Class I diesel to Sweden after the introduction of the tax differentials. In anticipation of tax incentives across Europe for 50 ppm and 10 ppm diesel, it spread its operations the UK in 1994, and to Germany, Switzerland, and Finland in 1996. It sourced its fuel from Scandinavian refineries, which were already producing ultra-low sulfur fuels for the Swedish and Finnish market. As of 2000, it was the largest supplier of 50 and 10 ppm sulfur fuels. In response to the European Commission's "Call for Evidence" on fuel sulfur levels, Greenergy supported switching the whole European market to sulfur free (below 10 ppm) fuels (Greenergy 2000). This clearly would offer financial benefits to Greenergy, because of its position as a leader in supplying very low sulfur fuels. The privately-held Greenergy has grown dramatically in the last 5 years. Within 4 years, it increased its total fuel sales volume sixfold: from a monthly fuel volume of 20 million liters (76 million gallons) in January 2001 to 180 million liters (680 million gallons) in July 2004 (Greenergy 2005). Greenergy prides itself on its influence on UK government fuels policy. It acknowledges actively lobbying for tax incentives in the UK, Germany, and Switzerland for ultra-low sulfur fuels (Greenergy 2005).

9.2.5 Sweden and Finland's influence on EU sulfur standards

Sweden and Finland encouraged the European Commission to use their extensive experience with low sulfur diesel as a basis for its decision-making on EU-wide diesel sulfur levels. The Swedish and Finnish governments even hired Arthur D. Little to create a case study for informational and instructive purposes (Arthur D. Little 1998). When critics claimed that getting down to 10 ppm sulfur content would be too difficult, the Commission pointed to these early-mover countries' success in promoting the rapid, widespread adoption of 10 ppm fuel through tax incentives. Moreover, the Arthur D. Little study claimed that the sulfur reductions could be done at costs lower than those estimated in the Auto-Oil Programme. In response to the Commission's 2000 Call for Evidence about the sulfur content of gasoline and diesel, the

Swedish Environment Ministry explained its tax differentiation system, the industry response, and the resulting environmental benefits (Swedish Ministry of the Environment 2000). The Swedish and Finnish experiences demonstrated that very low sulfur levels could be introduced successfully, giving the European Commission confidence to introduce low sulfur fuel throughout the EU.

9.2.6 Auto Oil I's influence on EU sulfur standards

When the European Commission, the European auto industry (as represented by ACEA) and the European oil industry (as represented by EUROPIA) collaborated on the Auto Oil Programme, they evaluated the effect of fuel quality on vehicle emission reduction. Both phases of the program, 1993-97 Auto Oil I and 1997-2000 Auto Oil II, made recommendations on maximum diesel sulfur levels to the European Commission. Those recommendations formed the basis of the EU diesel sulfur limits. In 1998, the European Commission passed Directive 98/70, which specified a diesel fuel sulfur limit of 350 ppm for 2000 and 50 ppm for 2005. Auto Oil II led to Directive 2003/17/EC which confirmed setting the sulfur limit of 50 ppm for January 2005. Diesel fuel with 10 ppm sulfur would have to be available on a limited, “appropriately balanced geographical basis,” and then on a systemwide basis by January 2009.

9.2.7 Expected supporters of lower sulfur

The automotive and truck industries have been longtime supporters of cleaner fuel because it helps vehicles achieve lower vehicle emission levels. Since 1998, an international coalition of engine and auto manufacturers has supported a Worldwide Fuel Charter calling for a maximum sulfur level of 5-10 ppm for both gasoline and diesel fuels, which are very low compared to the levels mandated for 2000 (ACEA, Alliance et al. 2002). While some emission control devices operate effectively at the 50 ppm sulfur level, two key technologies – catalyzed particulate filters and NOx adsorbers – require sulfur levels of 10-15 ppm or less.

The European oil industry recognized the value of getting down to 50 ppm for 2005, but was more hesitant about further reduction to 10 ppm. Two of its industry associations,

CONCAWE (Oil Companies' European Organization for Environmental and Health Protection) and EUROPIA (European Petroleum Industry Association), pointed out that the direct emission reductions were "insignificant" and that the sulfur-sensitive technologies were still under development. More R&D could reveal ways to reduce their sulfur sensitivity. They also expressed their concerns about the considerable refinery investment needed to go from 50 ppm to 10 ppm, and the increased CO₂ emissions from the more intensive desulfurization processes. The associations recommended further joint research on vehicle technologies and required sulfur levels, a suggestion would also delay new mandates (EUROPIA/CONCAWE 2000).

9.2.8 EU-wide fuel sulfur reduction

In 1998, following review of submissions by various governments and industry groups, the European Commission approved Directive 98/70 requiring maximum gasoline and diesel fuel sulfur levels of 50 ppm and limited availability of 10 ppm fuel by 2005. Individual member nations could offer fiscal incentives to encourage early production. At this point, Sweden and Finland had already achieved full adoption of ultra-low sulfur fuel because of their tax differentiation policy dating back to the early 1990s. Several other countries, such as the UK, Germany, and Denmark, followed suit in using differential tax rates to accelerate adoption.

9.2.9 Early movers in the UK, motivated by tax incentives

Seeking to accelerate the adoption of lower sulfur fuels, several EU countries created tax incentives for ultra-low sulfur fuels (below 50 ppm) sold before 2005. The UK government offered a 1-pence per liter tax reduction on ultra-low sulfur fuels in 1997, followed by a 2-pence reduction in 1998, and then a 3-pence reduction in 1999.⁴² The 3-pence differential in 1999 led to an estimated reduction of 21% of PM and 2% of NO_x (Olivastrri and Williamson 2000). The first 1-pence tax differential prompted two large UK supermarket chains, Sainsbury's and Tesco, which also sell motor fuel, to purchase the 10 ppm sulfur "city diesel" from fuel supplier

⁴² One pence is approximately equivalent to 1.6 cents in 1997 US currency (FXTOP 2001).

Greenergy and sell it at no additional cost to the consumer. Greenergy had already supplied fuel of the same specification in Sweden, and was eager to expand its market to the UK.

Sainsbury's had been selling Greenergy's city diesel since 1995, but at a 2-pence per liter price premium over standard diesel. Once the 2-pence per liter differential went into effect in 1998, Sainsbury's could sell the standard and 10 ppm diesel products at parity. As a result, Sainsbury's city diesel sales jumped from 30% to over 50% of the total diesel sales in March 1998. Because of the city diesel's popularity, it was anticipated that the supermarket chain would no longer have to offer standard diesel in the future. Sainsbury's share of total diesel sales is significant. In 1998, it sold 300,000 metric tons per year of diesel, 16% of total UK diesel sales (FT Energy 1998; Sainsbury's 1998).

Environmental NGOs in the UK criticized the major oil companies, especially British-based BP and Shell (number 2 and 3 in the global market), for not following the supermarkets' example. BP and Shell responded that the 1-pence duty differential was inadequate to cover the estimated additional 3 pence per liter cost of producing ultra-low sulfur fuel for widespread use. They limited their sales of the fuel to heavy-duty commercial fleets (Buie 1998). Although they had the capability at their Haven and Grangemouth refineries to produce the fuel, they were also tied up in exchange agreements with partners that could not match the very low 10 ppm sulfur specification (FT Energy 1998).

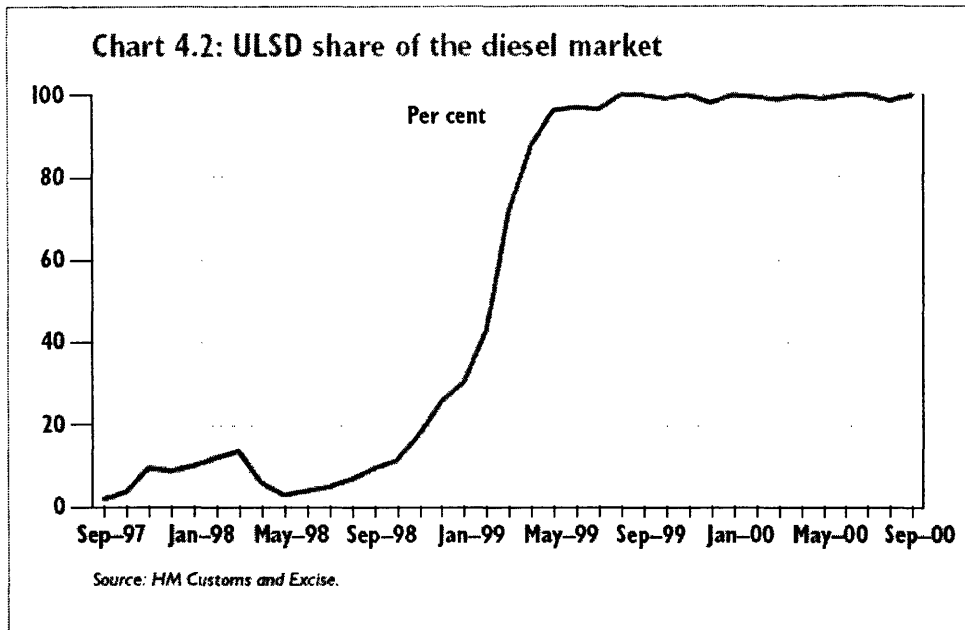
Independent fuel supplier Greenergy continued to sell to supermarkets and fleets, and growing its business in the UK, where it is headquartered. It benefited financially by selling a specialty product to environmentally-minded businesses and customers. By 2005, Greenergy had achieved a 5% market share of the UK fuels market (Greenergy 2005). However, it did not take long for increasingly large tax differentials in the UK to attract competition from the oil majors. Soon after the UK duty differential rose to 3 pence per liter in 1999, the large energy producers reconsidered their previous reluctance to sell 10 ppm sulfur diesel (Automotive Environment Analyst 1998a).

9.2.10 Tax incentives motivate BP

BP was one of the major oil companies that waited for more substantial tax incentives before selling 50 ppm sulfur diesel. In 1999, BP began marketing gasoline and diesel fuels with sulfur levels below 50 ppm. Its Clean Cities Programme promised to voluntarily provide cleaner fuel to 40 cities by 2000. In its home market in the UK, BP quickly introduced its new “BP Greener Diesel” to replace standard diesel at all its retail stations, making it the first major oil company to sell ultra-low sulfur diesel nationwide at no additional cost to the consumer. At that time, many oil companies were offering 50 ppm sulfur diesel to urban fleet operators, but very few retail stations carried the fuel (HM Customs and Excise 2000). By the end of 2000, BP had cleaner fuels available in 59 cities and in 110 cities by the end of 2001 (BP 2005). In countries like the UK, Denmark, and Germany, lower tax rates on ultra-low sulfur fuels offset the higher production cost and encouraged 100% penetration of the new fuels, well ahead of the 2005 deadline. In 1999, BP introduced the clean fuels in 40 stations in Paris, and then to all 240 stations, but France did not offer tax incentives (Olivastrri and Williamson 2000). The company proceeded to actively lobby the French government, albeit unsuccessfully, for clean fuel incentives (Europe Environment 2002). The lack of incentives has inhibited the widespread introduction of ultra-low sulfur fuels in France before the EU-wide deadline.

EUROPIA, the European oil industry association, had been resistant to the European Commission’s interest in lowering sulfur levels below 50 ppm. It also did not support accelerating sulfur reduction through financial incentives. EUROPIA argued that when one company switched to ultra-low sulfur fuel, others would be pressured to follow, disrupting industrial structure and disadvantaging smaller producers (FT Energy 2001). Because of the tax differentials, this scenario did actually occur, and other large oil companies like Shell and Esso joined BP in offering 50 ppm sulfur diesel. In the UK, the market penetration of 50 ppm diesel rapidly climbed to almost 100% by August 1999, just months after the 3-pence differential was announced in March 1999 (HM Customs and Excise 2000).

Figure 9-3: ULSD Adoption in the UK



Source: HM Customs and Excise (2000)

The new fuel requirements have led to industry restructuring. Already in a market suffering from overcapacity problems, some European refineries have found it more feasible to close rather than upgrade (Knott 1998). In 1998, the European Commission received a report entitled, "Oil Refining in the European Community," which estimated a surplus capacity of 1.4 to 2.0 million barrels per day, meaning that 9 to 13 refineries would have to closed (Petroleum Economist 1998). As the world's second largest publicly traded oil company after ExxonMobil, BP benefited from scale economies in producing ultra-low sulfur fuels, and used its political clout to push for tax incentives in more countries. BP was better equipped to afford refinery upgrades than small, independent refiners. In the mid-1990s, BP made upgrade investments at its refinery at Grangemouth, Scotland, in anticipation of more stringent fuel requirements (McCrone 1999). While its competitors eventually reduced sulfur levels in their fuels, BP took advantage of learning from early investment and positive publicity from regulators, the media, and environmental groups. BP has also been able to leverage its global presence and introduce ultra-low sulfur fuels in other markets, such as Australia and the US. While Greenergy was the first to supply ultra-low sulfur fuels to the UK market, their small size and limited geographical

reach did not attract the same type of attention that BP received for being the first mover of the large energy producers. However, any financial advantage that BP had over other oil companies was short-lived, because soon every major oil company in Europe was marketing ULSD. Its longer-term benefits extended to other markets, such as Australia and the US, where ULSD had not yet been widespread.

It is clear that without the tax incentives, companies like Sainsbury's, Greenergy, and BP would not have offered the ultra-low sulfur diesel fuel at the same price as standard diesel. Because desulfurization requires costly refinery investment, it would not have made economic sense to produce the fuel without tax incentives. Consumers willing to pay extra for cleaner fuel are a small majority. In order for clean fuels to become widespread, they had to be cost-competitive with standard fuel. Additional proof that the early introduction of clean fuels was motivated primarily by tax incentives is the delayed adoption of low-sulfur gasoline in the UK. Gasoline did not benefit from the same tax advantages as diesel until later, and therefore, did not experience the same rapid adoption until later. For example, in the UK, it was not until 2000 that the UK government introduced a 1-pence tax differential on ultra-low sulfur gasoline (< 50 ppm sulfur). A year later, the UK increased the differential to 3 pence, expecting that cleaner gasoline would be adopted as quickly as diesel (HM Customs and Excise 2000). The switch was very successful: by July 2001, 98% of all UK retail sites had replaced their standard unleaded gasoline with ultra-low sulfur gasoline (Williamson 2001).

9.2.11 Environmental benefits in the UK

The UK government estimated the direct emission benefits of switching to 50 ppm sulfur diesel before the 2005 EU deadline. Including the use of aftertreatment technology, the fuel switch led to 5.3-5.5% less PM10 emissions and 0.4% less NOx emissions annually from road transport in 2001-04 (HM Customs and Excise 2000). Aftertreatment systems enabled by ultra-low sulfur fuel will lead to further reductions.

The early adoption of ultra-low sulfur fuels in Sweden, Finland, and the UK relied on preferential tax differentials on clean fuels, which created customer demand and motivation for refinery investment. While some companies showed initiative in getting the fuels to the market

first, they would have not done so without government action. However, when Sweden successfully used tax differentiation, it created a precedent for other countries to do the same. In these cases, it was countries, not companies, which were first movers. Once companies learned from their experiences in the first-mover countries, they moved to lobbying other countries for similar policies.

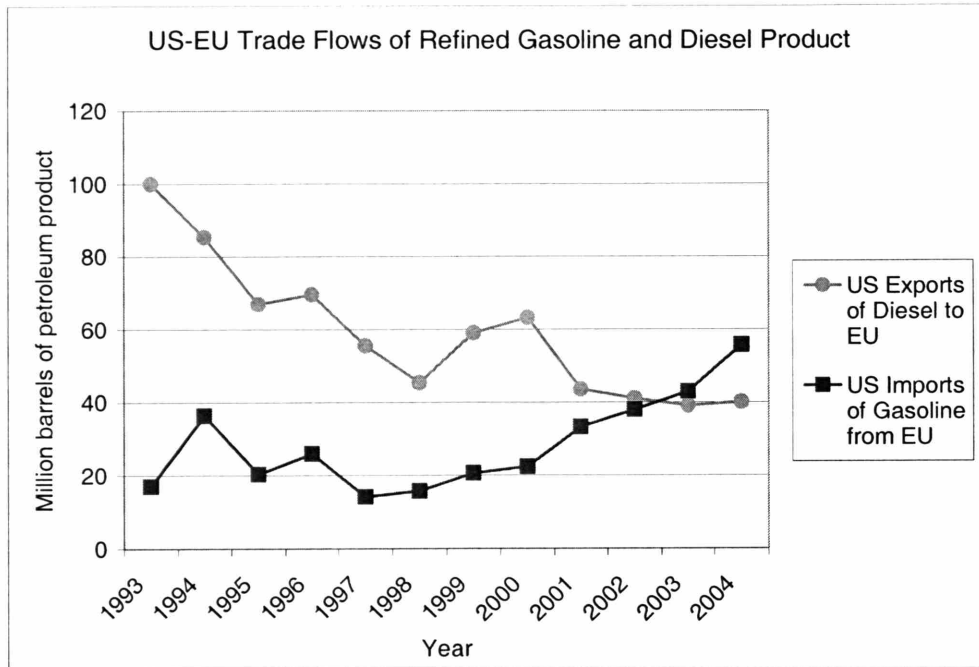
9.2.12 System-wide problems

As more countries adopt cleaner fuels, the popularity of low sulfur diesel has led to an uneven geographic distribution of benefits and costs. The use of tax incentives by some countries to encourage the introduction of 10 or 50 ppm sulfur diesel ahead of the EU deadlines poses serious problems for the fuel supply. Strong demand for light, sweet crude product, which contains lower levels of contaminants like hydrogen and sulfur, has raised ultra-low sulfur fuel costs. The North Sea and Nigeria are sources of this sweet crude, while most of the Middle East, Venezuela, and Russia produce heavy, sour crude. European refineries with capability to refine low quality, sour crude benefit from major discounts for fuel exporters in the Middle East, central Europe, and Russia. However, many are equipped only to handle lower sulfur crude product. Refineries with the technology to refine sour crude stand to do well in the marketplace (Petroleum Economist 2005).

The growth of diesel vehicles and the resulting fuel demand in Europe has also led to an imbalance in diesel and gasoline demand. Even though the EU suffered from overcapacity in the 1990s, amounting to 510 to 730 million barrels per day, overinvestment in catalytic cracking resulted in excess gasoline production and insufficient diesel fuel. One approach has been to reduce the price gap between diesel and gasoline by increasing taxes on diesel, which has historically lower tax rates in most EU countries. Another option has been the export of excess gasoline to the US and the import of diesel fuel from the US. While the US and EU export petroleum products to other countries, they still import refined gasoline and diesel product because of the demand for specific product specifications. There is a distinct difference in the gasoline-diesel trade flow: in 2002, the US imported 182 million barrels of gasoline vs. 97.6 million barrels of diesel. In the same year, Western Europe imported 257 million barrels of

gasoline vs. 650 million barrels of diesel (EIA-DOE 2003). Presently, about one-third of the US imported motor gasoline comes from Europe (EIA-DOE 2006b).

Figure 9-4: US-EU Petroleum Product Trade Flows



Source: EIA-DOE (2006b)

Countries without requirements for low-sulfur fuel could find themselves dumping grounds for the cheaper, high-sulfur fuel. Many of these countries are developing nations with a rapidly growing passenger vehicle fleet. For example, China's growing petroleum demand has increased its reliance on imported crude, which tends to have higher sulfur content than its domestic crude. With the more industrialized countries demanding lower sulfur feedstock, the prices of sour crude have dropped significantly, attracting Chinese refineries (Chinese Academy of Engineering 2003). Countries with less stringent sulfur standards may find their own fuel quality worse off than before the European countries adopted cleaner fuels.

Not all regions in Europe have access to low-sulfur crude. Refineries in southern Europe are at a cost disadvantage because they have predominately sour crude feedstock. Their feedstock for 2005 was estimated to be 59% sour and 35% sweet, while northern Europe's is

28% sour and 58% sweet (Birch and Olivieri 2000). Sweet crude is preferred because sour crude has higher sulfur and hydrogen content, and therefore is more difficult and costly to refine. Even while it is important to value the rapid adoption of ultra-low sulfur diesel in some of the European countries, the trade and cost imbalances caused by dramatic sulfur reductions are real. As more countries converge toward requiring very low fuel sulfur levels, there will be a greater need to encourage refinery investment in desulfurization technology capable of handling sour crude.

