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Abstract: The extent to which ex-ante estimates of the costs of regulation differ from ex-post estimates is an empirical question of considerable interest to policymakers, regulated entities, and the public. This paper examines evidence on the actual costs of compliance with the 2004 Automobile and Light-Duty Truck Surface Coating NESHAP and then compares these estimates to the EPA's ex-ante cost estimates to identify key drivers of any differences. This regulation is particularly interesting from a cost perspective because at the time of promulgation the EPA considered it to be economically significant (and it was therefore accompanied by an extensive cost analysis), under stood who was likely to be regulated under the NESHAP, and had identified several available technologies that could be used to reduce HAP emissions.

Data on ex-post costs are gathered from a subset of the industry via survey and follow-up interview. We find that the EPA overestimated the cost of compliance for these plants and that overestimation was driven primarily by use of estimation methods that did not account for regulatory flexibilities such as the ability to utilize any effective HAPs control method. Thus, we find that differences between ex ante and ex post cost estimates for our sample of facilities are primarily driven by differences in the method of compliance rather than differences in the per-unit cost associated with a given compliance approach. In particular, the EPA expected facilities to install pollution abatement control technologies in their paint shops to reduce emissions of hazardous air pollutants, but instead these plants complied by reformulating their coatings.

JEL Codes: Q52, Q53, Q55, Q58

Key Words: retrospective cost analysis, air regulation, benefit-cost analysis, transportation

1. Introduction[1]

The extent to which the U.S. Environmental Protection Agency's (EPA) ex-ante estimates of the costs of regulation differ from ex-post estimates is an empirical question of considerable interest to policymakers, regulated entities, and the public. Executive Orders 13563 and 13610 state that "it is particularly important for agencies to conduct retrospective analyses of existing rules to examine whether they remain justified and whether they should be modified or streamlined in light of changed circumstances, including the rise of new technologies" (White House 2011, 2012). The Office of Management and Budget (OMB), which reviews regulatory impact analyses for major rulemakings, similarly emphasize the role of retrospective analysis (OMB 2016). The accuracy of ex-ante cost estimates for proposed regulations also is frequently the subject of public comment. However, despite its potential importance, "rigorous retrospective analysis of federal regulation is not commonly conducted…[S]uch analysis can be both complicated and expensive to develop" (Morgenstern 2015).

A number of survey articles have examined evidence on the costs of EPA regulations ex-post (e.g., Putnam, et al. 1980; Hodges 1997; Harrington, et al. 2000; and OMB 2005). While these studies indicate that ex-ante cost estimates are more often over-estimates of the actual costs of compliance, it is difficult to draw solid conclusions for several reasons. First, since ex-post data on compliance costs are surprisingly difficult to find and vary in quality, ex-post cost estimates likely have large error bounds. Second, the scope of analysis varies widely by study. For example, some studies focus only on capital costs, while others include operating costs in their ex-post estimates. Third, studies often vary substantially in methodology. For instance, a major difference across studies is the way in which investments due to regulatory requirements are distinguished from those that would have occurred

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anyway for other reasons, referred to as the baseline or counterfactual (EPA 2014). Fourth, the number of regulations that have been examined within and outside of the EPA is actually quite small relative to the universe of major environmental regulations promulgated by the EPA and favors market-based approaches, which are a relatively rare regulatory approach (e.g., Harrington, et al. 2000).

Some of these studies also explored why ex-ante and ex-post cost estimates might differ. Goodstein and Hodges (1997) observed that a key reason for overestimating costs, for the subset of regulations they examined, was failure to account for the technology-forcing nature of the requirements, which in turn induced innovation and lowered the costs of compliance. Harrington, et al. (2000) examined a broader set of possible explanations for why ex-ante estimates might differ from ex-post estimates of the cost of regulation, including errors in how the baseline was specified, optimistic compliance assumptions, and reliance on maximum instead of mean cost information. They found that the EPA tended to overestimate aggregate costs due to assumptions regarding technological innovation and the emission reductions required to meet the standard. The EPA's ability to accurately estimate per-unit costs ex-ante was found to be mixed.

Two recent projects by the EPA (2014) and Resources for the Future (Morgenstern 2015) have attempted to expand the literature by conducting new ex-post cost evaluations for a wider array of environmental regulations with a focus on identifying the underlying reasons for inconsistencies between ex-ante and ex-post estimates. The purpose of the case studies is not necessarily to estimate ex post costs as accurately as possible, but rather to gather enough information to make a general determination regarding the extent to which ex ante cost estimates likely differ from ex post cost estimates (EPA 2014). To accomplish this task, researchers investigated the key drivers of compliance costs in each case and what underlying factors contribute to differences (or similarities) between ex ante and ex post estimates.