9.3 United States

Unlike Europe, where diesel-powered cars account for half of new car sales, the US passenger car fleet is predominantly gasoline-powered. Highway diesel fuel is used primarily to power buses and trucks. In the 1990s, research studies on the detrimental health impacts of diesel exhaust galvanized US environmental officials to take stronger action on diesel emissions. California, arguably the most environmentally progressive state in the US, designated diesel particulate matter as a toxic air contaminant in 1998. This designation initiated a formal state plan to reduce diesel emissions, and threatened to decrease the demand for diesel fuel. States unable to meet their ambient air quality standards for ozone, particulate matter, and other pollutants are expected to adopt more stringent measures to reach attainment levels, or risk losing federal highway funding. California contains many severe or serious nonattainment areas for ozone and particulates.

NGO-led campaigns drawing attention to diesel exhaust's detrimental health effects targeted transit agencies, which operated large diesel-powered bus fleets. For example, the Natural Resources Defense Council (NRDC) launched the "Dump Dirty Diesels" campaign in New York City in 1995, to raise public awareness and put pressure on transit officials to switch to alternative fuels, like natural gas, ethanol, or electricity, or use ultra-low sulfur diesel with retrofitted buses (NRDC 2002). In response to these pressures, state regulators passed more stringent vehicle emission standards for public fleets and offered fiscal incentives for municipal and school bus fleets to purchase compressed natural gas (CNG) vehicles as an alternative to diesel-powered vehicles (EESI 2005). Some municipalities funded the installation of emission

control equipment and the purchase of ultra-low sulfur fuel for diesel bus retrofits. It was largely state and local initiatives that led to limited industry action to adopt ultra-low sulfur fuels ahead of federal regulation.

9.3.1 Regulatory process

Since 1994, the US has had a maximum diesel fuel sulfur limit of 500 ppm. The average sulfur level is 340 ppm, and because of more restrictions in California, CARB diesel has 120 ppm sulfur. With diesel emission standards becoming more stringent, vehicle and engine manufacturers had been pushing EPA for years to lower sulfur limits as well. In the late 1990s, Europe and Japan had announced plans to lower their diesel sulfur levels from 500 ppm to 50 ppm by 2005. Around this time, government and industry agreed on the need to address emission reduction by considering engines/vehicles, aftertreatment, and fuel quality as a single system. Regulations should reflect their interdependency.

In 1999, EPA initiated the regulatory procedure for proposing new heavy-duty diesel engine emission standards and diesel fuel sulfur levels. EPA gave advance notice of its rulemaking process in May 1999, followed by a proposal in June 2000. In addition to analysis performed by EPA staff, comments from industry and other interested parties were considered in setting the standards. Deciding the sulfur level in diesel fuel turned out to be the most contentious part of the rulemaking. The automobile, engine, and emission control manufacturers pushed for very low sulfur levels, while the petroleum industry argued for a more moderate reduction.

9.3.2 Industry supporters

It comes as no surprise that US automobile, engine, and emission control manufacturers would want sulfur levels as low as possible. Low sulfur levels improve the performance of emission control devices, making it easier for vehicle and engine manufacturers to meet the more stringent emission standards. Even sulfur levels as low as 30 ppm had been shown to lower the effectiveness of particulate removal in filters (EPA 1999c). The Alliance of Automobile

Manufacturers (AAM), the Engine Manufacturers Association (EMA), and the Manufacturers of Emission Control Association (MECA) were major advocates of a 15 ppm sulfur standard.

Emission control manufacturers made a strong case for reducing diesel fuel sulfur levels well below 50 ppm. In its communications with EPA, CDPF manufacturer Johnson Matthey attributed the success of CDPFs in European test fleets to very low fuel sulfur levels. Comparisons between the Swedish and Finnish fleets revealed that 50 ppm fuel sulfur levels were sufficiently high in sulfur to block oxidation of NO to NO₂ and inhibit proper filter regeneration in cold weather. The higher sulfur levels compromised the reliability of the DPFs. The Swedish fleets ran successfully on 10 ppm fuel, while the Finnish fleets suffered a 10% failure rate when running on 50 ppm fuel (EPA 2000b).

9.3.3 Industry opponents

The petroleum industry, as represented by the American Petroleum Institute (API) and the National Petrochemical and Refiners Association (NPRRA), contended that a 15 ppm sulfur standard was unnecessarily low. They questioned the alleged air quality benefits and scientific rationale behind the standard. API claimed that nearly the same emission benefits could be obtained at a much lower cost with a maximum 50 ppm cap/30 ppm average sulfur standard (EPA 2000a). EPA disagreed with the petroleum industry's claims, and put substantial consideration into fuel quality as an enabler of emission control technologies (EPA 2000a).

Through their responses to the rulemaking, API, NPRRA, and individual oil companies Marathon Ashland and ExxonMobil demonstrated their strong opposition to the EPA's proposed 15 ppm sulfur standard. However, not all oil companies were adamantly opposed to the standard. BP had expressed its ability to meet the 15 ppm sulfur limit in the timeframe proposed by the EPA. In its comments to EPA, it was more concerned with the details of meeting the regulation (i.e. timing of supply introduction, opposition to an averaging system or phase-in approach) than the standard itself (EPA 2000a). According to senior EPA officials, BP was at odds with the other oil companies and its own trade associations by not opposing the 15 ppm limit. BP had already positioned itself as a supplier of cleaner fuels and saw market share growth potential in stepping forward. BP's introduction of 10 ppm sulfur diesel in Europe, especially in the UK and

Germany, had given it experience to roll out ultra-low sulfur diesel in the US. Moreover, it had recently acquired the California-based energy company ARCO, which had already been working closely with the California Air Resources Board since 1999 to introduce ultra-low sulfur diesel to California.

9.3.4 Early action from ARCO/BP

In the late 1990s, federal regulators were focusing on new gasoline standards, and did not plan to address new diesel sulfur levels until 1999 or 2000. Even though the final diesel sulfur standard was not yet known at the time, many large metropolitan areas began requiring filter retrofits and ULSD for their diesel-powered public buses. For example, the California Air Resources Board mandated that by July 2002, all of its urban diesel-powered bus fleets had to run on ULSD (CARB, 2000).

ARCO, later acquired by BP in 1999, responded to the growing public and regulatory attention to diesel emission control. Concerned about diesel fuel losing market share to CNG, ARCO sought to demonstrate emission reductions enabled by cleaner diesel fuel. In 1999, it began providing ultra-low sulfur diesel (ULSD) to municipal fleets in selected California cities for an additional 5 cents per gallon. In large metropolitan areas with serious air quality problems, government air quality and transit agencies provided subsidies to cover the costs of retrofits and ULSD. Early that year, ARCO had initiated the EC-Diesel program, a fleet technology validation program, in California to evaluate the use of catalyzed diesel particulate filters with ULSD. It compared the performance of retrofitted vehicles with ULSD and CARB diesel (120 ppm sulfur). Based on testing of eight vehicle fleets, the combination of CDPFs and ULSD produced over 90% less PM, CO, and HC than CARB-fueled vehicles without filters (LeTavec and al. 2002). ARCO conducted the demonstration projects as a response to the strong anti-diesel sentiment growing in California. It wanted to demonstrate that clean diesel was competitive with CNG vehicles in terms of cost and emission reduction. From an economic standpoint, it was important that diesel stay viable as a product because a decreased demand for diesel in favor of natural gas could disrupt the balance in supply of other petroleum products.⁴³

⁴³ Interview with a senior expert in the diesel vehicle and fuel industry, February 2003

Unlike the UK or other European countries, the US did not have federal tax incentives to make the cost of ULSD comparable to that of regular diesel fuel. However, some municipalities had set aside funds to subsidize ULSD and vehicle retrofits. EPA has also offered grants to some fleets through its Voluntary Diesel Retrofit Program. These different incentive schemes changed BP's sales and distribution strategy in the US. Rather than introducing ULSD throughout its retail stations, BP chose a more targeted sales approach and sold limited quantities directly to urban municipal or school district fleets. BP entered in direct contracts with the fleets, mainly providing ULSD to retrofitted school and urban buses.

Table 9-6 lists some of BP's ULSD contracts. For many cities, the combination of ULSD and new or retrofitted clean diesel buses proved to be more cost-effective than CNG buses. For instance, the Cleveland Regional Transit Authority chose diesel over CNG after estimating that a diesel bus running on ULSD would cost \$419,000 to operate over its average 12-year lifespan, compared to \$550,000 for a CNG bus (Bennett 2002). As a result of the publicity generated from successful local projects across the US, BP entered into numerous ULSD contracts with local fleet operators.

Table 9-6: BP's Major ULSD Offerings in the US

Client	Contract	Scope
Ann Arbor Transit Authority	2002: 1 million gallons ULSD annually for 12 cents/gallon premium	90-bus fleet Plans to install EGR/DPF retrofit kits in all buses within 3 years
California	1999: ULSD sold to municipal fleets for 5 ¢/gal over CARB diesel; 2002: ULSD sold at ARCO stations statewide for 5 ¢/gal premium	Full potential: 750,000 diesel vehicles in CA
Chicago Transit Authority	2003: 21.2 million gallons of ULSD annually	226 cleaner filter-equipped diesel buses 484 filter retrofits
Cleveland Regional Transit Authority	2002: ULSD for 225 new buses	225 new filter-equipped diesel buses will use ULSD; potential to replace 521 diesel buses
Houston	2001: Fleet testing programs	
Minneapolis Metro Transit	2004: \$4-5 million annually for ULSD	400 out of fleet's 867 buses will receive fuel

Sources: Blake (2004), BP (2002; 2003)

9.3.5 BP's input into CARB and EPA rulemaking

BP's early introduction of ULSD and its collaborative efforts with regulators, engine and bus manufacturers, and emission control manufacturers did not escape the attention of state and federal environmental officials. The California Air Resources Board used the initial results of diesel retrofit demonstration projects involving ARCO's ULSD to shape its 2000 public transit bus fleet rule. The dramatic 91-99% PM emission reduction possible with ULSD prompted regulators to treat retrofitted or new clean diesel buses running on ULSD as an equivalent option alongside CNG vehicles (CARB 1999). Interim reports of diesel retrofit projects involving BP's ULSD fuel were reviewed by the EPA staff as they finalized diesel fuel sulfur standards for 2006.

In response to the oil industry's complaints prior to the rule's finalization, EPA cited BP/ARCO's early introduction of 15 ppm ULSD in California as evidence of technological and cost feasibility. The final rule requires at least 80% of the diesel fuel supply to have a maximum 15 ppm sulfur content. The timing of the compliance deadline was another subject of debate. EPA initially proposed a June 1, 2006 full retail compliance date. Desiring more time because of the transition from winter to summer gasoline, API recommended a January 1, 2007 deadline, while BP recommended a September 1, 2006 retail deadline. Ultimately, EPA finalized the rule with a September 1, 2006 retail deadline (EPA 2000a). Since then, EPA has extended the deadline by 45 days to October 15, 2006 to allow for a smoother refinery-to-retail transition (EPA 2005).

9.3.6 Other early movers and ULSD supporters

Although BP may have been the largest and most vocal of the oil companies supporting ULSD at 15 ppm, there were a few other oil companies that did not join API and NPRA in opposing EPA's sulfur standard. Tosco, the largest independent refiner in the US, produced ULSD (sulfur levels < 30 ppm) for municipal fleets. In 2000, it began its contract with New York City to supply 126,000 gallons of fuel per day to the city's 4400 transit buses (Tosco 2001). In its response to EPA's sulfur rulemaking, it openly supported a nationwide 15 ppm sulfur standard by 2006. Tosco often shared the same positions on the regulatory details as

environmental groups and regulatory officials. BP and Tosco's support for the regulation is perhaps best reflected in the EPA's response: "Statements by refining companies, such as BP Amoco and Tosco, that they will desulfurize their highway diesel fuel earlier than necessary is further evidence that this rule is affordable" (EPA 2000a). Because BP and Tosco were ready to make the investments to supply ULSD even before 2006, they both opposed EPA's granting of extensions or hardship waivers to companies (EPA 2000a).

9.3.7 Limited early adoption

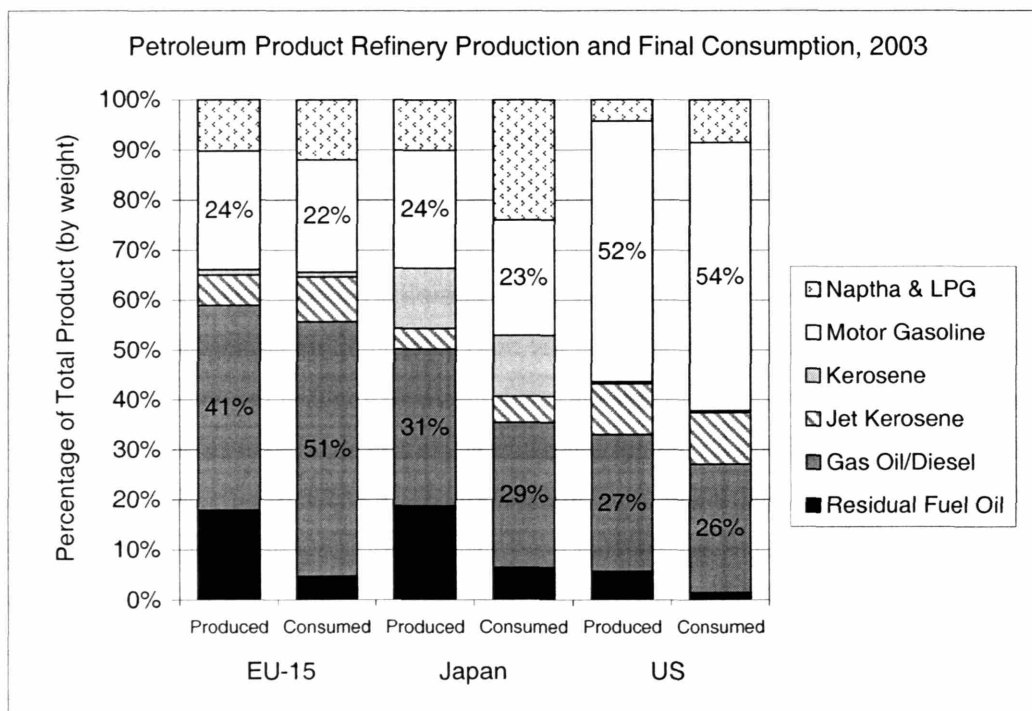
Other than demonstration projects and fleet contracts, availability of ultra-low diesel fuel has been limited in the US. Without tax incentives, major oil companies have little motivation to introduce a cleaner but more costly product to the market before the regulatory deadline. EPA does allow for companies to obtain tradable credits beginning in 2005 if they produce 15 ppm diesel fuel before the 2006 deadline. However, it does not provide enough incentive to act early, and it creates an allowance for oil companies to continue producing 500 ppm fuel past 2006. It is unlikely that ULSD will be marketed on a widespread basis until fall 2006. EPA's temporary compliance option allows 20% of refiners to sell the high-sulfur product until 2010, as long as they purchase credits from those who produce 15 ppm fuel. Small refiners, which make up 5% of the US highway diesel fuel, face significantly higher compliance costs, so the EPA rule permits them to delay selling ULSD until 2010 without purchasing credits (EPA 2000b). In the absence of these flexibility options, companies with higher compliance costs would leave the market. Although it is likely more efficient to leave the market to the more technologically advanced and larger refineries, this could disrupt the available fuel supply in the short term and hurt small businesses (EIA-DOE 2001). The government clearly has an interest in balancing the economic health of the refining industry with environmental benefits.

Demand estimates conducted by the Department of Energy indicate that the ULSD supply may not be enough to meet diesel demand (EIA-DOE 2001). The ULSD shortage could lead to sharp short-term price increases. This could spur refiners to maximize ULSD production by shifting other distillate streams to ULSD.

The availability of ULSD in 2006 in the US could open the light-duty vehicle market for diesel cars and trucks capable of meeting the Tier 2 standards, to be phased in between 2004 and 2007. The steep rise in gasoline prices in the past few years has provoked serious discussion about increased light-duty diesel penetration. Regular grade gasoline prices rose from an average of \$1.13 per gallon in the 1990s to an average of \$2.27 per gallon in 2005 (EIA-DOE 2006b). High prices have led automakers, politicians, and regulators alike to think more seriously about the potential for diesels in the US.

A growth in diesel market share would have a major impact on the refining industry. Existing US refineries have been designed to maximize gasoline output, so increasing diesel output would require costly refinery upgrades, which could raise diesel prices. Figure 9-5 shows that the US refineries are optimized to produce more gasoline rather than middle distillates (gas oil and diesel fuel). Meanwhile, the Japanese and European refineries produce only 24% gasoline, and significantly more gas oil/diesel fuel.

Figure 9-5: Refinery Product and Final Consumption Mix in 2003



Source: IEA Energy Statistics (2003)

This is not the first time that modifying the diesel-gasoline fleet mix has brought concerns for the refining industry. In the late 1970s, in the midst of the oil crises, speculation about dramatic diesel growth in the US cast similar doubts about feedstock availability and prices (Chemical Week 1977). Any significant increase in diesel demand in the US could also have adverse effects on Europe, which imports excess diesel fuel from the US and exports its excess gasoline to the US. Europe would have to find other sources of refined, low-sulfur diesel product. Increased diesel demand in the US would put a strain on ULSD, which may already be in tight supply following the US implementation of the 2006 sulfur standard (Tippee 2005). On the upside, refineries capable of refining sour crude would do well because they can take advantage of the growing price differential between sweet and sour crude.

For example, Valero Energy, the largest North American independent oil refiner, aggressively acquired refineries divested after major oil mergers in the 1990s as well as other refineries from smaller companies. It then upgraded those refineries to turn sour crude into very clean, low-sulfur products. The company recognized the trend towards cleaner fuels, heavier feedstock, and more expensive sweet crude. According to Philip Verleger, an independent petroleum economist and former Valero director, “Valero saw early on that the oil was going to become heavier and tighter regulations meant that products were going to have to be cleaner” (Morrison 2005). This has turned into a very lucrative strategy for Valero Energy, which has quadrupled its earnings between 2000 and 2004.

US refineries are actually far better equipped than most Asian and European refineries to refine sour crudes. Even before the very low sulfur standards for gasoline and diesel were proposed, US refineries had invested in greater desulfurization capacity – over 80% of the total domestic refining capacity – to cope with the higher sulfur content in imported crude oil from Mexico, Venezuela, and the Middle East (Petroleum Intelligence Weekly 2005). As the world harmonizes towards lower sulfur fuels and less sweet crude becomes available, US refineries are better prepared to adapt to these trends. Refineries that can produce diesel with even lower sulfur levels, like 5 ppm, will be in a strong competitive position, as automobile manufacturers contend that the most advanced aftertreatment technologies require fuel sulfur levels near zero.

9.4 Japan

In November 2000, the Japan Central Environment Council issued its Fourth Recommendation for “Future Policy for Motor Vehicle Exhaust Emission Reduction.” Along with its proposed vehicle emission limits, it also stipulated fuel quality measures, one of them lowering the fuel sulfur limits from 500 ppm to 50 ppm. The Council recognized the importance of low sulfur diesel for new vehicles to attain the long-term diesel target for 2005. At that time, the Council considered 50 ppm to be the technical limit, but anticipated further reductions in the future. It set the end of 2004 as the deadline for getting both diesel and gasoline sulfur levels down to 50 ppm (Japan Central Environment Council 2000). Unlike the European and US standard-setting process, there was no observable industry opposition to this proposal, because it was the product of earlier negotiations between the government and auto industry.

9.4.1 Oil industry cooperation

In March 2000, the Japan Automobile Manufacturers Association (JAMA) and the Petroleum Association of Japan (PAJ) announced plans to voluntarily introduce vehicles compliant with the long-term emission targets and 50 ppm sulfur diesel fuel two years ahead of schedule. Originally, the Japanese government had expected the long-term targets to be met in 2007 and the 50 ppm fuel to be ready in 2005. After significant pressure and negotiations with the Tokyo Metropolitan Government, the auto and oil industries jointly agreed to accelerate the introduction of cleaner vehicles and fuels. The Tokyo Metropolitan Government (TMG) took credit for the accelerated adoption.

TMG began anti-diesel measures in 1999, after heavily criticizing the central government for not doing enough to regulate diesel vehicle exhaust (Asahi News 2000). TMG persuaded the PAJ to market low-sulfur fuel early by lobbying the association and then the oil companies individually (TMG 2003). According to the oil industry, 50 ppm sulfur diesel fuel would cost 20 yen per liter (US\$0.70/gallon) more to produce than the 500 ppm product (Jiji Press 2001). TMG responded by providing oil manufacturers with subsidies of up to 10 yen per liter

(US\$0.35/gallon) for 50 ppm sulfur diesel fuel as part of a two-year subsidy during FY2001-2003 (TMG 2003). Previous estimates from a Petroleum Council study had estimated a small 2-yen per liter (US\$0.07/gallon) price premium, but this spread the total 200 billion yen (US\$1.86 billion) production investment over years of fuel production (Petroleum Council 2000).⁴⁴ The higher estimates were more indicative of short-term costs. TMG's subsidy was a major driver in motivating oil companies to invest in desulfurization equipment. By April 2003, the oil companies were expected to supply 50 ppm diesel to the Tokyo area. Because of the pressure to move early from the Tokyo government, oil companies agreed to accelerate their introduction of 50 ppm diesel to the rest of Japan.

Under the national agreement, automakers would begin rolling out 2005-compliant diesel vehicles in 2003 and 2004. Oil companies would have a partial supply of 50 ppm diesel fuel ready in 2003, followed by a full transition by the end of 2004 (Japan Central Environment Council 2000). By April 2003, Japanese oil companies introduced 50 ppm sulfur diesel fuel virtually nationwide, almost 2 years ahead of the government deadline (PAJ 2005).

Seeing the EU's desulfurization trends, Japan anticipated reducing sulfur levels down to 10 ppm as well. In its 2002 Fifth Report on "Future Policy for Motor Vehicle Exhaust Emission Reduction," it remarked on Sweden and Germany's successful adoption of 10 ppm sulfur fuel because of favorable tax incentives (Japan Central Environment Council 2002). Seeing that the EU would have 10 ppm sulfur diesel available by 2005, the Japanese government was not content to rest at 50 ppm. In addition to the environmental benefits, there was also the issue of technological competitiveness. If the automakers were to design vehicles around 10 ppm sulfur diesel fuel in Europe, the Japanese automakers should also benefit from having similar high-quality in their own country. Diesel cars developed in Europe could also have market potential in the US; low quality diesel fuel would no longer be a barrier. For example, Toyota's promising DPNR system, initially developed for the European passenger car market, requires sulfur levels of 10 ppm or lower. With similarly low levels in Japan, DPNR-equipped vehicles may have the opportunity to penetrate the Japanese market. The central government called for 10 ppm diesel fuel by 2007.

In 2004, the Japanese Ministries of Industry, Finance, and Environment announced the Oil and Energy Conservation Fund, a 5.2 billion yen (US\$48 million) cash subsidy to refiners

⁴⁴ Historic exchange rate from FXTOP.com: In 2000, 100 yen = US\$0.928.

who produced 10ppm sulfur diesel.⁴⁵ The subsidy would be rewarded on a first-come, first-serve basis for producers or importers of the fuel (Huizenga, Fabian et al. 2005). This policy no doubt had an influence on the petroleum industry's decision to voluntarily start selling 10 ppm fuel by 2005, earlier than the 2007 deadline. It announced this voluntary commitment at an international setting in May 2003 – the Society of Automotive Engineers Spring Fuels and Lubricants Meeting. They kept their promise and in January 2005, began selling the fuel, with the anticipation of widespread availability by 2008 (PAJ 2005; Peckham 2003g).

9.4.2 Explanations for cooperation

Unlike the oil industry in Europe and the United States, the Japanese oil industry was very cooperative with the government and automobile industry's push for lower sulfur fuels. The automobile industry's agreement to roll out cleaner vehicles two years ahead of the original 2007 deadline hinged on the oil industry's commitment to have 50 ppm sulfur fuel by 2005. Automakers were comfortable with the accelerated deadline if it meant securing the availability of 50 ppm sulfur diesel and gasoline fuel. In addition to recognizing the synergy between the auto and oil industries in reducing vehicle exhaust, the oil industry had several other important motivations.

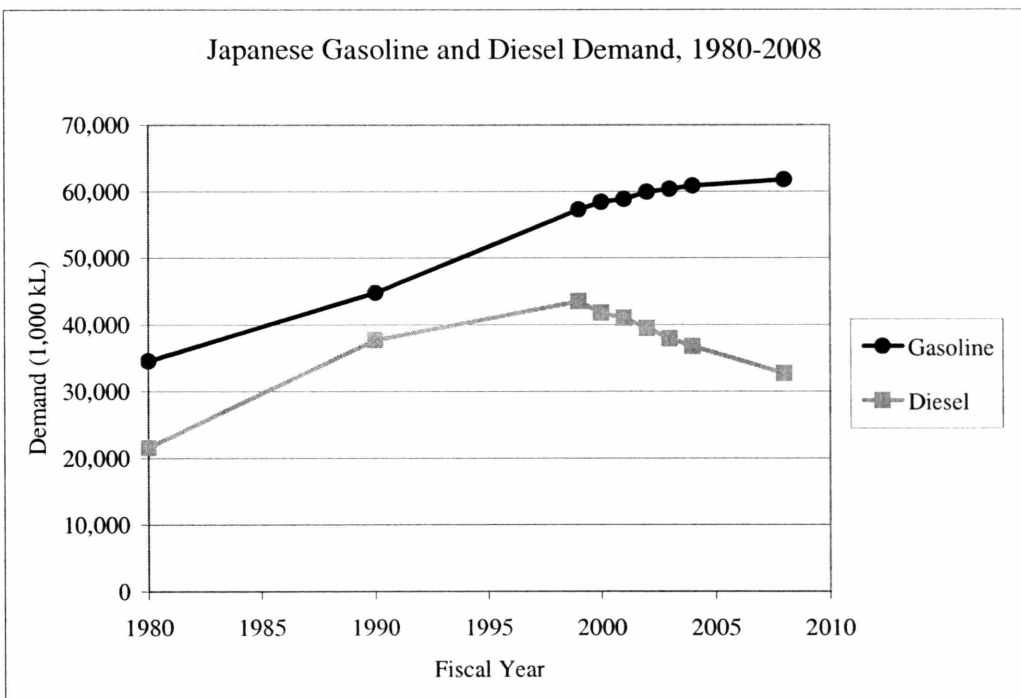
By 1998, it was known worldwide that Europe's diesel fuel would reach as low as 10 ppm in 2005. The EU's next installation of emission regulations, Euro IV, was also set to go into effect in 2005. With Japanese automakers hoping to strengthen their presence in Europe, the Japanese government was very aware of JAMA's desire for greater harmonization of vehicle and fuel standards between the two regions. Having comparable regulations would help Japanese auto manufacturers more easily develop products suitable for both markets.

Another important motivation was the need to maintain diesel vehicle and fuel demand. The very stringent national emission standards and the Automobile NOx/PM law revised in the early 2000s dampened diesel vehicle sales. The Tokyo Metropolitan Government's anti-diesel campaign, which had the slogan "Say No to Diesel Vehicles," contributed to a negative consumer perception of diesels. Tokyo Governor Shintaro Ishihara, very passionate about

⁴⁵ Historic exchange rate from FXTOP.com: in 2004, 100 yen = US\$0.925.

cutting diesel emissions, urged consumers not to ride, buy, or sell diesel passenger cars in the metropolitan area (Asahi Shimbun 2002) As a result, highway diesel fuel demand began to decline. The oil industry’s support for cleaner fuels coincided with forecasts of further decreases in highway diesel fuel demand. In its 2004 annual report, the Petroleum Association of Japan forecast a decline in diesel fuel sales: “Transportation fuel demand for gasoline and jet fuel will continue to increase but demand for gas oil [same as diesel] will decline mainly owing to the decrease of the number of diesel cars” (PAJ 2005).

Figure 9-6: Japanese Gasoline Demand Increases as Diesel Demand Declines



Note: The FY2004 and FY2008 figures are forecasts made in 2004.

Source: PAJ (2005)

The availability of cleaner fuels would enable the auto industry to produce cleaner vehicles, compliant with the new 2005 standards. Low-polluting diesel vehicles would sustain the diesel fuel market and perhaps reverse the downward trend of diesel fuel demand. The petroleum industry in Japan, like in Europe and the US, seeks balance in its refined product

portfolio. If the trends of the early 2000s continue, Japanese refineries would face a gasoline shortage and a diesel surplus.

Another explanation for the Japanese oil companies' support of cleaner fuels is the use of fuel quality regulation to block foreign competition. Beginning in 1987, the Japanese petroleum industry underwent deregulation, which was designed to lower fuel prices and increase international and domestic competition. The late 1990s were characterized by fierce competition from imports (PAJ 2005). By limiting fuel sulfur levels to 50 ppm, Japanese companies could prevent other Asian oil companies from selling higher sulfur gasoline and diesel fuel to Japan. All Japanese companies would be required to make substantial investments, and outside firms not dedicated to the Japanese market were unlikely to do the same. The high vehicle and fuel standards would also prevent competition from rival auto companies. Automobile companies based in countries with lower vehicle and fuel standards would not be able to meet the stringent Japanese standards.

Initially, the oil companies did request fiscal assistance from the government in introducing lower sulfur fuel. However, they made their announcement to introduce 50 ppm sulfur diesel, and then 10 ppm sulfur diesel, without any expectation of tax incentives or subsidies. Even though the Tokyo Metropolitan Government provided a 10 yen per liter subsidy to oil producers for 50 ppm sulfur fuel in fiscal years 2001-2002, no fiscal incentives were granted by the central government. There had already been criticism by environmental groups and municipalities that diesel fuel had long benefited from lower taxes than gasoline fuel (TMG 2003). Even the president of one of Japan's leading automakers suggested that consumers should be responsible for paying more for cleaner fuels and vehicles (Asahi News 2000).

When the industry decided to uniformly adopt ultra-low sulfur diesel, a sluggish economy depressed oil demand and led to refinery closures and industry consolidation. By the end of 2002, oil refiner Idemitsu announced the closure of two of its refineries. Companies began consolidating into four main groups to improve efficiency and capacity utilization (Financial Times 2002; Kyodo 2002). Since refineries were already in the midst of reorganization, producing higher-value 50 ppm sulfur diesel (thanks to government subsidies) may have fit in well with their plans to upgrade refineries for greater efficiency.

9.4.3 Environmental benefits

In addition to the direct emission reduction benefits from cleaner fuels, the early adoption of 50 ppm sulfur diesel fuels has facilitated the installation of diesel particulate filters in existing vehicles, according to the retrofit requirements of the Automobile NO_x/PM Law. Without the low sulfur fuel, fleet and vehicle owners would not be able to successfully retrofit their existing vehicles with sulfur-sensitive emission control technology. While reduction to 50 ppm sulfur is sufficient for catalyzed particulate filters, the proper operation of NO_x reduction technologies, such as NO_x adsorbers, oxidation catalysts, and lean NO_x catalysts, require near-zero fuel sulfur levels (10 ppm or less).

9.5 Summary

This chapter illustrates the role of first-mover countries in spurring cleaner technology, which, in this case, is ultra-low sulfur diesel fuel. Sweden foresaw the benefits of lower sulfur fuels, and used tax differentiation to get consumers and refiners to switch fuels. Sweden's early action inspired Finland to follow suit, and together they put pressure on the EU to also adopt 50 ppm sulfur fuel, and eventually 10 ppm sulfur fuel. This created a "snowball effect" that led to a rapid adoption of ultra-low sulfur diesel in industrialized countries. The Swedish and Finnish experiences were cited by Japanese and American regulators as they considered their approach towards desulfurization.

The companies that stepped forward ahead of required standards to offer clean fuels were motivated by tax incentives, the prospect of future tax incentives or subsidies, or a desire to carve out a place in a small but potentially lucrative market. Greenergy responded quickly to the tax differentials in Sweden and the UK. It also recognized that some clients, like the UK supermarkets and their customers, would be willing to pay a premium for a "green" product. Although BP's readiness to market clean fuels in Europe was not markedly different from its competitors', its European experience put BP at the forefront in the US regulatory scene, where BP stood apart from most of the US oil industry in supporting the 15 ppm sulfur standard.

The opposition of the oil industry to very low fuel sulfur levels was much stronger in the US than in the EU and Japan. There are several possible explanations for this. The most salient explanation is the lack of fiscal incentives, compared to the differential taxation in several European countries or the subsidies offered by Tokyo Metropolitan Government. These incentives helped to ease the cost of upgrading refineries to meet the new standards. The relationship between regulators and regulated industries is usually more contentious in the US, where the political climate is perceived as more conducive to cooperation and negotiation. The sulfur reduction in the US was much more dramatic, going from 500 ppm to 15 ppm, while the EU went from 350 ppm to 50 ppm to 10 ppm, and Japan went from 500 ppm to 50 ppm to 10 ppm. The magnitude of the reductions makes the required capital investments in the US much more costly, an economic threat to older and smaller refineries. Although Japan did not have national fiscal incentives, the local subsidies in Tokyo were enough to jumpstart the switch to lower sulfur fuels. Also, the combination of pressure from citizen groups and the powerful Japanese automobile industry, and the competitive threat of high-sulfur imports made Japanese oil companies amenable to desulfurization. This type of market share threat was also felt by BP/ARCO in the US as it faced substantial anti-diesel sentiment. To reverse public perception of “dirty diesel,” it adopted a clean fuels strategy designed to maintain diesel demand.

Demonstration projects and fleet contracts were effective tools in showcasing the emission benefits of low-sulfur diesel to customers and regulators. They did not carry the risk of investing in extensive distribution infrastructure because fuel could be transported in a tank truck from a single refinery. Results from these small projects inspired additional projects and provided feedback to technology vendors. They were also used as evidence of technical feasibility by regulators.

The direct emission benefits from lowering sulfur levels occur once the clean fuels are marketed, but the greater benefits from enabling cleaner vehicle technologies will only be felt once new, cleaner vehicles are purchased or existing vehicles are retrofitted. Now with fuel sulfur levels lowered, the attention will be on the vehicle, engine, and emission control industries to develop technologies that they assured were possible with ultra-low sulfur fuel.

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CHAPTER 10 – Discussion

10.1 Introduction

The past five chapters evaluated regulatory processes in the EU, Japan, and the US, where some companies chose to act ahead of regulatory requirements. Such behavior constitutes a deviation from the norm, which is to meet regulations no earlier than the compliance deadline. Regulatory and market contexts shaped corporate decisions to pursue early compliance or technology introductions beyond existing regulatory requirements. This chapter reviews the lessons learned from those cases. While there are significant motivations and potential benefits from early and first-mover behavior, the disincentives tend to dominate, leading companies to behave more cautiously. However, in cases where firms did step forward, the environmental benefits were significant, especially when the technology spread to other companies and countries. The chapter explains the corporate strategies behind those technological introductions and ways in which regulatory policy and public pressure encourage early and first-mover behavior. The chapter ends with recommendations to make regulatory competition more attractive to firms and beneficial to the public.

10.2 Regulatory context

The regulatory context in which companies operate shapes their technology choices and response to new or anticipated regulation. Proactive governments, environmentally-minded citizens, regulatory timing and stringency, and compliance details had significant roles in technology development and the emergence of technology leaders.

10.2.1 First-mover countries, states, and municipalities

The regulatory cycles in vehicles, engines, and fuels demonstrated that lead countries with more stringent or earlier regulations and fiscal incentives encourage the market introduction of clean technologies ahead of regulatory requirements. While the main emphasis of this research has been on proactive behavior by companies, their behavior is heavily influenced by their home government's transport and environmental policies. Sweden's tax differential between standard diesel and 10 ppm sulfur diesel was responsible for the rapid adoption of desulfurization by Swedish refiners. Sweden's early leadership in the 1990s led to the creation of Greenergy, a fuel supplier that sold ultra-low sulfur diesel (ULSD) to the Swedish market, and then ultimately introduced the same diesel product to the UK market. The environmentally-proactive Scandinavian countries have been known to adopt "green" policies ahead of the rest of Europe. Compared to the rest of Europe, the UK was quick to adopt ULSD because the British government followed Sweden's example in imposing tax differentials. This resulted in large oil majors like BP and Shell acting as early movers, selling ULSD well ahead of the 2005 Euro 4 deadline.

Even if a company's home market is not a first-mover country, it may find more responsive governments in its export markets. Germany's UBA has historically been a very progressive environmental agency. It recommends very stringent emission standards to the German Environment Ministry, which then applies pressure at the EU level for tighter standards. The proactive environmental behavior of the UBA and Germany as a country explains why the French company PSA chose to focus its filter introduction in Germany rather than its home market of France. As early as the development phase of PSA's filter systems, UBA was an eager participant in testing and rallied behind filter tax incentives. Even when other companies began to introduce filters as an added-cost option in their vehicles, around 80% of German car customers did pay extra for a car filter if available. As mentioned in Chapter 6, the percentage of customers in other European countries requesting the option was negligible. Much of this was a result of the extensive media coverage of the "No Diesel without Filter" campaign in Germany. The customer response was attributable to country-specific prioritization of environmental concerns. In numerous interviews, industry representatives described the German public as more

concerned and aware about environmental issues than people in other EU countries. This coincides with the assertive regulatory officials at UBA, who often challenge the German government's reticence towards environmental policies by engaging public and media support.

A country may have first movers in local and state governments that take the lead on emission reduction policy. Not surprisingly, this often coincides with regions that are most seriously affected by the health effects of vehicle exhaust. In response to air pollution problems in Tokyo, the Tokyo Metropolitan Government (TMG) has frequently passed regulations whose stringency far surpasses the Japanese Central Government's regulation. For example, the Tokyo Diesel Retrofit Program and the Automobile NO_x/PM law restricted access to Tokyo for in-use diesel vehicles not retrofitted by a certain deadline. Before then, only new vehicles were subject to emission standards, but TMG sought a more hostile policy toward older diesels to improve air quality. Many particulate filter manufacturers were borne from TMG's regulatory requirements and filter subsidy program.

California, which also suffers from serious air pollution problems, has been a longtime leader in emissions policy in the US. Because its motor vehicle emission standards predated the existence of EPA, California is the only state legally allowed to pass light-duty vehicle emission standards more stringent than EPA's. It has taken advantage of this legal situation to establish its Low Emission Vehicle (LEV) Program, which has also been adopted by several Northeast states. As an indication of California's influence on EPA policy, environmental groups and industry representatives alike will use the state as a forum for policy debate. They recognize that once California paves the way for a certain environmental regulation, the rest of the country will eventually follow. Automakers Honda and Toyota use California as their test market for many new, low-emission models. BP/ARCO chose California as the first state to make its 15 ppm sulfur diesel fuel widely available at retail stations. The California Air Resources Board (CARB) has a reputation as a regulatory trailblazer. A recently published National Research Council report called California "a laboratory for emissions-control innovations." CARB can change standards more rapidly than EPA, making it more responsive to market and technological change. The risk of failure is limited to one state, while successes can be spread to the rest of the country (National Research Council 2006). Its staff members share some of the same tenacity in pursuing emission reduction goals as its counterparts at Germany's UBA.

Table 10-1 summarizes how first-mover governments spur companies to develop emission reduction technologies and encourage the diffusion of the technology and regulation to other regions. The details of the activities by each first-mover government can be found in the indicated chapter(s).

Table 10-1: First-mover Governments Influence Technology Development and Other Regulatory Decisions

Ch	Regulation	Resulting diesel technology/product	Technology/product transferred to:	Impact on other regulation
5	US Tier 2 and California LEV II require gasoline and diesel cars to meet the same emission standards	Mercedes E320 with Bluetec urea solution for 45 states (expected Fall 2006)		2009 Japanese standards will also require equal treatment
5	Tax incentives for early Euro 4 compliance in Germany, UK	Most automakers had Euro 4-compliant vehicles 2 years early	Rest of Europe	Increased receptivity to diesels for US Tier 2
5,6	Tokyo Automobile NOx/PM Law	Hino's NOx reduction technology for trucks Particulate filters (various) Toyota D-CAT for cars	Rest of Japan; D-CAT-equipped Toyota Avensis in Europe	Japan's 2005 diesel vehicle emission standard; US Tier 2; Possible influence on Euro 6
8	Japan's 2005 diesel vehicle emission standard	Isuzu and Hino Motors EGR and DPF engine technology	Isuzu: DMAX joint venture with GM in US Hino Motors: Nissan Diesel	None observed
9	Swedish tax differentiation favoring ULSD (1992)	Greenergy's "city diesel"; all Swedish refineries within 3 years	UK, Germany, Switzerland	Euro 4 (50 ppm with 10 ppm availability) and Euro 5 (10 ppm); US' 15 ppm sulfur diesel standard; Japan's 50 and 10 ppm sulfur diesel standard
9	UK tax differentiation favoring 50-ppm ULSD (1997)	Greenergy's ULSD, sold through supermarkets Sainsbury's and Tesco; later BP's ULSD; all British retailers by 1999	BP/Arco prepared for US distribution of ULSD	US' 15 ppm sulfur diesel standard; Japan's 50 and 10 ppm sulfur diesel standard
8,9	California requirement that all urban diesel bus fleets run on ULSD by 2002	ARCO's ULSD; International's Green Diesel Technology	Rest of the US	2006 US requirement for 15 ppm sulfur levels
9	Tokyo offers subsidies to oil companies to sell 50 ppm sulfur diesel (2001-03)	50 ppm sulfur diesel by all Japanese oil companies	Rest of Japan	Adoption of 10 ppm sulfur diesel accelerated to 2005, instead of 2007

First-mover governments have used fiscal incentives as well as emission standards as regulatory instruments. Fiscal incentives such as tax differentiation and direct subsidies seem to elicit more uniform industry responses with technology introductions, while regulatory standards result in one or two early technology introductions, if at all. Granted, incentives are usually offered only when industry has the technology available but it costs too much to be competitive with the existing product.