The EPA (2014) also sought to bring greater consistency to the way in which costs are assessed retrospectively through the development and use of a common conceptual framework. In line with older studies, both efforts found evidence of the overestimation of costs ex ante in some cases. Identified reasons for differences between ex-ante and ex-post estimates included faster – and in one case, slower - than expected technological innovation, failure to account for how flexibilities available in the regulation would affect costs, failure to account for behavioral responses, and exogenous factors such as unexpected changes in fuel prices. Both also caution against generalizing their initial findings to the larger regulatory space due to numerous data challenges, and the limited and non-representative nature of the case studies conducted (EPA 2014; Morgenstern 2015).

In this paper, we build on earlier efforts by utilizing the EPA's conceptual framework to compare ex-ante estimates of the costs of compliance with the 2004 National Emission Standard for Hazardous Air Pollutants (NESHAP) for surface coating of light-duty automobiles and light-duty trucks to an ex-post assessment of costs, identifying possible underlying factors contributing to the differences between these estimates. The 2004 NESHAP set a minimum standard for hazardous air pollutants (HAPs) emitted by paint shops at automotive manufacturing plants (EPA 2004b). Hazardous air pollutants are known to cause cancer and other serious health impacts. The Clean Air Act requires the EPA to regulate toxic air pollutants from various categories of industrial facilities.[2] This regulation is particularly interesting from a cost perspective because at the time of promulgation it was considered economically significant based on the magnitude of the annualized costs (and was therefore accompanied by an extensive cost analysis),[3] the regulated universe consisted of a relatively well understood and already regulated sector

[2] See https://www.epa.gov/haps .

[3] Regulations that "have an annual effect on the economy of $100 million or more or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or tribal governments or communities" are subject to analytic requirements per Executive Order 12866 (White House 1993).

(for other pollutants such as VOCs), and the EPA had identified several available technologies that could be used to bring HAP emissions into compliance.

As part of EPA's efforts to conduct retrospective analyses, the 2004 surface coating NESHAP for automobiles and light trucks was chosen randomly, among many candidate regulations; these three interesting features played no part in its selection for a case study. To our knowledge, no other retrospective study of the costs of meeting the 2004 NESHAP requirements has been conducted.

Ideally, the EPA would estimate the social cost of a regulation ex-ante (i.e., sum all opportunity costs incurred as a result of the regulation). In practice, many ex-ante regulatory analyses only quantify compliance costs. As such, we also focus mainly on compliance costs for ex post analysis. As previously mentioned, the EPA (2014) developed a conceptual framework to provide a systematic way to assess what factors influence a divergence between ex-ante and ex-post estimates of costs. We rely on this analytic framework to examine the 2004 light-duty vehicle surface coating NESHAP, though the degree to which we can conduct ex-post analysis varies by component. The main components are:

- Regulated Universe – What types of entities must comply with the rule? How many entities of each type must comply?
- Methods of Compliance – What types of technologies or methods are used to comply? How often are these compliance strategies used?
- Baseline Compliance – To what extent are technologies already in use prior to the rule?
- Direct Compliance Costs – What are the initial or one-time (costs of compliance (e.g., fixed or variable associated with new capital)? What are the ongoing costs of compliance (e.g., operation and maintenance)?
- Indirect Compliance Costs – Are there indirect costs (e.g. quality trade-offs)?

- Other Indirect Opportunity Costs – What are the major opportunity costs associated with the rule (e.g., in related markets)?

The paper is organized as follows. Section 2 describes the impetus and timeline for regulatory action. Section 3 summarizes EPA's ex-ante cost estimates for the 2004 automobile and light-duty truck surface coating NESHAP, including key drivers, sources of uncertainty, and possible exogenous factors. Section 4 discusses the approach and data used to conduct an ex-post assessment of compliance costs. Section 5 presents the results. Section 6 discusses the overall implications and key limitations of the analysis.