The first-mover government often represents a more environmentally-minded segment of a country or region. Once the new regulation and technology adoption have been “proven” in first-mover market, it diffuses through the rest of the region or to neighboring countries. Sweden and Germany have served this function for the EU, Tokyo for Japan, and California for the US. The main challenge for industry is to develop the new technology for the first-mover markets. Once the technology is available, expanding it to more markets within a region can take advantage of scale economies. This occurred with early Euro 4 compliance, the Tokyo Automobile NO_x/PM Law, and several regions’ ultra-low sulfur diesel (ULSD) introduction.

The most far-reaching consequence of first-mover government activity is its impact on other regulation. Despite differences in regulatory procedures and timing, there has been a surprising amount of cross-country influence. Sweden’s tax differentiation on ultra-low sulfur diesel not only influenced Euro 4 and 5 standards, but ultimately ULSD standard-setting in the US and Japan. Japan, conscious of its vehicle industry’s reliance on export markets, has mirrored several regulatory moves by the US and European governments. Japan has followed the US on equal treatment of gasoline and diesel cars and Europe’s movement toward very low diesel sulfur levels. Harmonizing regulations helps its companies remain competitive in those larger markets. Regulatory influence has also worked in the reverse direction, with Japan influencing other markets. Toyota subsidiary Hino Motors originally designed its DPNR NO_x reduction technology to meet Tokyo’s stringent truck standards. Toyota adapted it on its diesel Avensis car for the European market. Its achievement of low NO_x levels relative to other diesel cars intrigued regulators during Euro 5 consultations, and may affect NO_x levels for Euro 6.

Economic drivers

As noted earlier, first-mover countries and regions are usually those that are more environmentally minded, though this is not always the case. For example, automakers and emission control manufacturers claim that the UK is not known for its environmental awareness, yet it was the first European country outside of Scandinavia to offer tax differentials favoring ultra-low sulfur diesel fuel. News reports from the UK attribute the tax policy to greater concern about air quality, while others speculate that the tax differential may have been a concession to the UK's trucking industry. At the same time that the ultra-low sulfur diesel 1-pence tax reduction was announced, the UK Chancellor also increased diesel and gasoline tax by 3-pence per liter (Brown 1996). The UK's early tax incentive for ULSD was meant to appease critics of the tax increases. □ Environmental measures can also be a result of governments' seeking to improve national competitiveness. They support regulation that offers domestic companies an advantage over foreign competitors in domestic or international markets. Until the past decade, foreign companies had major difficulty negotiating with government officials, who favored the domestic companies. For instance, Japanese companies had long been excluded from discussions among European automakers, which formed a tight-knit network through trade associations. Now the lines between domestic and foreign automakers has been blurred by international alliances, joint ventures, and insourcing.⁴⁶ Many of those interviewed noted that industry lobbyists tend to have more influence on elected officials than regulatory officials, who are usually career bureaucrats. While regulators may be eager to implement regulations in the interest of public health, other parts of the government have competing concerns about the industry's stability and employment. For example, the 2005 Euro 4 fuel standards and 2006 ULSD requirement in the US raised concerns about refinery closures and disadvantages to small domestic refiners. On the other hand, the Japanese refining industry cooperated with the Japanese government's push for ULSD because it offered them a competitive advantage over their nearby Asian rivals, who could no longer export their high-sulfur product without making the costly desulfurization investments.

⁴⁶ Insourcing refers to a foreign company making substantial investments in facilities and creating jobs in the home country. An example is Toyota's building automobile plants in the United States.

Regulatory policy influenced by national competitiveness may manifest itself as a national government's support for specific technologies. Germany has been a major advocate of urea SCR (selective catalytic reduction) technology, primarily because its domestic heavy-duty vehicle companies have chosen SCR over EGR, the predominant choice of US companies. The German automobile trade association, VDA, has considerable influence on the German ministries and the Chancellor. VDA has previously used the threat of job loss as an argument for or against particular regulatory policies (VDA 2006). The British government has supported a very stringent PM standard at the EU level, motivated heavily by its home-grown company Johnson Matthey, an industry leader in catalyzed particulate filter technology. When PSA introduced its particulate filters in Germany, it initially seemed that the German Ministry of the Environment was uncharacteristically supporting the French company's filters, to the disadvantage of its own German automakers. However, the German government ultimately delayed implemented filter tax incentives until its own automakers finally agreed to also offer filters.

10.2.2 Stringency and timing

While many of the cases presented in the past five chapters highlight the fiscal incentives used by European countries and the cooperative approach pursued by Japan, the US differs from the EU and Japan in its frequent use of technology-forcing regulations. The European and Japanese emission reduction strategy focuses on rapid diffusion of best available technology, i.e. technology that is leading-edge, but commercially available. The time between new emission standards in the US is generally longer than in the EU and Japan; this comes from the long, contentious process accompanying many environmental regulations and the built-in minimum timing requirements. US legislation requires at least 4 years of lead time and 3 years of stability in the heavy-duty engine emission standards. Meanwhile, the US reductions compensate for lower frequency of revision by being more dramatic, amounting to 70-90% emission reductions as opposed to the 30-50% reductions more common in EU and Japan. The same has been true of diesel fuel sulfur standards, in which the US will drop from 500 ppm to 15 ppm, while the

Europeans and Japanese have taken a more incremental path toward near-zero sulfur levels (see Figure 10-5).

Figures 10-1 to 10-5 show the emission and fuel standards over several regulatory periods. The different testing cycles and requirements make them difficult to compare directly, but they do illustrate some important general points about the standards. Although the US and California standards are technology-forcing, the more gradual standard revision in the EU and Japan has recently led to relatively comparable standard levels in PM standards and fuel sulfur levels. The US still has the most stringent NO_x emission levels, and its test procedures and durability requirements are considered by industry experts to be more challenging. However, the EU and Japan can adapt more quickly to changing technologies, instead of waiting a decade or longer to lower emission standards. These shorter time frames give technology leaders more opportunities to influence the level of regulatory stringency. They will be giving their feedback on regulatory proposals when their technology is near commercialization rather than in the experimental stage, which is often the case in the US. In forming a technical basis for standard-setting, regulators tend to place more credence in technologies that have already been field-tested. While the US or California standards are often known to be the most stringent at the time they are proposed, the EU and Japan make incremental reductions during the interim period that can match or surpass the US levels until the next cycle of new US standards.

Within the US, California has been first to adopt the most stringent standards, which has resulted in a virtual ban on diesel cars in recent years. Its levels have been followed by Maine, Massachusetts, New York, and Vermont. These five states comprise 24% of the new passenger car market (US Bureau of Transportation Statistics 2005). Limiting sales to a 45-state market has discouraged any significant diesel car penetration in the US. So far only Volkswagen and Mercedes have sold small volumes of diesel passenger cars in the US. Even if diesel emission reduction technology improves after a particular regulatory standard has taken effect for several years, the next proposed set of standards threatens to shut out diesels again. It may not be worth the cost and effort for a diesel car manufacturer to introduce a model for the “tail end” of an existing regulatory period and then be forced to pull it off the market after new regulations take effect.

Figure 10-1: Diesel Passenger Car PM Standards

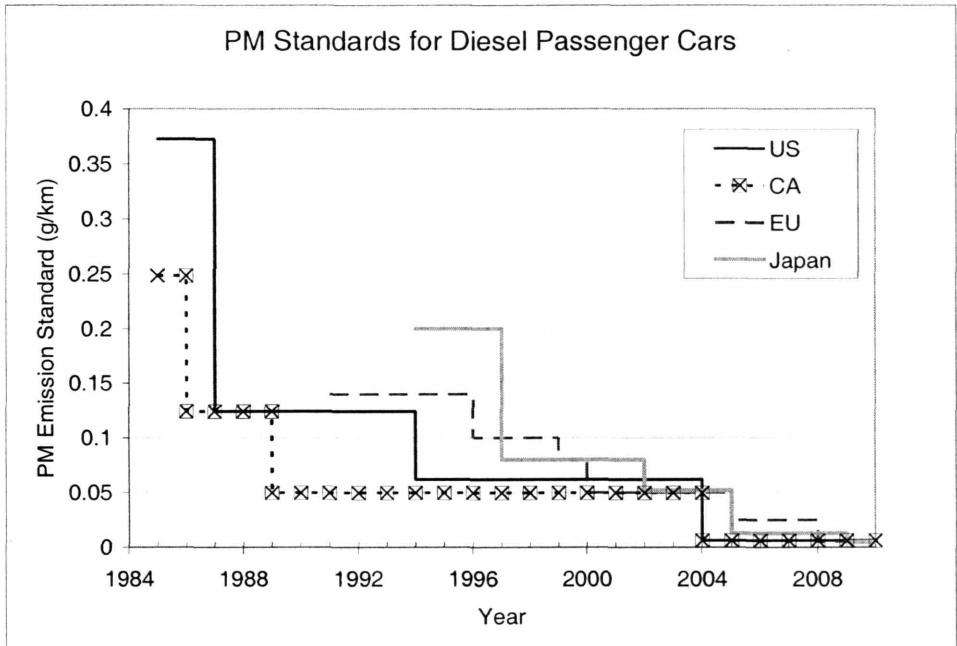
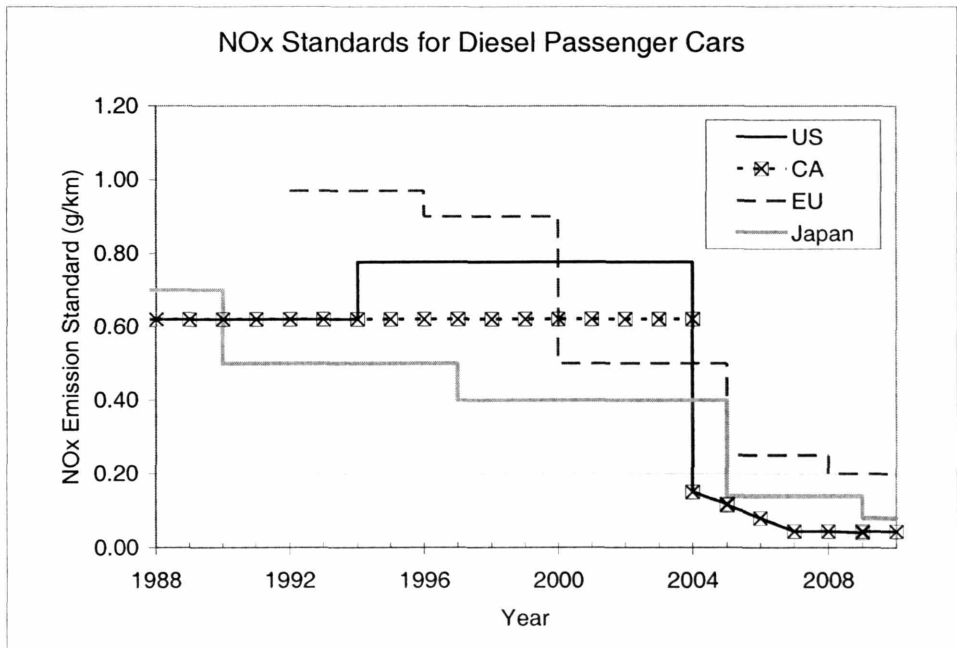


Figure 10-2: Diesel Passenger Car NOx Standards



Note: US NOx standards increased in 1994 because durability requirements increased from 50,000 miles to 100,000 miles.

Figure 10-3: Diesel Engine PM Standards

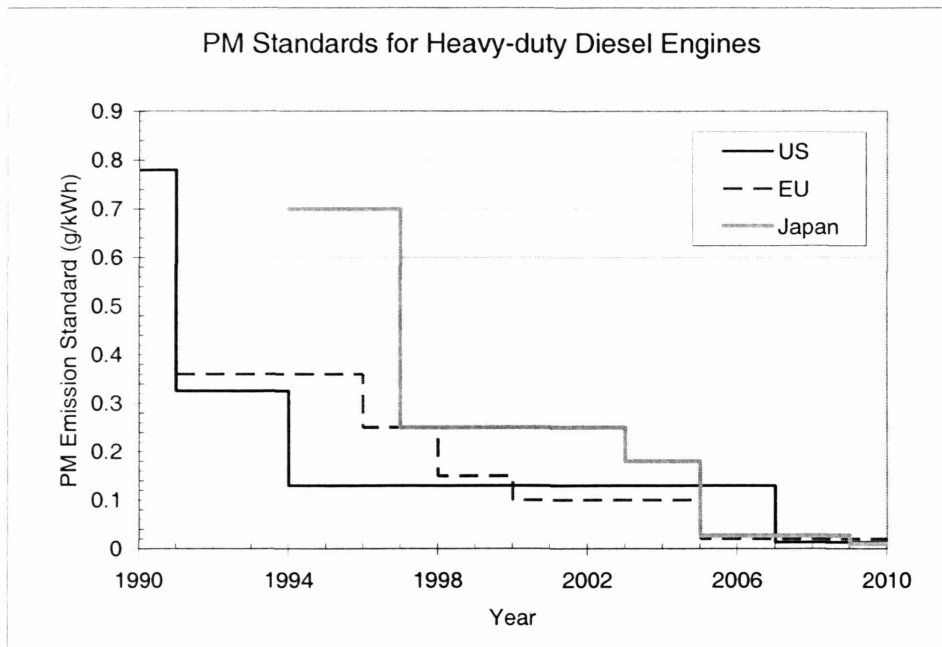
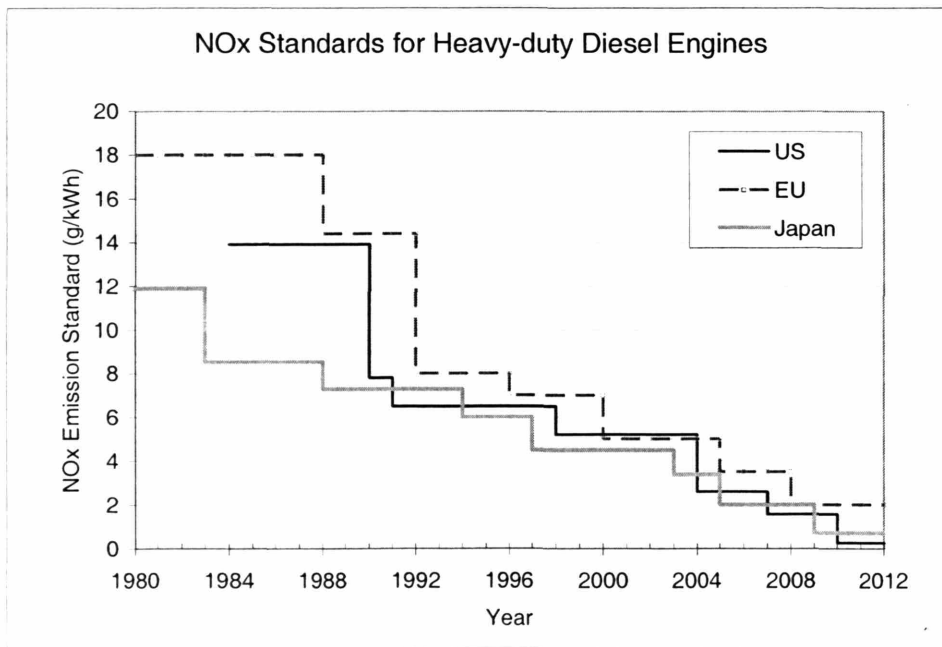
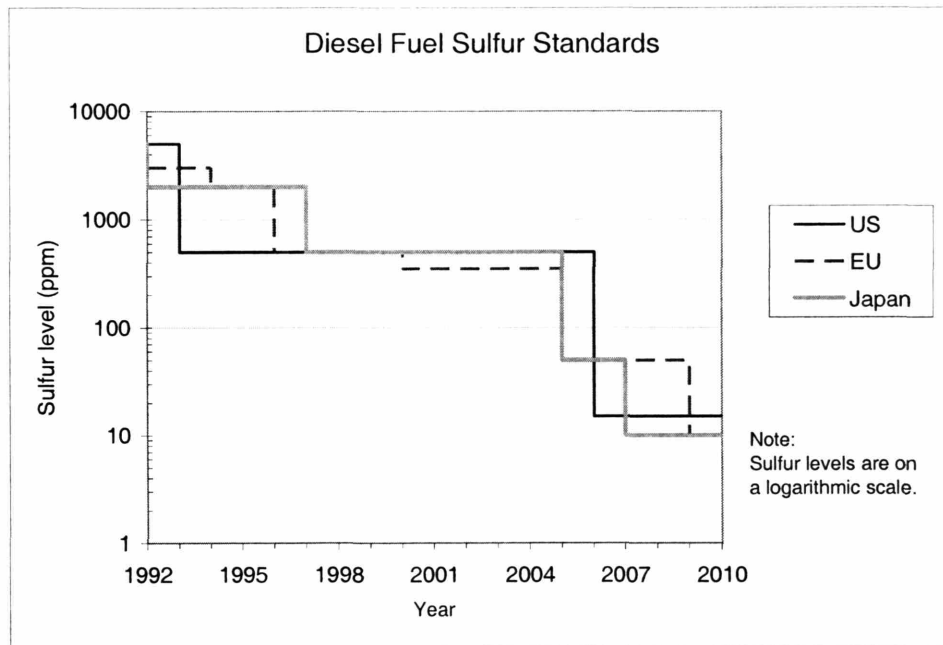


Figure 10-4: Diesel Engine NOx Standards



Note: US, EU, and Japanese emission standards are not directly comparable because of differences in testing requirements.

Figure 10-5: Diesel Fuel Sulfur Standards



Sources: Dieselnets (2006); Original Sources: European Parliament and the Council, Japan Central Environment Council, EPA, CARB.

A series of increasingly stringent NO_x standards in Japan have also posed a barrier to European diesel manufacturers seeking to expand their overseas markets. Even though high fuel prices make vehicle fuel efficiency greatly valued, diesels have not been very popular. The perception of diesels as polluting and the Japanese auto industry's strength in highly efficient, low-emission gasoline cars have made it politically easier to maintain stringent NO_x standards. As shown in Figure 10-2, Japan has also maintained relatively low NO_x levels since the 1980s. Until recently, it has prioritized NO_x reduction over PM reduction.

The timing and stringency of standards also depend on the characteristics of the technology itself. Thanks to the aftertreatment industry, major improvements in the effectiveness and cost of particulate filters for trucks enabled dramatic reductions in PM levels in the 1990s. Greater difficulty reducing NO_x emissions has been manifested in more gradual NO_x reductions, as shown in Figure 10-4. Although the US heavy-duty engine standards have recently changed more frequently than the US diesel car standards, federal legislation guarantees the heavy-duty vehicle industry minimum lead time and stability. The US Clean Air Act requires at least 4 years of lead time and 3 years of stable regulatory levels for heavy-duty engine

emission standards. This gives the industry the security of sufficient R&D and field testing time. The smaller product volumes in the heavy-duty vehicle industry mean that companies need longer production runs to recoup their costs.⁴⁷ For diesel fuel sulfur levels, it is helpful for governments to set out a pathway and timetable for reductions. This allows individual refineries to plan investments in desulphurization equipment efficiently. For example, in some cases it may make most sense to install new equipment for the complete reduction in one step; in other refineries intermediate reductions may be achieved by modifying existing desulphurization equipment as an intermediate step towards a more major restructuring of the refinery or by closing it.⁴⁸ By the early 2000s, technology already existed for levels below 10 ppm (Blumberg, Walsh et al. 2003).

10.2.3 Regulatory details

The details of compliance, such as certification procedures and enforcement, can influence public and private outcomes as much as the standards themselves. In the EU and Japan, regulators do not have testing facilities and must rely on the manufacturers to submit documentation of their product's attainment of performance requirements. While the necessary data is often generated by reputable third-party testing facilities, the lack of routine regulatory verification means that the regulators are dependent on the honesty of the regulated firms. The US EPA and California Air Resource Board (CARB) each have their own testing facilities which certify new engine and vehicle models. However, even passing government tests and receiving certification does not necessarily mean the product is performing as the regulation intended.

The use of "defeat devices" to circumvent NO_x controls in US and European engines, described in Chapter 7, is probably the best demonstration of the discrepancy between emission performance during testing and emission performance during actual driving conditions. In the US, in-use NO_x emissions were 2-3 times higher than the maximum limit, which made the resulting emissions even worse than levels mandated in older standards. The penalties and accelerated deadlines of the consent decree between the US engine manufacturers and EPA

⁴⁷ Interviews with senior experts in the diesel vehicle industry, 2006.

⁴⁸ Interview with Stewart Kempell, Hydrocarbon Fuel Strategy Manager, Shell International Ltd., September 28, 2005.

resulted in a competitive disadvantage to most US manufacturers and consumer skepticism of the new, compliant engines. In a further twist, consent decree manufacturers who produced compliant engines on time suffered market share losses because of the structure of the non-compliance penalties and fuel economy-emission reduction trade-off. Although European engine manufacturers made use of “defeat device” software as well, there was no legal mechanism at the time to hold them accountable for doing so. In Japan, the leading particulate filter supplier, Mitsui, falsified emissions data to qualify for Tokyo’s filter subsidy program. Its filters’ removal rate was only 70-80% of the rate required by the Tokyo Metropolitan Government. Although Mitsui had clearly betrayed the government, TMG’s reliance on manufacturer submissions and its zealotry in accelerating filter adoption may have also facilitated Mitsui’s deception. Discovery of these undesired outcomes have led to reexamination and revision of certification testing and enforcement procedures.

National governments and companies have sought to agree upon harmonized test cycles for engines and vehicles, which would make it easier for multinational companies to certify engines in different markets. The current variety of test cycles makes emission standards impossible to compare directly. Governments tend to advocate the worldwide adoption of their preferred cycle, and companies often prefer the test cycle and requirements of their home market, positions which bolster domestic companies.

Past experience with compliance problems affected some regulators’ perception of future technologies and user responses. US regulators were very hesitant about urea SCR technology because it required the truck operator to keep the urea tank from going empty. Concerns about compliance no doubt stemmed from the recent defeat device experience as well as the 1980s experience of catalyst poisoning from leaded fuel.

Table 10-2: Comparison of Select Regulatory Compliance Details

Item	Europe	Japan	US
Source of certification data	From manufacturers	From manufacturers; ex: Mitsui's data falsification to gain government approval for its filters	From manufacturers and regulatory agencies' own testing facilities
Durability requirements for passenger vehicles	100,000 km for Euro 4 and 160,000 km for Euro 5	80,000 km for 2005 and 2009	193,000 km for Tier 2; Required "full life" is significantly longer than Europe and Japan's
Treatment of gasoline vs. diesel passenger vehicles	More lenient NOx standards for diesels	Diesel and gasoline vehicles will be treated the same in 2009	Diesel and gasoline vehicles treated the same since 2004*; EPA bin averaging may allow for diesels in the more lenient bins; CA's LEV standard is a fixed level so harder for diesels
Off-cycle heavy-duty emissions	Excessive off-cycle NOx emissions from Euro II engines by optimizing for fuel economy outside of test points; Changed from steady-state to transient test cycle	Changed from steady-state to transient test cycle because the effectiveness of new emission control technology depends on exhaust temperature changes	Excessive off-cycle NOx emissions from 1988-1998 engines caused by dual mapping (EPA test cycle vs. highway conditions); EPA adopted EU's transient test as a supplemental test
Impact of testing and durability requirements on urea-SCR technology		Low exhaust temperatures over the JE05 test cycles led to poor SCR performance until diesel oxidation catalyst added	Urea refilling every 31,000 miles does not meet EPA's minimum 150,000-mile maintenance interval for emission control devices
End-user issues for urea SCR for heavy-duty engines	No requirements for sensor system to detect proper urea tank refilling until 2009	Warning lamp on Nissan Diesel's SCR-equipped trucks is a poor incentive for urea refilling	EPA concerned about user tampering or negligence with urea refilling

*However, as of March 2006, the EPA was considering the temporary relaxation of the diesel passenger car standard to encourage fuel efficiency.

Earlier, it was mentioned that US and California standards are generally more difficult to meet – the stringency of the standards is not the only reason. EPA and CARB have longer durability requirements, equal standards for diesel and gasoline cars, and closer scrutiny of end-user problems. They have also been more cautious about operational issues associated with new technologies that are very different from existing ones. While the EU and Japan have taken a “try it and fix problems later” approach to urea SCR technology, EPA has proceeded more cautiously. Existing compliance requirements such as the 150,000-mile maintenance interval

and avoidance of user misfueling also make the US a less hospitable place for the manufacturers of SCR-equipped vehicles.

10.3 Market context

The diesel vehicle industry has faced very different market conditions in Europe, Japan, and the US, which are often shaped by the government's regulatory priorities. At the same time, the regulations are a reflection of the market conditions. Fuel prices, climate change concerns, diesel market share, and product mix affect each company's competitiveness.

10.3.1 Fuel prices and CO₂ constraints

High fuel prices have driven the pursuit for fuel efficiency, while domestic industry strengths have determined the technologies used to meet that goal. Regulations may be designed to accommodate each region's technological solutions. In Europe and Japan, fuel prices for both diesel and gasoline are approximately twice that of the US. This has motivated customers' demand for more fuel-efficient vehicles. In most European countries, tax differentials favoring diesel over gasoline and the European automotive industry's strength in diesel vehicles have made diesel cars the predominant fuel-efficient choice. In Japan, diesel fuel is slightly cheaper than gasoline, yet because of the Japanese automotive industry's strength in gasoline vehicles, small gasoline-powered cars have dominated Japan's pathway to fuel efficiency. Moreover, greater attention to climate change has also led the EU and Japan to adopt transport policies giving tax advantages to vehicles with lower CO₂ emissions, which tend to be diesels and smaller vehicles. In the US, the relatively low price of fuel and cultural acceptance of larger cars have popularized gasoline-powered passenger trucks and SUVs. However, recent increases in fuel prices in the US have prompted the government to seriously weigh the trade-off between pollutant emissions and fuel efficiency, which may lead to more diesel-friendly policies.

10.3.2 Diesel market share

With diesels increasingly making up the majority of the European new car market, EU environmental regulatory officials designed their policies to allow clean diesels to thrive. They offered incentives for very low diesel fuel sulfur levels and incrementally tightened NO_x and PM standards to levels readily attainable by industry. The same was not true in Japan and the US, which view low-emission gasoline vehicles as a more environmentally beneficial alternative to diesels. Because diesels are such a small portion of the light-duty market share, regulators can be more aggressive with the light-duty standards, even if it means regulating diesels out of the market. EPA and CARB officials have been accused of doing exactly that because of their very stringent NO_x standards. The Tokyo Metropolitan Government's anti-diesel stance and its retroactive diesel regulations also send an unwelcome signal to diesel car purchases. The strongest opponents to these unfriendly diesel policies have been the European automobile manufacturers, who have less influence in the US and Japan than domestic automakers.

Product mix

Automotive/truck companies with a narrower product line, specifically those with inherently lower emissions and fuel consumption, have tended to fare better with the advent of more stringent regulation. This is especially true if different size classes face the same standards. For example, Japanese and European automakers (not including DaimlerChrysler) have historically focused on compact to medium-sized passenger cars, which comprise over two-thirds of their global sales. Meanwhile, almost half of the "Big 3" American automakers' global sales are in light trucks, SUVs, and vans (Austin, Rosinski et al. 2003). In the last 2 years, fuel prices have increased significantly and US Tier 2 emission standards have begun to treat light trucks, SUVs, and vans like passenger vehicles. As a result, American manufacturers face greater challenges to meeting customer demand for fuel-efficiency and regulatory demand for emission reduction. In the US, they are shifting their product mix to smaller vehicles like "cross-over" SUVs and passenger sedans, in which Japanese firms already hold a third of the US passenger car market (Ward's Automotive Yearbook 2005).

In Europe and Japan, where fiscal incentives exist for purchasing low-CO₂ vehicles, companies whose product line already consists mostly of fuel-efficient, low-CO₂ vehicles stand to perform well against the competition. “Changing Drivers,” the investor report by Sustainable Asset Management and the World Resources Institute, points out that PSA and VW have lower risk from CO₂ constraints than their competitors because the majority of their sales are already in low carbon intensity vehicles (Austin, Rosinski et al. 2003)

International Truck and Engine was more supportive of the 2007 US heavy-duty engine emission standards than the rest of the engine manufacturers and certified a compliant school bus 6 years early. Its narrower range of truck and engine products – mid-range engines, medium trucks, and school buses – may have made it easier to meet proposed regulations. Other manufacturers that make a wider range of engines claimed that International’s narrow range of engine types helped them obtain certification early.⁴⁹ It could concentrate its R&D on a limited portfolio of engine types, while other major engine manufacturers had to develop emission control systems for a broad range of engine types, including vocational (off-road) equipment. Moreover, International catered to the school bus market, which is more sensitive to protecting children from diesel exhaust.

The regulatory and market context in which the companies develop technologies and compete shapes their potential for competitive advantage. Their home country or region’s tax or environmental policy, public attitudes, technology choices, and product mix affect their preparedness for more stringent emission and fuel standards. This study acknowledges that companies do not start out with the same opportunities, but their regulatory and market context does not lock them into a specific decision or strategy. Even when a company has a potential competitive advantage, there are conditions that either motivate or discourage early or first-mover behavior. Identifying and explaining these motives and disincentives responds directly to the original research questions:

Under what conditions do competitive regulatory strategies succeed in providing private benefits to first-mover firms and environmental benefits to the public? What motivates firms to engage in first-mover behavior?

⁴⁹ Interview with Rich Kassel, Senior Attorney, Natural Resources Defense Council, September 8, 2005.

10.4 Motives for early and first-mover behavior

A company generally does not introduce a cleaner, but more costly, product in the absence of customer or regulatory demand. However, based on several instances of early and first-mover behavior, economic incentives, market preservation, and technology development can provide adequate motivation to introduce a technology ahead of regulatory requirements.

10.4.1 Tax incentives encourage early adoption

A company sitting on a technology capable of surpassing existing regulations would be hesitant to introduce it because of the uncertainty of customer and regulatory demand. Tax incentives or other types of similar economic instruments (e.g. subsidies, tradable credits) may tip the balance in favor of introducing the cleaner product early. Virtually all the interviewees in industry were supportive of tax incentives as an attractive scheme to promote clean technology. Tax incentives help cover the R&D or investment costs associated with technology development. Many of those company officials interviewed supported tax incentives that go to customers, not to the companies. The incentives create certainty in customer demand that is crucial to new product introduction. They offset the higher retail price associated with cleaner technologies, which then become more cost-competitive with the older technology. In order to keep tax incentives revenue-neutral, governments may penalize the most polluting products while lessening taxes or registration fees on the cleanest products. For example, the Swedish tax differentials on diesel fuel consisted of raising taxes on standard diesel and lowering taxes on ultra-low sulfur diesel.

The power of tax incentives as a motivator for early adoption is evidenced by the different choices made by the same company in an environment with incentives and one without. For example, BP introduced ultra-low sulfur diesel throughout retail stations in the UK immediately following the 3-pence tax differential favoring ULSD. However, in the US, where no ULSD tax incentives exist, BP has been selling the fuel at a 5¢/gallon premium to fleets and to California stations. According to an EPA representative, a few companies, including BP, came forward as early as 2003, offering to sell 15 ppm sulfur prior to the 2006 deadline if tax

incentives were made available. EPA only offered them tradable credits for early sales in 2005 to mid-2006. The lack of more substantial incentives resulted in limited ULSD availability, mostly for municipal bus fleets. The US outcome stands in sharp contrast with the rapid, near 100% adoption of the cleaner fuel in Sweden, UK, and Germany, well ahead of the 2005 Euro 4 deadline.

Tax incentives assume that the next set of regulatory standards have been established, so companies frequently lobby for tax incentives once the regulations are already finalized. Occasionally, companies will introduce their cleaner product on a limited basis in hopes that it will persuade regulators to adopt tax incentives for widespread adoption. This was BP's strategy in France, but it did not appear to work. Toyota and PSA asserted that they did not actively pursue incentives before introducing their hybrid cars and particulate filter-equipped cars, respectively, but they were cooperative with regulators who proposed incentives favoring their technology.

Tax incentives are meant to be a complement to regulations, not a replacement for standards. Not all companies in industry favor tax incentives, perhaps because they tend to distort markets, complicate pricing, and lead to demand spikes. Most oil companies prefer “to have clear regulation and clear standards for fuel quality, and to follow them, rather than incentives.”⁵⁰

10.4.2 Market preservation and protection from competing technologies

Absent fiscal incentives, adoption of cleaner and more costly technologies ahead of regulatory requirements seldom occurred in the diesel vehicle industry. While promoting a “green” image to the public was cited as important to companies, the rare cases of genuine first-mover behavior were not exclusively motivated by the hopes for favorable publicity or an altruistic commitment to good citizenship. Instead, the companies were executing a strategy motivated by concern about market share erosion; they saw their existing market share threatened if they did not introduce a less polluting product.

⁵⁰ Interview with Stewart Kempbell, Hydrocarbon Fuel Strategy Manager, Shell International Ltd., September 28, 2005.

PSA noticed a dip in diesel market share in the mid-1990s because of growing health concerns about diesel exhaust, especially from the medical community. If manufacturers did not help “clean up” diesel’s image, PSA, with a diesel-heavy product portfolio, stood to be one of the companies to hurt the most from a diesel backlash. As a result, PSA began to voluntarily equip its cars with particulate filters even though the upcoming Euro 4 standards did not require them. ARCO/BP introduced ultra-low sulfur diesel fuel in California because state regulators seemed to be targeting diesel buses for extinction, steering municipalities towards CNG. Recognizing that an increase in CNG’s popularity would cut into the diesel market share, ARCO/BP offered a cleaner fuel that would enable diesel retrofit technology. International also recognized the threat of CNG competition and introduced its Green Diesel Technology school buses 6 years before the new 2007 standards. Companies recognized the impact of the media and environmental and citizen groups on regulatory attitudes towards diesels. These outside pressures reinforced the need to preserve the diesel market for the entire industry, not just for individual competitive interests. A Toyota representative noted in an interview that a company foremost wants to remain a car manufacturer and therefore must form a long-term vision of sustaining the car market.⁵¹ Countering environmental and health concerns by continuously introducing cleaner products fits into this vision.

The actions of these first-movers have long-run spillover benefits to their competitors. Initially, their competitors may view following in their footsteps as burdensome and unnecessary, but the adoption and diffusion of the less-polluting technology gives both regulators and customers additional confidence in the longevity of the technology. For example, any competitive advantage that PSA had with the filters was narrowed once its rivals marketed effective filter-equipped cars as well. If its main objective has been to preserve the market for the entire diesel industry, other companies could free-ride from its first-mover behavior. Although the whole industry may be criticized for being laggards at first, the first mover takes the initiative to improve the image of the industry. It is no surprise that the companies to take on this burden are also some of the largest companies within their market – e.g. BP in fuels, PSA in diesel cars, International in school buses. In terms of financial benefits, any competitive advantage to the company may not extend long into the future. The first mover is better prepared to meet upcoming regulations than its competitors, and it usually receives praise from regulators

⁵¹ Interview with Didier Stevens, Manager of Government Affairs, Toyota Motor Europe, August 24, 2005.

and NGOs. However, once regulations are implemented and everyone must reach the same standard, others quickly mobilize to market similar technology. In the initial years, the first-mover companies' lower unit costs and greater learning experience may help it maintain an edge over the competition until the regulatory and public eye focuses on the next round of regulations. This sentiment was echoed by representatives at the first-mover companies, who often viewed these technology introductions as repeated rounds, for which they led in one round, and then quickly moved on to compete in the next.

A market share threat from foreign competition may also make companies less resistant to their first-mover government's plans to require cleaner products. This occurred in the promotion of cleaner diesel fuel in Scandinavia and in Japan. In Sweden and Finland, refineries were facing potential competition from Russian refiners, who were beginning to reorganize their industry and sell refined petroleum products in addition to crude oil. It was in the interest of the Swedish and Finnish refineries to make costly desulfurization investments to stave off future imports of cheap, higher sulfur Russian diesel fuel. A similar situation occurred in Japan, which faced tough competition with Asian refineries exporting inexpensive, high-sulfur fuel to Japan. Japanese refineries may have been more cooperative with their government's requirement of 50 ppm sulfur diesel because they benefited from trade protection.

10.4.3 Technology development to test the market

Another motive besides market share preservation is technology development. A company may foresee increased stringency in the future and decide to introduce its advanced technology at small volumes prior to the regulatory deadline. Field experience and feedback from customers and regulators will help to improve the technology. By the time that the regulation does require the technology's use, it will be easier for the company to ramp up to high volumes. This is a major motivation for technology vendors, such as emission control manufacturers, to engage in demonstration projects to showcase their upcoming products to regulators and potential customers. Johnson Matthey and Engelhard, two leaders in catalyzed diesel particulate filter (CDPF) technology, participated in many field tests and fleet retrofits in the US and Europe, even though there were no regulations requiring CDPFs at the time.

Although the availability of retrofit subsidies did partially drive their efforts, they anticipated that future regulations would require truck and bus OEMs (original equipment manufacturers) to use their technology. The on-road experiences helped them see how their emission control systems operated once integrated into the vehicle. In the late 1990s, the SiNOx SCR system manufacturer Siemens (later Argillon) participated in demonstration projects with US engine/truck manufacturers, fleet owners, and regulators to increase receptivity to SiNOx. Since Johnson Matthey, Engelhard, and Siemens/Argillon are suppliers, they could not sell their products independently at a large scale without regulatory-driven commercial demand. Even their retrofit equipment sales were subject to the availability of public subsidies.

Engaging in proactive behavior for technology development is not only the purview of technology vendors. The desire for technology development was behind the introductions of PSA's particulate filter and Toyota's D-CAT system. In both cases, the automakers offered the technologies for commercial sale, not just through demonstration projects. The development of the emission control system in-house allowed the companies to dictate when their new products would be introduced. Even though PSA attributes its decision to adopt filters to preserve diesel market share, its approach to the filter introduction suggests that it viewed the technology as an opportunity to expand its market share, especially in Germany. It started with the Peugeot 607 first, and then each year gradually expanded to more Peugeot and Citroën models. Incremental filter improvement and filter-equipped vehicle sales occurred in parallel. By 2005, when industry experts expected most automakers to offer filters as standard in cars, PSA already had a "running start" on its competitors. Toyota also pursued a similar strategy with its D-CAT system, though upcoming regulations have not yet required a ramp-up of production beyond the small number of Avensis and Corolla Verso cars sold. Instead of keeping the technology in-house until regulations were implemented, PSA and Toyota chose to get their technologies out on the market early, even if it initially cost more for them to do so.

Small-scale production followed by production ramp-up also occurred with the Toyota Prius, the gasoline-electric hybrid car. It debuted in Japan in 1997, and sold 30,000 units in its first 2 years (Automotive News International 1999). Toyota kept Prius sales within Japan until 2000, concerned about how their new car would behave in foreign driving and climate conditions (Dawson 2005). The small production numbers allowed the Prius to be produced on existing production lines for the Camry and other mainstream models. In the event that the Prius was

unsuccessful, Toyota did not have to commit itself to a new production line (Dawson 2005). When Toyota expanded Prius sales worldwide, with the US as the biggest customer, production numbers increased significantly. In the first few years of limited production, monthly production numbers averaged 1,000 units, but once the second-generation Prius model was introduced in September 2003, monthly production jumped to an average of 5,000 (AutoInfoBank 2005). US sales of the Prius have grown from 15,556 in 2001, the first full year of sales, to nearly 100,000 in 2005 (Ward's Automotive Yearbook 2005). Toyota has already migrated its hybrid powertrain to popular existing models like the Highlander, Lexus RX 400, and Camry (Toyota 2005). Although the production ramp-up was driven by customer demand rather than preparation for more stringent regulation, the Prius introduction shares a similar pattern with the PSA filter and Toyota D-CAT's gradual diffusion into larger production volumes and more models.

10.5 Disincentives to early and first-mover behavior

Earlier, it was mentioned that companies will typically not pursue any type of first-mover or early-mover behavior without certainty in regulatory or customer demand. There are strong disincentives to being first to the market, so technology leaders may choose to wait until after regulations are implemented. Although the lack of a business case is the strongest disincentive to proactive environmental behavior, companies with a financial incentive to move forward still face other deterrents.