2. Impetus and Timeline for Regulatory Action

Section 112 of the Clean Air Act (CAA) requires the EPA to list industrial categories of major sources of one or more HAPs and to then establish a NESHAP for those categories. Major sources of HAPs are defined as new or existing facilities that emit 10 tons or more annually of any single HAP or 25 tons or more annually of a combination of HAPs. A NESHAP is typically based on an assessment of the degree to which emission reductions have been achieved at the best performing facilities in a particular source category using existing abatement control techniques. This standard is referred to as a Maximum Achievable Control Technology (or MACT) because it specifies the minimum level of HAPs control required (i.e., a "MACT floor"). Specifically, "the CAA requires the NESHAP to reflect the maximum degree of reduction in emissions of HAP that is achievable, taking into consideration the cost of achieving the emission reduction, any non-air quality health and environmental impacts, and energy requirements (EPA 2004b). For existing sources, the MACT floor is the average emission rate of the least-emitting 12 percent of facilities within that industry at the time of promulgation.[4]

[4] To accomplish this task, the EPA gathered data on emission rates for each facility, ranking facilities from lowest-emission rate to highest and then calculated the average emission rate for the relevant subset of facilities.

Surface coating operations for automobile and light-duty trucks were listed as a major source category in 1992.[5] The NESHAP was proposed at the end of 2002 and finalized in 2004. Surface coating operations at existing plants had up to three years from promulgation to comply, while new plants were expected to be in compliance as soon as operations began. It is worth noting that many of the air toxics from surface coating operations at light-duty vehicle assembly plants are also volatile organic compounds (VOCs) and therefore were already subject to existing VOC regulations prior to the NESHAP.[6]

The EPA characterized surface coating of light-duty vehicles at U.S. assembly plants as having three main steps: surface preparation, priming operations, and finishing operations (EPA 2004a). Most of the HAPs from surface coating are reportedly released in the second and third steps and therefore subject to the 2004 NESHAP. As the name suggests, priming operations prepare the assembled body of a vehicle for finishing through the application of several layers of coatings to prevent corrosion and promote adhesion of each subsequent coating. According to the EPA, there are four steps associated with priming operations, each of which apply a coating or sealant: specifically, a primer coating via electrodeposition, which is then cured in an oven; a sealant for spot-welded joints; an anti-chip sealant for vulnerable areas of the body; and a primer-surfacer coating (EPA 2004a). The EPA describes the finishing operations as the application of the topcoat - a basecoat to add color to the body and a clearcoat to protect the color coating.

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[5] Organic HAPs released during automobile and light-duty truck surface coating operations are associated with a number of adverse human health effects. These include effects on the central nervous system, kidneys, liver, and blood; as well as respiratory and developmental effects. The 2004 NESHAP was expected to reduce emissions of these HAPs by 6,000 tons per year or about 60 percent.

[6] At the time of the 2004 NESHAP, 14 states and one air control district in California regulated VOCs from these sources consistent with 1977 national control technology guidelines (state-implementation plans for areas out of attainment with national ambient air quality standards adhere to these guidelines). New or substantially modified surface coating operations also were subject to 1979 new source performance standards for VOC emissions.

3. The EPA's Ex-Ante Cost Estimates

This section describes the methods used and main drivers of compliance costs in the ex-ante analysis, and assesses the main sources of uncertainty and exogenous factors (e.g., unrelated changes in market demands, oil prices) that are important to consider during an ex-post assessment.

3.1 Ex Ante Cost-Estimation

The EPA estimated ex-ante that the total annualized costs of the 2004 NESHAP for light-duty surface coating would be $154 million (in 1999$), and expected them to be divided fairly evenly between capital ($75 million), and operating and maintenance ($76 million) costs.[7] Administrative costs only accounted for a small portion of total ex-ante compliance costs (about $2 million annually). On average, these compliance costs translated to about $25,000 per ton of HAP controlled (EPA 2004a).

The EPA used an engineering cost approach to estimate facility-level compliance costs for the 2004 NESHAP.[8] Engineering cost categories were annual capital, operation and maintenance, and monitoring costs. The engineering cost approach assumed no behavioral market adjustment by producers or consumers (e.g., changes in output quantities and prices) (EPA 2004a).[9] While work practice standards were required for compliance, they also were not analyzed in the EPA's ex-ante cost analysis.