10.5.1 Lack of a business case

The most frequent response given by interviewees for the rarity of first-mover behavior is the lack of a business case. This fits with the earlier proposition about tax or other fiscal incentives being the best way to persuade companies to act early.

Senior environmental officials in major automobile and truck manufacturers claimed that they have the technology to introduce more environmental features in vehicles, but customers are

unwilling to pay extra for them. Even if a company were to introduce extra emission-reducing technology as an option for more environmentally minded customers, the low volumes would make the technology too expensive. It only becomes affordable when produced at high volumes or when other companies adopt the technology. When different suppliers have to compete for the OEMs' business, the competition drives prices down. An executive at Ford Europe commented that a company's need to attend to short-term profitability prevents a company from coming out as an environmental leader and pushing the regulations themselves.⁵²

Leading emission control manufacturers like Johnson Matthey and Engelhard use technology improvements to achieve lower-cost compliance rather than regulation-surpassing performance. They recognize that this is what their customers (OEMs) want. If one company were to market expensive, high-end catalysts while another sold cheaper but adequate catalysts, the latter would win out in the marketplace. Auto and truck makers also take cues from their customers' buying preferences. According to a senior manager at a major auto company, if his company were able to introduce diesels in the US because of improved NOx reduction technology, it would use diesel power to make larger SUVs and trucks rather than to reduce fuel economy. American customers are perceived as caring more about vehicle size and power than fuel economy.

Companies in the truck and engine business viewed their customers as even more sensitive to cost than the average private vehicle owner. According to engine manufacturers, emissions are among the last priority of heavy-duty truck customers, who care mainly about performance, reliability, and cost. With the exception of government fleets, school buses, and economic incentives, there is no customer demand for more emission control than is required by law.⁵³ As described in Chapter 7, even a 3-5% fuel penalty from required emission control equipment may motivate a truck buyer to seek a more fuel-efficient engine. If an engine manufacturer elected to meet more stringent emission standards unilaterally, and raised the prices of their engines to cover the added cost, customers in general would not be willing to pay the incremental expense.⁵⁴

⁵² Interview with Dr. Wolfgang Schneider, Vice President of Legal, Governmental, and Environmental Affairs, Ford Europe, August 31, 2004.

⁵³ Interview with Joseph Suchecki, Engine Manufacturers Association, July 14, 2005.

⁵⁴ Interview with Dr. John Wall, Chief Technical Officer, Cummins, November 11, 2003.

Government policy protecting small and medium-sized businesses may also minimize or eliminate any advantage to firms applying a competitive regulatory strategy. If lead firms could anticipate squeezing firms with lower environmental quality out of the market, they might have a strong business case to use regulatory stringency for competitive advantage. However, governments have an interest in preserving even the most poorly-performing firms to avoid job losses. For example, the US has provisions in its 2006 ultra-low sulfur diesel rule that gives exemptions and longer compliance deadlines to small refineries, much to the chagrin of the large refineries. From an environmental standpoint, it may make sense for refineries to be closed or acquired if they cannot meet the desulphurization requirements. However, from an economic standpoint, closing a refinery may mean worker unemployment and fuel supply disruption.

10.5.2 Corporate risk aversion

Companies are generally risk-averse, and do not want to make technology promises that cannot be kept or that promote additional regulation. They are hesitant to make technology assurances to regulators if there are still uncertainties associated with the technology or market. Although emission control manufacturers are the most optimistic about emission control technology, they still do not want to overstate their capabilities. In the interviews, regulators, industry representatives, and NGO leaders overwhelmingly agreed that companies tend to make very conservative estimates about costs and technological progress. It is more acceptable to deliver more than expected than to under-perform. For example, a Toyota representative distinguished that the company's approach is to work collaboratively with regulators.⁵⁵ Some companies are wary of provoking more regulation if they demonstrate their ability to go further than their competitors. A senior manager at a major auto company said that it would not lobby for tighter standards even if the company did make a major R&D discovery. Pushing for more regulations would be "self-defeating" and "dangerous," because regulators might push the standards even further, beyond the lead company's capability. Once regulations are finalized, companies no longer feel such constraint, and compete aggressively to improve technology and lower cost.

⁵⁵ Interview with Dave Baxter, Vice President of Corporate Planning, Toyota Technical Center USA, September 12, 2005.

Regulators inherently favor more optimistic technology reports, since they are eager to see environmental improvements. They actively seek out evidence to support their next set of standards, so a company coming forward with a promising technology would attract their interest. EPA staff use past certification data to set standards. They seek instances where companies were certified well below the standard as indications that lowering standards further is possible.

Sometimes being the second-mover company has its advantages. It may already have the technology or product ready in-house, but allow the first mover to face the problems first. If the first-mover's technology introduction encounters any problems, the second-mover company can make improvements in-house and market a "better" product. For example, the first two generations of PSA's particulate filter required replacement every 80,000 and 150,000 km, respectively, and did not meet the Euro 4 NOx standard. These weaknesses were exploited by other car manufacturers, like DaimlerChrysler, who came out with filters three years later, but could declare their products as maintenance-free and Euro 4-compliant. Fortunately for PSA, its third-generation filter in 2003 finally met both of these requirements, so the comparison quickly became a moot point.

Individual companies may have the same level of capability to meet more stringent standards, but they vary considerably in their attitude towards regulation. While BP and Tosco were willing to bring US diesel fuel sulfur levels down to 15 ppm, large companies like ExxonMobil and ChevronTexaco joined independent refiners in strongly opposing to the 15 ppm limit. Those large companies have the size and investment capacity to handle the new standard, and benefit from squeezing out small, independent refiners from the market. However, their overall resistance to additional costly regulation may have outweighed any perceived competitive benefits. Now that 15 ppm is the required sulfur level, ExxonMobil and ChevronTexaco will still have an advantage over the smaller refiners. They may have foreseen their competitive benefit irrespective of their regulatory position, weakening the impetus to come forward earlier.

10.5.3 Industry pressure

Throughout the regulatory cycles explored in the previous chapters, there were instances when individual companies or an entire industry, in the case of emission control manufacturers, would almost certainly benefit from more stringent regulation. Their technology surpassed regulatory requirements and was cost-effective enough to be introduced in the market. Nevertheless, those companies chose not to push for greater stringency, or at least do so more passively than their economic interest would suggest. These would-be first movers face pressure from other industry sectors and from competitors not to advocate for more stringent regulations.

Emission control manufacturers have always had to walk a fine line between supporting more stringent regulations to create demand for their products, and not appearing to antagonize automobile and engine manufacturers by actively supporting more costly regulation. Keeping a low profile in regulatory activities has become increasingly important, because more OEMs are working exclusively with one catalyst supplier at the early stages of product development, rather than selecting a supplier at the end of the development process, or sourcing from various suppliers for the same engine platform. The emission control industry addresses this dilemma by using their trade associations to make their arguments with the regulators.⁵⁶ The most well-known trade associations include US-based MECA (Manufacturers of Emission Control Association) and Europe-based AECC (Association for Emission Control by Catalyst). The companies can stand behind a group of companies, without any single company having to take the initiative and risking a boycott from the OEMs. According to one experienced veteran of the emission control industry, his company used to get phone calls from auto companies in the 1980s, asking them to stop promoting regulations, but in recent years, this has been occurring less. Emission control manufacturers could stand to lose lucrative contracts if they were perceived as lobbying regulators against the OEM's wishes.

In some cases, emission control manufacturers have tried to make their support of regulatory activities anonymous, preferring to demonstrate their technologies "behind the scenes." During the first year of Germany's "No Diesel without Filter" campaign, the NGO organizers were unable to get any financial support from filter manufacturers. Even though they

⁵⁶ Interviews with senior experts in the diesel vehicle industry, 2005 and 2006.

clearly had a financial interest in promoting filter use, they were afraid to anger their potential clients. Later into the campaign, some filter manufacturers did contribute funds but requested anonymity. DUH, the German environmental NGO leading the campaign, had broad level support from the manufacturers but could not publicize the individual donor companies. When DUH installed a filter on a Mercedes SmartCar, it could not reveal the brand of filter used.

Manufacturers frequently offer prototypes for regulators to conduct testing. In the late 1990s, in preparation for California's LEV II rulemaking, an emission control manufacturer participated in a light-duty truck test program with the California Air Resources Board. At the time, light-duty trucks were subject to weaker emission standards than passenger cars. The testing could demonstrate that light-duty trucks could reach passenger car standards. The manufacturer did not reveal its participation, fearing that auto companies would boycott its products. However, the auto companies eventually discovered its involvement, and they were not pleased.⁵⁷

A more industry-friendly strategy would be to provide information about R&D activities and future products to industry and to regulators at the same time, so that they are not accused of privately feeding data to regulators. Emission control manufacturers have been very forthcoming about presenting their latest technologies at conferences, publishing in industry journals like SAE, and participating in pilot projects and subsidy programs – more indirect ways of advocating for more stringent regulations.

Pressure from within the same industry to oppose stringent regulations was a major deterrent to first-mover behavior. Typically, a regulated industry resists additional environmental regulation, so tension arises when one firm or a subset of firms in the industry adopts a technology or stance that is inconsistent with the industry view. Trade associations and industry groups aim to reach consensus on regulatory issues, so it is unusual for a member company to adopt a different position. Most of the company and industry association representatives interviewed explained the importance of showing a unified front. Unity gives them greater influence with regulators and elected government officials. In the rare case where there is a difference in opinion, trade associations will either pick a majority position or stay silent on the issue altogether. They would expect the companies to not emphasize the difference to the public or the media, in order to maintain a show of solidarity.

⁵⁷ Interview with a senior industry expert, August 2005.

Even among companies that may have had a technological advantage in deviating from the industry position, their representatives described little dissent in their industry. However, their actual position and behavior might lead to some conflict within the industry. For instance, Toyota's product line of more fuel-efficient and lower-emission vehicles suggests that it might gain an advantage from differentiating itself from its fellow automakers. According to EPA and CARB regulators, Toyota and Honda are often ahead of the curve in terms of technology and regulatory compliance, and are very open about sharing their technology development with technical regulatory staff. Even so, Toyota USA has chosen to downplay its differences from the rest of industry. A Toyota representative in the US noted that the company has never come forward to show they oppose what its industry association, the Alliance of Automobile Manufacturers (AAM) is doing.⁵⁸ Demonstrating technical competence is less aggressive than actively pursuing more stringent regulations, an action that would give first movers many enemies in the industry.

The US auto industry might be a more tight-knit, unified group than the US oil industry, which did have dissenters on the 15 ppm diesel sulfur standard. BP and Tosco's support of the standard differentiated them from other oil companies.⁵⁹ Even though BP and Tosco generally supported the standard in their public comments to EPA, the companies tried to keep a low profile in the public eye. Representatives from BP with experience in the US and UK said that within the oil industry, individual companies are always free to retain their individual points of view. BP did not feel pressured to adopt the same position as its trade associations, and if differences are too great, BP can withdraw, as it did with the Global Climate Coalition.⁶⁰

PSA's introduction of diesel particulate filters in its passenger cars angered German automakers, who prided themselves in reaching Euro 4 standards without any filters. Although PSA worked with regulators in testing their technology and marketed the standard filter option in Germany, they were careful not to get involved in the "No Diesel without Filter" campaign or appear to support more stringent PM standards. According to representatives at both PSA and the German environmental group DUH, PSA was invited to participate in the filter campaign but

⁵⁸ Interview with Toyota representative, September 12, 2005.

⁵⁹ Interview with a senior expert in the diesel vehicle and fuel industry, February 2003.

⁶⁰ Interviews with Gary Stewart, General Manager, State Government Affairs, BP, August 16, 2005, and Kathryn Shanks, VP External Relations - Environment, BP, July 25, 2005. BP withdrew from the Global Climate Coalition in 1997 because the GCC opposed any policies supporting CO₂ emission reductions, whereas BP supported taking policy action to address climate change.

refused, preferring to keep its distance from the NGO alliance's activities. The company did not want to antagonize the other automakers. It recognized that it could not go alone with filter technology – others would have to adopt filters in order to make the technology viable and affordable. Technology introductions happen repeatedly and congenial relationships are desirable, so “sportsmanlike” conduct is essential. This time, PSA had the lead on filters, though in the future another company might take the lead on another technology, and then choose to attack PSA in retaliation for its past behavior.⁶¹

PSA's filter decision was very unusual. Although different companies take the lead on various automobile technologies, it was not expected that a company would introduce an emission control device not required by upcoming legislation. Had PSA been a German company instead of a French company, it is unlikely that it would have introduced the filters. According to a senior German environmental official at UBA, one or two German manufacturers had prepared to introduce filters earlier, but they stopped production because they could not reach agreement within VDA, the German auto industry association.⁶² VDA provided a strong constraint on first-mover behavior from its members. Non-VDA members like Renault, Fiat, and Toyota began promising to add filters once they saw the customer demand in Germany. When Ford Europe, a VDA member, chose to license PSA's filter technology for its vehicles, some German companies tried to pressure Ford to stop offering filters.⁶³ PSA's reputation as a diesel technology leader and its status as an outsider to the tight-knit German auto industry allowed it to pursue its own strategy without much deference to the German companies.

Even companies that achieve compliance ahead of schedule face criticism from their competitors. Caterpillar heavily criticized Cummins and Detroit Diesel's new engines after the EPA certified them as meeting the October 2002 deadline. When International certified its school bus engine well ahead of the 2007 deadline, Caterpillar argued that it was much easier for International to meet the standards because it sells in a much narrower range of engine types. Many industry observers note that trade associations tend to defer to the least common denominator when deciding on a regulatory position. While this promotes consensus and camaraderie, it can discourage the more proactive companies from supporting more

⁶¹ Interview with Bruno Costes, Technical and Political Affairs, PSA Peugeot Citroën, September 3, 2004, and Jürgen Resch, Executive Director, Deutsche Umwelthilfe e.V. (DUH), September 3, 2004.

⁶² Interview with German UBA representative, October 2004.

⁶³ Interview with Jürgen Resch, Executive Director, Deutsche Umwelthilfe e.V. (DUH), September 3, 2004.

environmentally protective policies. Granted, every company is free to select its own technologies and products. However, companies would be more likely to act as first movers and garner success if they can convince their industry peers to follow their example. In countries in the EU and in Japan, it is unlikely that one or two lone first movers in industry would be able to steer the government towards policy changes. Whereas the US may base its technology-forcing regulations on progress by the industry leaders, the EU and Japan seek to ensure that the majority of industry can meet the regulations.

Pressure from other companies acts as a powerful constraint against self-promotion and lobbying for more stringent regulation, even if the company has a clear competitive advantage. Companies prefer to stay out of the limelight, wait for the regulations to be finalized, and then promote their technology afterwards.

10.5.4 Lack of infrastructure

The lack of supporting infrastructure or complementary technologies can delay or block the first-mover technology introductions and/or limit their effectiveness. Because of the interdependence of engines, fuel, and aftertreatment devices in emission control, a “missing link” can prevent the adoption of a cleaner technology. Many aftertreatment technologies, such as Toyota’s NO_x adsorber in its D-CAT system and Johnson Matthey’s CRT particulate filter, are very effective at reducing emissions, but cannot reach their 90% or higher conversion rate without ultra-low sulfur diesel (ULSD) fuel. The main argument for ULSD is not for its direct role in reducing PM and sulfate emissions. Rather, it is most valued for its enabling role in the installation of catalyst and filter equipment on new and in-use vehicles. Although Johnson Matthey had their CRT filters ready for commercialization in the 1980s, the lack of a ULSD distribution infrastructure delayed its introduction until the early 1990s in Scandinavia, and the late 1990s in the rest of Europe and the US.

Urea infrastructure is a constraining factor in the adoption of SCR technology, which has the support of the majority of European heavy-duty vehicle manufacturers and regulators. Difficulty ensuring a reliable urea supply threatens to put a freeze on SCR’s popularity. In Japan, Nissan Diesel stood alone in wanting to use SCR, so it had to develop the urea infrastructure on

its own. Because of the large geographic size and decentralized diesel fuel distribution infrastructure in the US and Europe, an economically viable urea infrastructure depends on the majority of manufacturers' committing to SCR.

10.6 Public and private outcomes

Table 10-3 summarizes the major early- and first-mover companies discussed in the regulatory cycles in Chapters 5-9. It omits the myriad activities of emission control manufacturers, because it is almost always in their commercial interest to support more stringent regulation. The list focuses on industries that would normally be opposed to more regulation. First movers introduced technology that surpassed any existing or known upcoming standards, while early movers introduced technology ahead of known compliance deadlines. While both types of behavior resulted in public health and environmental benefits, first movers deal with greater uncertainty and have greater impact on the development of future regulation and technology.

The public benefits of proactive behavior often extended beyond the individual actions of one government or company. Governments engage in their own type of regulatory competition by trying to pass the most ambitious emission or fuel standards. The successful introduction of a cleaner product by one firm frequently had the effect of causing a diffusion of the associated technology (e.g. particulate filters, ultra-low sulfur diesel) throughout the industry.

Private benefits, if observable, came in the form of stronger sales and contracts, either through technology licensing or supply contracts. In many cases, private benefits to the companies were not easily measurable or directly attributable to environmental performance. Instead, the benefits were often intangible: improved relations with environmental groups and regulators, preparedness for the next round of regulations, or an environmentally-friendly public image. Public benefits usually consist of emission reductions occurring earlier than required by the upcoming compliance deadline.

In several cases, products relied on complementary technologies for deployment or full benefits. Without the necessary urea infrastructure, DaimlerChrysler/Siemens and Nissan Diesel could not introduce their SCR-equipped trucks. Ultra-low sulfur diesel fuel had two-tiered

benefits – the immediate but minor pollutant reductions from using the fuel, and the dramatic reductions made possible by installation of aftertreatment equipment. Toyota D-CAT technology has been constrained by the availability of ULSD. D-CAT-equipped cars were initially sold only in the UK and Germany, which have 100% ULSD adoption.

Table 10-3: Public and Private Outcomes from Early Compliance or First-mover Behavior

Ch	Technology (1st commercial introduction)	Motivation	Type of behavior	Private outcomes	Public outcomes	Regulatory impact
5	VW's Ecomatic diesel-electric car (1994)	Improve company image; electric car competition	First mover	High cost and low sales volumes (~2,000) ended production in 1995	Compared to diesel Golf, 22% lower CO ₂ and fuel consumption, 60% lower PM, 25% lower HC+NOx, but not enough to reach Euro 3	None observed
5	Toyota, PSA, VW, Vauxhall, Audi, Fiat, PSA, BMW diesel cars (2003)	UK and German tax incentives	Early compliance	Increased sales because cars qualify for tax incentive	Euro 4 compliance 2 years early	None observed
5,6	Toyota DCAT/DPNR system (2003)	Prepare technology for Euro 5	First mover	Weak sales (~3,000 in 2005) because of no added incentive and lack of ULSD; stronger relationship with EU regulators	90% lower PM and 50% lower NOx from Euro 4	Unsuccessful attempt to influence Euro 5 NOx limits, Data to support EPA's equal treatment of diesel and gasoline cars in Tier 2; influence on US 2007 HD NOx standard, potential influence on Euro 6 NOx limit and US post-Tier 2
6	PSA particulate filter (2000)	Protect diesel market share	First mover	Strong sales and reputation; business for filter subsidiary Faurecia; German market share doubled from 1999-2003	96% lower PM from Euro 4; over 1 million filter-equipped cars by 2005; other companies also added filters	Low-PM tax incentives in several European countries; Very low PM standard in Euro 5; Low PM expectations for US Tier 2
8	International Green Diesel Technology (2001)	Protect diesel market share; CNG competition in bus market	Early compliance	Retrofits and new buses qualify for public subsidies; 200 Green Diesel buses sold in CA	200 buses which comply with 2007 NMHC and PM standards; lower operation costs for municipalities and school districts than CNG	2007 US heavy-duty rule and 2006 ULSD requirement; Demonstrated need for ULSD
8	Daimler-Chrysler/Siemens SiNOx SCR (2004)	Demonstration of superiority over SCR; German toll incentives and other tax schemes	Early compliance	Ability to win over EU regulators to the urea concept, and maybe eventually EPA	3-5% fuel economy benefit, 65-85% lower NOx	R&D had possible influence on Euro 4 NOx standard; Government acceptance of urea SCR as dominant heavy-duty engine strategy for Euro 5; Possible impact on US in post-2010; German tolling scheme favors SCR

Ch	Technology (1st commercial introduction)	Motivation	Type of behavior	Private outcomes	Public outcomes	Regulatory impact
8	Nissan Diesel SCR system FLEDS (2004)	Allow time for urea infrastructure to be established	Early compliance	Licensed technology to Mitsubishi Fuso	Compliance with 2005 standard 1 yr early	None observed
9	Greenery 50 and 10 ppm diesel fuel (1992)	Tax differentials (in Sweden, UK, Germany, Switzerland, Finland)	Early compliance	Fuel sales volume grew sixfold from 2001-2004	w/o aftertreatment, reduces PM by 10-30%, NOx by 5-11%, SO2 by 99%; w/ aftertreatment, reduces PM, HC, CO by 90%	Influence on Euro 4 and Euro 5 standards to move towards widespread 10 ppm fuel sulfur levels; Promoted tax incentives for ultra-low sulfur diesel in UK
9	BP 50 ppm and 10 ppm diesel fuel (1999)	Tax differentials in UK, Germany, Denmark	Early compliance	Improved public image; competitors followed suit very quickly	50 ppm: w/o aftertreatment, reduces PM by 30% and SO2 by 85%; w/ aftertreatment, reduces PM, HC, CO by 90%; annual UK road transport in 2001-04: reduced PM10 by 5.3-5.5% and NOx by 0.4%; Available in all UK and select EU cities	Evidence to US regulators of feasibility of ULSD; Unsuccessful attempt to get tax incentives in France
9	ARCO/BP 15 ppm ECD diesel fuel (1999)	Protect diesel market share after CA declared diesel a toxic air contaminant; CNG competition	First mover	Improved public image; fleet contracts for ULSD; preparedness for future 15-ppm requirement	w/o aftertreatment, reduced PM by 10% and SO2 by 90%; w/ aftertreatment, reduces PM, HC, CO by 90%; ULSD available in all CA by 2002 and for fleets in US; Enabling technology for new or retrofitted buses and trucks	Boosted EPA's confidence in the feasibility of the 2006 requirement for 15 ppm ULSD
9	Tosco 15 ppm diesel fuel (2000)	Demand from municipal fleets in NYC; CNG competition	First mover	Improved public image; fleet contracts for ULSD; preparedness for future 15-ppm requirement	w/o aftertreatment, reduced PM by 10% and SO2 by 90%; w/ aftertreatment, reduces PM, HC, CO by 90%; ULSD for New York City's 4400 transit buses; Enabling technology for new or retrofitted buses and trucks	Boosted EPA's confidence in the feasibility of the 2006 requirement for 15 ppm ULSD

Note: Table does not include activity by emission control manufacturers.

10.6.1 Comparing across cases

Earlier in this chapter, fiscal incentives, market preservation, and technology development were discussed as key motives for early and first-mover behavior. Table 10-3 shows a relationship among motive, size of response, and type of behavior. Tax incentives have been a strong motivator for early movers, such as auto manufacturers' early Euro 4-compliant vehicles and fuel companies' ultra-low sulfur diesel introductions in Sweden, Finland, UK, and other parts of Europe. They help to motivate the majority of companies into technology adoption because of the certain financial benefits and intention to support best available technology. First-mover behavior is exhibited by a much smaller number of companies because of the greater uncertainty in the competitive advantages of stepping forward. The first movers in the cases were most often motivated by the desire to protect market share from a competing technology (VW's diesel-electric car vs. electric cars, PSA's diesel cars vs. non-diesel cars, and ARCO/BP/Tosco's diesel fuel vs. CNG). The Toyota first-mover case does stand out from this group, in that the company has far less at stake with diesel technology because of its strong portfolio of gasoline and hybrid gasoline-electric vehicles. However, realizing Europe's preference for diesels, Toyota anticipated the need for further emission reductions and used the D-CAT technology launch to prepare for a more full-scale introduction when required by future regulations.

The tendency of first-mover behavior to arise from the desire for market share protection or regulatory preparedness reveals the important role that interest group and regulatory pressure has on the pace of technology introduction. Several of the competing technologies to diesels, like electric-powered and CNG vehicles, rose in popularity because of growing attention to diesel exhaust's harmful health effects. When environmental and regulatory groups endorsed switching to competing technologies, companies in the diesel vehicle industry responded by making their technology cleaner. While these were defensive responses, they altered the previous anti-diesel mindset of environmental groups and many regulators, which later came to endorse the clean diesel technologies.

The cases document great variability in the level of success of the corporate strategies. Significant private financial and reputational benefits and public environmental benefits are good

success indicators. While there were instances of non-compliant activities discussed in Chapter 7, there no observed cases of pure rent-seeking, where companies successfully used regulations for their own competitive advantage, without any significant benefits to the environment. However, the most successful cases had limited private benefits and significant public benefits. The greatest public benefits came from behavior that resulted in the widespread adoption of an environmentally superior technology or performance level. If considered from the standpoint of health and environmental protection, the big early and first-mover successes are the PSA filter introduction, several auto manufacturers' early Euro 4 compliance, Greenergy and BP's clean fuels introduction, and accelerated compliance deadlines by the auto and oil industries in Japan. Regulatory activity by first-mover governments deserves credit for the last three cases. The existence or expectation of fiscal incentives gave greater traction to the technology introductions. Customers saw value in purchasing the new technology, not just because of environmental benefits, but because tax schemes or subsidies promised to offset the additional cost. Other products, like International's Green Diesel Technology, Toyota's D-CAT system, and BP and Tosco's ULSD in the US, sold in very limited quantities. They had clear emission benefits, but they did not have accompanying government incentives to support widespread adoption. Many companies began with technology demonstrations or small-scale sales first. Some remained at this stage, like VW's Ecomatic, but others quickly expanded in production once regulatory or customer demand came into play.

There were no indications of heavy lobbying by companies for more regulatory stringency. Instead, the results of technology demonstrations spoke for themselves. Since regulators base rulemaking on technological progress, many of the technologies influenced the upcoming level of stringency or boosted regulators' confidence about the feasibility of proposed standards.

10.6.2 Paired comparisons

Several of the cases share similar characteristics, but result in very different outcomes. Pairing such cases for comparison is a useful exercise for understanding the reasons behind those differences.

PSA's filters and Toyota's D-CAT technology

PSA's particulate filter introduction shares several similarities with Toyota's D-CAT technology. Both were first movers because they introduced diesel car technologies that exceeded known existing or upcoming regulations. The companies targeted the European market, with their introductions occurring before the implementation of the 2005 Euro 4 standards and before the finalization of the Euro 5 standards. They performed technology demonstrations and field studies, freely disclosed performance data at industry and regulatory meetings, and received praise from environmental groups and the media. Their actions deviated from mainstream industry, predominantly drawing criticism from the German auto manufacturers. PSA is an outsider to the German auto industry just as Toyota is an outsider to the EU auto industry. However, filter adoption became a Germany-wide, and later, an EU-wide trend, while sales of D-CAT-equipped Toyota diesels remain small. PSA added its filter as standard in its models, while Toyota offered the D-CAT system for an extra cost. This still does not explain the discrepancy because German customers did pay extra for filter-equipped diesels from other manufacturers who offered filters as an added-cost option. Chapter 6 discusses the likely reasons for the starkly different outcomes, concluding that PSA benefited from earlier product introduction timing relative to Euro 5 standard-setting, higher NGO involvement, greater public attention to PM than NO_x, and compatibility with the existing fuel infrastructure. Toyota's sulfur-sensitive D-CAT system was constrained by the limited availability of ULSD.

PSA's filters and International's Green Diesel Technology

PSA and International Truck and Engine were primarily motivated by diesel market share protection. Both introduced filter technologies ahead of requirements, and were very focused on PM reduction rather than NO_x. They recognized that the growing antagonism towards diesels came from those worried about the health effects of diesel PM. Both companies have diesels as their core business – PSA in small diesel passenger cars and International in medium-duty diesel engines and trucks and buses. Their different outcomes – widespread filter popularity vs. limited sales of Green Diesel buses – may come from industry-specific differences. Passenger car filters cost considerably less than heavy-duty engine filters. Passenger car models also have higher volumes across which to spread the costs. Heavy-duty engines have tougher durability requirements because of their usage patterns.

BP in Europe and the US

Another interesting paired comparison takes the same firm and technology – BP’s ULSD – and seeks to explain why the company had such different experiences in Europe and the US. The availability of government incentives offers the best explanation for the differences. In Europe, BP frequently followed on the heels of tax incentives as fuel tax differentials made ULSD competitive with regular diesel. The company quickly introduced ULSD in all its retail stations in countries with favorable tax incentives. In the US, BP had to pursue an entirely different strategy because the US had no tax incentives for introducing ULSD before the 2006 deadline. BP sold ULSD in limited quantities to municipal or school district fleets. It offered ULSD statewide in California, because state laws require buses run on the fuel. On the upside, BP had more influence on regulations in US than in EU because it had already successfully marketed ULSD in Europe.

SCR technology in Europe and Japan

The most recent round of heavy-duty engine emission standards have required engine manufacturers to decide between SCR and non-SCR strategies. While the US has so far taken a strictly non-SCR approach, the choices by manufacturers in the EU and Japan have been mixed. DaimlerChrysler and Nissan Diesel have been the SCR technology leaders in the two regions. Although they have picked the same technology path, geographical and logistical differences influence the extent to which each manufacturer had to get buy-in for their technology. It was crucial to DaimlerChrysler to get other manufacturers to adopt SCR and to persuade European regulators of its superiority to EGR. Installing the AdBlue urea infrastructure would be worthwhile only if the vast majority of trucks ran on SCR systems. In contrast, Nissan Diesel was able to go alone on SCR in Japan because of the country’s relatively small size and more centralized fuel distribution network. With fewer AdBlue refueling points, Nissan Diesel could manage to single-handedly establish the urea infrastructure for its truck customers.

10.7 Technology development as an instrument for influencing regulation

Companies have used a variety of tools to influence environmental policy. Traditional tools include lobbying elected officials who may have influence on senior environmental officials or raising national competitiveness and employment concerns at the time of rulemaking.

Wary of introducing a product for which there is no regulatory or market demand and concerned about reproach from fellow companies, potential early or first movers have taken on more indirect ways of promoting their technology or ability to surpass existing regulations, namely:

- Presenting new technology at industry events, conferences, and other public forums.
- Meeting one-on-one with regulators to confidentially discuss proprietary technology under development.
- Teaming with public and private partners on technology demonstration projects.
- Selling the product in small volumes or on a limited basis to a niche market.
- Choosing to stay silent or neutral about proposed regulations while the rest of the industry launches a vocal opposition

These less aggressive ways of showcasing a product or technology are likely to still influence regulators, who are eager to find evidence of technological progress. Regulators may then use the technology leader's success for rulemaking or to persuade other companies to follow suit. Environmental interest groups and other NGOs with a strong focus on diesel issues are also quick to pick up on the latest technology developments. They often do the more vocal campaigning in favor of a certain technology or more stringent standards. However, their tactics are perceived as extreme, such as in the "No Diesel without Filter" campaign. Even though the campaign organizers praised PSA's filters, PSA intentionally steered clear from its activities. Instead of engaging in self-promotion and advertising, a company gains more credibility among the public when its technology is validated by regulators or environmental groups.

10.8 Recommendations

The findings from the cases developed in this thesis highlight many areas where corporate strategy, regulatory policy-making, and interest group activity can be improved to enhance private and public benefits. Based on the lessons learned from the cases, four key recommendations on fiscal incentives, environmental interest group/NGO involvement, communication of technological progress, and regulatory timing are discussed below.

Recommendation #1: Governments should use fiscal incentives as a tool to promote the diffusion of cleaner technologies.

The past chapters have shown that in countries and regulatory cycles where fiscal incentives exist, customers have more rapidly adopted the new, less polluting technologies. The incentives spur customer demand, which in turn gives companies the certainty they need to produce the cleaner products. Tax differentiation favoring the less polluting product ensures that the incentives are revenue-neutral. Fiscal incentives would be most helpful in promoting early compliance, rather than first-mover behavior, because it assumes target levels are already established by regulators. One possibility is to use industry's progress as a "moving target," such that products cleaner than the industry average receive a tax reduction and more polluting products face a higher tax.

This type of scheme is commonly known as a "feebate" program. Feebates have been increasingly discussed by energy experts as a cost-effective and revenue-neutral means to reduce vehicle fuel consumption and/or greenhouse gas emissions (Greene, Patterson et al. 2005; Jansen and Denis 1999; Johnson 2005; Johnson 2006; Michaelis and Davidson 1996). A vehicle feebate would charge an extra fee on purchases of more polluting vehicles and give a rebate for purchases of lower-emitting vehicles. A feebate program is based on a vehicle model's emissions performance relative to an industry average, which would presumably change as technology improved. Sweden's highly successful feebate-based program for large combustion plants reduced NO_x levels by 50% in 1995 from 1990 levels (Johnson 2006). Although vehicle feebate proposals have focused primarily on reducing CO₂, a program involving multiple pollutants or characteristics, such as fuel economy, CO₂, NO_x, PM, HC, and other pollutants might be possible.

California attempted to pass a feebate program in 1990 called “DRIVE+” (Demand-based Reductions in Vehicle Emissions). It reduced sales tax for vehicles with below-average fuel consumption and vehicle emissions (pollutants and CO₂) and raised sales tax for those with above-average fuel consumption and emissions. An annual review would adjust the fee/rebate schedule to maintain revenue neutrality. DRIVE+ included cars and light trucks, avoiding the loopholes for heavier vehicles found in weight class-based proposals. Although the bill passed by the legislature, it was vetoed by the governor (Schuster, Schuster et al. 2004).

Feebate programs encourage companies to continue innovating to be “above average.” They are rewarded by greater customer demand. Customers respond to the feebates by purchasing the cleaner vehicles in higher proportions than they would without the program. This helps to get around the information asymmetry that regulators face in assessing technologies. The industry baseline is determined directly by technological progress, not pre-established standards. There seems to be greater receptivity to feebates in Europe, where many countries already use tax differentiation for fuels.

Tax incentives have been very popular in Europe, especially Scandinavia, UK, Switzerland, the Netherlands, and Germany. However, it may not be easily transferable to Japan or the US. The Japanese regulatory environment encourages industry-government cooperation, where industry promises to meet a certain level of stringency. In return, the government frequently gives industry-wide subsidies to help alleviate costs in the first few years of a new regulation. In the US, tax incentives are popular instruments for encouraging cleaner choices, but penalizing more polluting choices with higher taxes would face political opposition. Although cigarette taxes are a notable exception, American culture’s emphasis on free choice and individuality generally discourages the use of tax instruments to punish undesirable customer behavior. Any tax differentiation policy would have to be accompanied by a strong consumer-supported movement against polluting technologies or creative packaging with more politically and socially pressing concerns, such as national energy security and fuel efficiency. The 2005 US energy bill did take the latter approach with vehicle fuel economy, but it emphasizes incentives over penalties. It offers tax incentives for the purchase of fuel-efficient hybrid, clean diesel, and fuel cell vehicles, but sets no penalties for less efficient vehicles. The “gas guzzler tax” on highly polluting cars still exists, but it exempts the light trucks and SUVs, far more fuel-consuming than automobiles. Unfortunately, these types of incentives and taxes only affect car

sales at the margins. Penalizing more polluting vehicle models through a feebate-type program would have broader impact, but would also draw strong opposition from major producers of light trucks and SUVs. This resistance might be overcome through mobilization by producers of cleaner, more efficient vehicles, regulatory agencies, and environmental groups.

By focusing on shaping customer behavior through economic incentives, regulators can avoid the problem of manufacturers' producing very clean products, but having no customers to buy them. Economic incentives may also be used to help phase-out older technologies. Although it is unlikely that the EU or the US will follow Japan's example of retroactively regulating the emissions of in-use vehicles, a differential vehicle tax favoring newer and cleaner vehicles may encourage more vehicle turnover. A penalty on very old vehicles could potentially hurt low-income individuals. As a solution, state governments could implement programs to trade in old, polluting vehicles for a voucher to apply to purchasing a new or newer car or a transit pass.

The countries that have been first to implement tax incentives often improve national competitiveness as well. Their domestic companies are better equipped to handle regulatory change when other markets' regulations become more stringent. The tax incentives push their home companies to invest and innovate in cleaner technologies, which can ultimately be transferred to other countries.

Recommendation #2: Public groups and NGOs can leverage their knowledge about technology development to make a strong impact on regulatory and corporate decision-making about clean technologies.

Anti-diesel movements in the US, Japan, and Europe had a strong impact on the stringency of government regulations and on corporate decisions. The environmental and public health NGOs supported their campaigns with scientific evidence from medical studies and technology assessments from government and private research projects. Despite the variety and quantity of information available, they are able to pull together the relevant pieces to build a focused argument for more protective regulation. This does require that NGOs have staff members or volunteers who are technically and politically savvy and who interact frequently with government and industry representatives. NGOs also have more freedom to use aggressive and even sensationalistic tactics not typically practiced by government agencies or companies

seeking to push for greater emission reduction. NGO activity can foster widespread customer awareness, which then creates the customer demand for cleaner products that persuades companies to invest and market less polluting technologies. Crucial to the NGOs' effectiveness is their ability to leverage concrete evidence of the technical and economic feasibility of their proposed regulatory changes.

In some early-mover and first-mover cases, companies felt compelled to introduce cleaner products to counter the prevailing idea that diesels are highly polluting. Fear of losing market share was a major driver. Even though the companies' actions seemed more reactive rather than proactive environmental strategies, they still achieved public benefits. The research findings imply that well-organized and focused public or NGO campaigns can shift public opinion and alter company strategies.

Recommendation #3: In an environment where openly supporting more stringent regulations might risk forfeiting customer loyalty or antagonizing the rest of the industry, companies should make use of technology demonstrations and public-private studies, which may be more credible and influential than independent claims from manufacturers.

Technology demonstration usually occurs once a company already has a product ready for commercialization. Conducting testing, demonstration projects, or pilot studies means that the upfront R&D investment must already have been made. A production-ready product attracts strong interest from regulators and NGOs alike. By allowing the capabilities of its product to speak for itself, a company can avoid accusations by its competitors of secretly lobbying regulators for more stringent regulations or tax incentives. It can also test how its product works within the entire vehicle-road system, especially if special fueling infrastructure is needed. Showing off the product as part of a well-coordinated public relations plan can also enhance the company's image as an environmental leader, winning reputation points with NGOs and the public. For technology vendors, like catalyst manufacturers, public demonstration projects are essential. Actual on-road results can more convincingly showcase their products' effectiveness to OEMs than data generated in-house at a laboratory.

Such projects indirectly influence regulatory decision-making, because regulators routinely use the results as a basis for future requirements. Programs that involve the regulatory agency as a partner can strengthen the relationship between the company representatives and the

regulators. When it is time to sit down one-on-one to discuss technological progress and future regulations, the parties will have already established trust and good will, hopefully making for less contentious debate in the standard-setting process.

Recommendation #4: Regulatory agencies and companies should establish both short-term and long-term performance-based emission targets.

Earlier in this chapter, it was explained that the US implements more dramatic emission reductions, but with longer time periods between new regulations. For instance, the US Tier 2 standards began in 1994, 10 years after Tier 1 first took effect. The phase-in period (usually 3-5 years) for US light-duty vehicles accommodate the typical 3 to 4-year lifespan of a given model's production run, allowing manufacturers to stagger the upgrade of production lines (EPA 1999c). Based on interviews with auto and truck company representatives, industry prefers the certainty that longer-term emission standards bring, rather than shorter-term standards that change every 3 to 4 years. On the other hand, longer time intervals make it harder for regulators to predict which technologies will be viable in the future, so it is important for regulators to monitor industry progress closely. While the longer time intervals allow for more innovative activity, the new vehicles entering the fleet annually have the same emission levels for several years. Except for natural fleet turnover and vehicle retrofits, there is no additional emission reduction from the vehicle fleets.

The relatively short 3- to 4-year lead times for new emission standards in Japan and Europe are less conducive to technology-forcing. The length of time is inadequate to include extensive R&D, experimentation, field testing, and mass production. There may be enough time for only the latter two. Such a short timeline assumes that the product is close to commercialization when the regulation is established. Japanese and EU regulations are based on best available technology, usually one that can be accomplished by the majority of companies. The advantage of this approach is that regulators can incorporate the latest developments in emission control technology more quickly. Through more adaptable, the shorter timelines preclude more ambitious emission reductions and seldom incorporate the type of technology-forcing that can lead to technological breakthroughs.

A hybrid approach would combine the best of both styles. After consulting with industry, regulatory agencies could set longer-term targets 8-12 years in advance, and then set

intermediate standards within that time frame, at 3-4 year intervals. For the auto and truck industry, these intervals would more closely correspond to the length of their production runs, so that changes in emission requirements coincide with model changes. Industry benefits from having some regulatory certainty and information to plan their emission reduction R&D well into the next decade. The public benefits from having incremental improvements to emission levels, rather than having to wait many years for the next set of requirements to take affect. Also, with more rounds of regulation to test their latest technology, companies have more opportunities to gather feedback and improve for the next set of targets.

The hybrid approach still does not get around the problem of regulators misjudging industry's long-term progress. If the long-term targets are too lenient, the full potential for emission reduction is not met. If the long-term targets are too strict, industry will be unable to meet them and the regulators will have to postpone or weaken them, which lowers the credibility of future targets. A feebate structure, which was discussed earlier in Recommendation #1, might solve this dilemma by using technology development as a moving target. The intermediate standards could be structured with feebates, which reward above-average companies with rebates on cleaner vehicles and penalize below-average companies with fees on more polluting vehicles. They institutionalize the regulatory competition that otherwise happens sporadically. The industry average and rebate/fee amounts can be revisited every 3-4 years, and adjusted based on companies' progress.

While industry will appreciate the certainty of the long-term targets, they may be resistant to the flexibility of readjusting interim standards or feebate rates every 3-4 years. In particular, the companies that tend to be technology followers rather than leaders will fear that the faster progress of technology leaders will tighten standards. Even government regulatory agencies may not readily accept such a hybrid approach because it requires regulatory staff to more frequently assess industry progress and set appropriate interim emission levels. However, a compromise plan might be one that guarantees industry a fixed long-term target for an 8-12 year time horizon in exchange for interim steps that accelerate interim technology adoption.

10.9 Conclusions

This chapter has brought together the insights gained from the regulatory cycles in the past five chapters. It has explained how a company's regulatory and market context affects its potential for competitive advantage from regulation. Proactive governments have a major influence over technology development in industry because their fiscal and regulatory policies spur innovation and technology adoption. Variations in regulatory stringency, timing, and compliance details shape the competitiveness of firms. The US has had more technology-forcing standards with longer regulatory cycles, while the EU and Japan have taken on smaller, incremental changes in shorter time frames. Since lead firms tend to draw attention to their environmental performance at later stages of product development, shorter, more frequent regulatory cycles put their technology in a better position to influence policy. Compliance details often escape the notice of the public and even environmental groups, but regulatory loopholes can undermine environmental benefits and distort competition. Existing market conditions are closely entwined with the regulatory environment. Tax policy, whether motivated by environmental or economic concerns, increases the attractiveness of introducing cleaner technologies. The technological strengths and the product portfolio of individual firms determine their preparedness for future regulations.

Even if firms do have the technological capacity to exceed regulatory requirements, there are external and internal challenges that restrict their willingness to step forward or their ability to reap benefits from competitive regulatory strategies. This has resulted in a diversity of responses among firms with similar capacity to meet more stringent regulations. According to the regulatory cycles studied, companies seldom strategically seek to shape the terms of competition by supporting more stringent regulation. Instead, corporate behavior is driven by other motivations that consequentially result in their technology influencing regulatory policy. The weak form of competitive regulatory strategy prevails, with technology leaders preparing for more stringent regulations through R&D and product introductions. In cases where companies did accelerate technology introductions, government-sponsored fiscal incentives have been the strongest driver. Meanwhile, the desire for market preservation and/or technology development has often been behind first-mover behavior.

Companies, even emission control manufacturers, seldom advocate directly for greater stringency, but their technology demonstrations do catch the attention of regulators and NGOs, who then go on to pursue tighter standards. Overall, proactive behavior has been a rarity because of the many obstacles firms face. The lack of a business case is probably the greatest disincentive. Cautiousness about overstating a product's performance or dissenting from the rest of industry also discourages firms from stepping forward. As vehicle technologies have become more dependent on appropriate emission control and fuel systems, the lack of available complementary technologies or infrastructure poses another serious obstacle. With these obstacles to implementing competitive regulatory strategies, companies have used more subtle strategies, such as technology demonstration and small-scale trials or sales. These actions signal to regulators that the company might be supportive of more stringent standards without the firm having to express its support explicitly.

From an environmental protection standpoint, it is desirable for the public benefits of proactive behavior to extend beyond the individual actions of one government or company. Governments engage in their own version of regulatory competition by trying to pass the most ambitious emission or fuel standards. Improving public health and responding to public pressure are key drivers, but regulatory agencies also pride themselves in being world leaders in regulatory stringency. The successful introduction of a cleaner product by one firm frequently has the effect of causing diffusion of the product throughout the industry. However, in order for technology introductions to reach beyond a single company or regional area, government intervention – in the form of fiscal incentives or new standards – has been crucial to encouraging widespread diffusion of the technology and its associated benefits.

In the interest of promoting more early- and first-mover behavior by firms, the final recommendations call for (1) greater use of tax incentives, (2) review and communication of scientific/medical findings and technological progress by public groups and NGOs (3) use of technology demonstrations and partnerships with regulators or NGOs to communicate technology readiness, and (4) adoption of a combination of short-term and long-term emission targets.

Through a systematic analysis of multiple regulatory cycles for diesel emission and fuel regulations, this research has identified factors that influence early and first-mover behavior and that generate private and public benefits. The industries covered in this thesis – the automotive,

truck, engine, fuel, and aftertreatment industries – shared commonalities in their decision-making and regulatory responses, but structural and technological differences did affect behavior and outcomes. This implies that there are limitations to extending the findings to other industries. The next and final chapter compares the research findings to recent empirical work in other industries.

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CHAPTER 11 – Future Work

11.1 Introduction

The focus on the diesel vehicle industry led to investigation into the automobile, truck, engine, fuel, and aftertreatment industries. Despite the wide-ranging differences among those individual industries, their interdependent technologies and their need to respond to frequently changing emission and fuel regulations produced many shared and similar experiences. After studying these industries in the context of diesel emission reduction, the next task is to consider the applicability of the research findings to other industries and technologies. This chapter compares the findings from the diesel vehicle industry to those in other industries, and seeks potentially generalizable conclusions. The contribution to the existing body of research on the interaction between environmental regulation and technology development is discussed. In terms of future work, this research study can be easily broadened to study more regulatory cycles and related technologies, or adapted to other regulated industries.

11.2 Comparing findings from other industries

Although some of the empirical work discussed in Chapter 2 is still in progress, preliminary findings show some important areas of commonality. The following section compares the thesis findings to research in other industries, with special attention to work completed through the AGS CARE (Competitive Advantage, Regulation, and the Environment) project. Based on a review of the limited, but valuable, empirical work from the CARE project and other similar studies, the following have been identified as important factors contributing to companies' ability to gain competitive advantage from regulatory stringency: size advantages, country-specific preferences, proactive governments, aligned NGO interests, and regulatory incentives for innovation. Evidence from this study supports and further refines those results.

11.2.1 Size advantages

Studies by CARE researchers and others have found that larger firms are more likely to capture competitive advantage from more stringent regulations, whether or not they actively seek greater stringency (Bernauer and Caduff 2004; Foster, Hilden et al. 2006; Foster 2001; Oye and Maxwell 1995; Vogel 1995). Their work has spanned several sectors, including electronic waste, food safety, pulp and paper, and chemicals. The motor vehicle and oil industries are more highly concentrated than these industries, and the motor vehicle industry (including automobiles, trucks, and engines) is more so. There is evidence of size advantages in the oil industry, but not in the motor vehicle industry. The impact of size was clearly seen in the oil industry's response to very low fuel sulfur levels, where the smaller refineries lobbied heavily against the new standards. Some refineries faced acquisition or closure because they could not afford to make the costly desulfurization investments. Meanwhile, some oil majors, like BP and Shell, were less resistant to the change. The one exception to this was Greenergy, which began as a small UK fuel supplier serving a niche market for ULSD. Since Greenergy does not have retail outlets, it also sells its fuel to BP and Shell, which distributes ULSD through its retail locations. Larger firms are also more likely to push for upward harmonization of standards, a trend which was discussed in Chapter 10. Because the motor vehicle industry is so concentrated in the EU, Japan, and US, it was difficult to determine whether size advantages exist in the industry. Companies with advanced technology that stood to benefit from more stringent standards – PSA, Toyota Europe, International, for example – are major players in their respective markets, but were not necessarily the market share leaders. There were many instances in the motor vehicle industry where the market share leaders were the most resistant to regulatory change.

The pulp and paper study by Foster, Hilden, et al. observed that the large, more efficient plants have difficulty adapting to changes in regulatory or customer demand. In the diesel vehicle industry, it does not appear that company or plant size is a hindrance to flexibility. Even Toyota and Honda, which came late to the European diesel market in the early 2000s, were still able to produce competitive models in a few years' time. They even added capacity to their European plants in response to the diesel demand. In the oil industry, large companies have responded to shifting customer and regulatory demand through major upgrades, acquiring smaller refineries, and managing imports and exports.

11.2.2 Country-specific preferences, lead markets, and proactive governments

Country-specific preferences have manifested themselves in the variety of customer and regulatory responses. The CARE research and other work have pointed to the more environmentally minded public in Scandinavia and Germany as an explanation for the countries' greater success in fostering cleaner technology. This is consistent with the countries which are most proactive in reducing diesel vehicle emissions in Europe. Sweden and Finland adopted tax differentiation policies for ULSD well ahead of other European countries. Because of the organized activism of its environmental groups, Germany was the starting place for the wave of particulate filter popularity throughout Europe. Despite its French identity, PSA strategically promoted its filter among groups in Germany. When other manufacturers offered filter-equipped cars at an extra cost, 80% of German customers paid for filters, in sharp contrast to the relative lack of interest in France and the UK.

National governments also adopt policies that boost the competitiveness of their domestic industries. For example, the Danish government's Renewable Energy Feed Tariffs helped expand its wind turbine production, making Denmark the lead market for wind energy and a lead exporter to other markets (Beise and Rennings 2005). The German government's interest in more stringent diesel regulations also encourages its own companies to exercise leadership in environmental innovation. Beise and Rennings call this the "Porter effect" based on Michael Porter's theory of regulation-induced innovation.

The automobile and truck industries in Europe, Japan, and the US all carry significant political clout with their governments. While government agencies do show sensitivity to the interests of their domestic firms, their desire for environmental protection can outweigh concerns about domestic competitiveness. European engine manufacturers lobbied EPA regulators to accommodate urea SCR systems to meet the 2007 heavy-duty engine emission standards. Initially, EPA had little incentive to make allowances for SCR systems because all the American engine manufacturers had planned to use non-SCR systems. However, in recent years, EPA has been more receptive to urea SCR systems, as manufacturers offer more concrete solutions to the lack of urea infrastructure and potential end-user problems. The German Environment Ministry wholeheartedly embraced French company PSA's filter technology, much to the chagrin of German automakers. EPA's consent decree with the US heavy-duty engine manufacturers

ultimately disadvantaged domestic firms and gave a competitive edge to foreign firms. The California Air Resources Board frequently praises the low-emissions automotive technologies from Japanese firms Honda and Toyota. Proactive government agencies like those in Germany, California, and Tokyo have used the leading technologies of foreign companies to challenge the progress of their domestic companies.

11.2.3 Alignment with NGO groups

Environmental groups can place pressure on companies to produce cleaner technologies by drawing attention to the health and environmental risks of existing products. Fearing additional regulation, companies may voluntarily introduce cleaner technologies to preempt more criticism and/or regulation. In the food safety case by Bernauer and Caduff, there is indication that companies push for higher standards to “buy political legitimacy and public goodwill” and increase regulatory certainty (Bernauer and Caduff 2004). This argument coincides with a key motivation behind the cooperative rulemaking between the Japanese government and its automobile and truck industry. With growing anti-diesel sentiment and a spate of diesel exhaust lawsuits in Japan, the automobile and truck manufacturers were eager to show that diesel vehicles were a clean technology. They agreed to accelerate their initial 2007 standard deadline to 2005. However, their NO_x emission reduction was not as significant as previously expected. As part of their negotiations with the Japanese government, they weakened their NO_x reduction in exchange for a more stringent PM standard. By being more proactive with the standard-setting, the Japanese companies were able to build in more flexibility and negotiate a more cost-effective NO_x-PM trade-off. As discussed in Chapter 10, many cases of early and first-mover behavior were motivated by the desire for market share protection and regulatory preparation. Companies like PSA, ARCO/BP, and International used their technology to counteract anti-diesel criticism from the scientific and environmental communities.

A company with a cleaner product may find itself the beneficiary of environmental groups' work to publicize the merits of cleaner technology. In some cases, companies may even work in concert with NGOs to promote more stringent regulation. David Vogel calls this a “Baptist and Bootlegger coalition.” Environmental groups (the “Baptists”) seek regulation to

promote environmental protection, while the companies (the “bootleggers”) seek regulation to improve product sales and market share (Vogel 1995). Bernauer and Caduff (2004) discuss the alignment of NGO and corporate interests occurring in their research. A commonly used example is the phase-out of ozone-depleting CFCs. CFC producers Dupont and ICI’s support of the phase-out helped ensure the passage of the Montreal Protocol, a great success for the environmental community, but a boon for the producers’ sales of more costly substitutes (Murphy 2002).

In the diesel vehicle industry, collaboration between companies and NGOs seldom occurred openly. Lead firms were hesitant to use their advanced technology to push for greater stringency, but once news of their technology’s performance reached NGOs, regulators, and the greater public, those groups advocated for regulations that would require their technology. The “No Diesel Without Filter” campaign’s praised PSA’s particulate filter; US environmental groups supported ARCO/BP’s ultra-low sulfur diesel introduction; and environmentally-oriented auto clubs and regulators referenced Toyota’s D-CAT-equipped Avensis during the Euro 5 consultations. The companies limited accusation of rent-seeking by broadly distributing information about their new technology, and then leaving it to third-party groups to advocate the environmental merits on their behalf. Even emission control manufacturers, who have a very clear interest in more stringent regulation, distanced themselves from direct collaboration with environmental groups. Otherwise, their clients, the engine and truck manufacturers, would perceive them as promoting more costly regulation. The “No Diesel without Filter” campaign ultimately received funding from emission control manufacturers under the conditions that the company donors would remain anonymous.

11.2.4 Regulatory incentives for innovation

The case studies in this thesis showed the important role of fiscal incentives in spurring firms to market cleaner technologies. Reduced vehicle registration fees for early Euro 4 compliant cars, German toll discounts for Euro 4 and Euro 5 compliant trucks, and Swedish ULSD tax differentiation are all examples of regulatory incentives for innovation. Similar dependence on government intervention was observed in the findings from the other studies.

Foster, Hilden, et al. emphasized the need for more government R&D funding for process innovations in the pulp and paper industry. The World Resources Institute “Changing Drivers” report on automotive industry competitiveness was based on the premise that carbon constraints, in the form of carbon standards or taxes, would induce firms to invest in lower-carbon technologies. The previously mentioned Danish Renewable Energy Feed Tariffs, which subsidized renewable energy producers, was instrumental in promoting wind turbine technologies in Denmark.

11.2.5 Findings unique to this study

While there are many shared findings between this study and other work, this research does have some findings that have not received significant attention in other studies. While much has been written on the role of environmental NGOs in industry responses to regulation, the role of another type of NGO – the industry trade association – has seldom been addressed. Instead, it is usually rolled into references to “industry” as a collective unit. This research has shown that trade associations play a crucial role in regulatory and corporate interactions. First and foremost, they all provide valuable information to regulators whose technology assessments form a basis for standard-setting. Some associations, like those for emission control manufacturers, actively promote new technologies, thereby making the case for more stringent regulations. Other organizations may work together to oppose or weaken the stringency of proposed regulations, by collectively citing the high cost of compliance. By doing so, they may discourage technology leaders from introducing advanced technology ahead of regulations, especially if this means deviating from the trade association’s position. This research has documented cases where early and first-movers have been subject to intense criticism and “peer pressure” from competitors or trade associations.

Regulatory compliance issues such as certification and enforcement procedures occasionally had an unintended impact on environmental benefits and regulated firms. These details rarely surface to the mainstream media, and often go ignored by the public, even environmental groups. However, this study shows that they deserve as much attention as the

standards themselves because of their potential effects on firm-level competitiveness and regulatory implementation.

Political lobbying was not necessarily the preferred vehicle for communicating readiness for more stringent regulation. Several cases showed how technology demonstration could be used as a more subtle and credible mechanism for influencing regulation. Regulators rely heavily on expert assessments and company-level data to determine the feasibility of proposed regulations. Regulatory documents and interviews with regulators show that they place significant weight on results from pilot studies and field tests.

11.3 Future work

This thesis adds evidence from company-level and industry-wide cases to improve understanding about factors affecting the terms of regulatory competition. The focused study of the automobile, truck, engine, aftertreatment, and fuel industries in the EU, Japan, and the US can facilitate additional cross-sector and cross-country comparisons. This next section discusses future work that can build on this research.

Research can be extended in several different directions. Within the area of diesel vehicle emission reduction, additional regulatory cycles can be evaluated, since emission and fuel standards have been promulgated since the 1970s. This research project limited its historical reach to the 1990s and 2000s because of greater data availability for recent years, but greater reliance on interviews with senior experts may help to compensate for limited access to contemporary documentation. The research design could be readily applied to studying regulation of gasoline emissions in the same three regions. During discussion of diesel technology, many interviewees also volunteered interesting insights into gasoline vehicle technology, which confirm the relevance of questions concerning regulatory competition.

Off-road equipment and marine vessels have recently been subject to increasingly stringent regulations, so the data on outcomes have been sparse. However, in a few years, after more technology introductions are observed, they will present good opportunities for study. Regulators and industry representatives have praised the significant government-industry cooperation on off-road emission standards. A close study could uncover how technological

competitiveness factors into the more collaborative outcome. The two-tier research methodology of examining regulatory cycles and then corporate and institutional behavior could be useful for other regulations that are tightened repeatedly. For example, regulations on combustion plant emissions have been revised multiple times since their first promulgation. Since they are process regulations rather than product regulations, they will not have the element of customer demand-driven or trade-related competition that vehicles have. These differences may reduce incentives for regulatory competition.

Automobile safety standards offer excellent material for study. Manufacturers already compete aggressively on safety performance and reputation. According to automobile industry surveys, customer valuation for safety is far higher than for environment (Källbäck 2004). As a result, customer demand is a stronger force than for emission reduction. Companies with superior safety features have more traction with transportation regulators, who will want to mandate installation of the best technologies as standard. It would be socially objectionable for safety features to be available only to consumers who can afford to pay. Automobile insurers seeking to reduce their accident liabilities and consumer groups seeking to reduce automobile-related deaths will also advocate for more stringent safety mandates.

Any focused industry study would require some “immersion” in the regulations and technologies important to that industry, in order to gain familiarity with the broader regulatory and market context. Understanding the technical issues, keeping up with trade publications, and interacting with experts at conferences have all been crucial to this research. The time and resource-intensive immersion process makes such focused industry studies particularly challenging. Relevant technical training or background is a valuable prerequisite for pursuing such studies.

This research relied heavily on publicly available documents as a main data source, with interviews operating as a secondary tool to supplement documentary findings. People from a representative sample of firms, agencies, and interest groups were interviewed, but time and resources did not allow for interviews with all major firms in the industry sectors studied. A more systematic interview process, with structured questionnaires, could be used to test the research findings across more firms within the diesel vehicle industry. Such an approach is being undertaken by members of the CARE group at the Swiss Federal Institute of Technology – Zurich. They are performing research at the firm and innovation field to understand the

determinants of “green innovation.” To build a larger dataset, they are developing questionnaires for individual firms, focusing on Swiss and German firms in the chemical and food industries (Bernauer, Engels et al. 2006).

Additional research could compare the effectiveness of political lobbying and technology demonstration as instruments for influencing policy. The results are likely to vary across different industries, particularly according to their organizational level and size. The research also illustrated significant cultural differences in regulatory styles, so further research could address the transferability of specific policies to other national settings.

11.4 Summary

Findings from this research are generally consistent with empirical findings from other qualitative studies of environmental innovation and regulatory competition. Size, national preferences for environmental protection, proactive governments, aligned NGO interests, and regulatory incentives for innovation have a positive effect on firms’ ability to benefit from more stringent environmental regulation. Additionally, this research addresses the role of industry trade associations, regulatory compliance details, and technology demonstration in shaping regulatory competition. Their demonstrated importance in this work should draw greater attention to considering these areas in further studies.

The research design can be extended to other time periods, industries, and regulations. While emissions regulations of off-road equipment and marine vehicles have not progressed enough to provide adequate research material, gasoline vehicle emissions, combustion plant emissions, and vehicle safety have a rich history of increasingly stringent regulation and corporate responses. Additional research in these areas can help establish the cross-sector reach of the findings, and determine their applicability to different types of regulations, such as product versus process regulations or environmental versus safety concerns.

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