The covered entities and the technologies they were expected to install or use in order to come into compliance with the new requirements were based on data that the EPA requested in a questionnaire

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[7] Annualized over the control equipment's expected lifetime of 15 years at a 7 percent discount rate.
[8] This cost approach was also used to estimate facility-level compliance costs for other NESHAPs at the time this rule was promulgated, and is described in the EPA Air Pollution Control Cost Manual, which is available at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution. This document also furnished the approaches (though not all of the necessary data) for estimating the annual capital and operating and maintenance for the specific control devices included in the cost analysis.
[9] In a separate chapter of the regulatory analysis, the EPA estimated that compliance costs from the 2004 NESHAP would increase the price of a light-duty car or truck by no more than $3.10 per vehicle (or no more than 0.01 percent), resulting in a decline in domestic vehicle production of between 17 and 384 vehicles (EPA 2004a).

submitted to potentially affected firms at the end of 1999 on each major surface coating operation in use at automobile assembly plants. In particular, the EPA asked for information on HAP emissions and control technologies and practices already in place for purposes of setting the MACT floor. Plants reported this information to the EPA differentiated by coating stage (i.e., electrodeposition primer, primer-surface coating, topcoat, miscellaneous assembly, cleaning, wastewater treatment, fueling). The EPA characterized the data associated with the application of primers and topcoats as particularly reliable since it used a "standard VOC emissions protocol developed by the industry and [the] EPA in the late 1980s" that was adapted to estimate organic HAP emissions (EPA 2002).

Based on the information it received, the EPA determined that five assembly plants were not subject to the rule because they did not operate paint shops. Four plants had more than one paint shop and reported each separately, resulting in information on 60 facilities (EPA 2002, EPA 2004a). The EPA identified compliance options for the 2004 NESHAP specific to the particular step in the coating process at which HAPs were released. The 8 least-emitting plants composing the MACT floor group (EPA 2002). [10]

The EPA assumed automobile and light-duty truck assembly plants with surface coating operations would use one or more of four strategies to comply with the MACT standard, in sequence (EPA 2004a):

(1) Facilities that do not already have controls on the electrodeposition oven will add an oxidizer at an average cost of about $8,200 per ton of HAP controlled.
(2) If the HAP/VOC ratio for primer-surfacer coating is greater than 0.3, the facility will use a reformulated surface coating that substitutes non-HAP solvents for HAP solvents to meet this ratio at an average cost of about $540 per ton of HAP controlled.

[10] Note that the EPA excluded four plants with the lowest emission rates from consideration when setting the MACT floor because they did not represent the latest technology for applying coatings at the time. Specifically, these plants did not apply a full body primer-surfacer coating to their vehicles in 1998, though they all subsequently converted to this technology in an effort to improve coating quality (EPA 2002).

(3) If the HAP/VOC ratio for the topcoat material is greater than 0.3, the facility will reformulate the top coating to meet this ratio.

(4) To control any remaining HAPS above the MACT floor, after applying strategies (1), (2), and (3), the plant will add controls to the exhaust from the automated zones of spray booths.

Table 1 summarizes the average cost of each compliance strategy and the number of assembly plants expected to adopt a particular strategy – alone or in combination with others. The regulatory analysis also included facility-level estimated compliance cost information, which we utilize as a basis of comparison in the ex post assessment (EPA 2004a).

Table 1: Ex-Ante Control Costs by Major Compliance Strategy

Compliance Strategy	Annualized Capital Cost (1999$)	Additional Annual Operating Cost (1999$)	Cost per Ton of HAP Controlled	Number of Plants Expected to Adopt
No additional controls	-	-		11
(1) Add regenerative thermal oxidizer to electrostatic oven for first primer coat	$118,000	$127,000/year	$8,200/ton	14
(2) Substitute non-HAP for HAP solvents in primer surface coating	None	$0.23/pound of solvent	$540/ton	21
(3) Substitute non-HAP for HAP solvents in top coating	None	$0.23/pound of solvent	$540/ton	15
(4) Install exhaust controls to spray booth	$20,000/ton	$20,000/ton	$40,000/ton	45

Source: EPA 2004, EPA 2002.

The EPA estimated that 11 existing plants (eight of which were used to set the MACT floor) would not need additional controls to comply and, as such, were expected to only face administrative costs. Of the 49 existing plants remaining, the EPA had useful interpretable data for all but two plants. The EPA expected that 11 plants would rely on a single strategy to comply with the NESHAP, 23 would rely on two strategies, and 13 would rely on three or more compliance strategies. The costs of those strategies varied from an average of about $540 per ton of HAP emissions controlled for strategy 2 or 3, to $8,200 per ton for strategy 1, to $40,000 per ton for strategy 4. By far, the most common compliance strategy identified by the EPA in its ex ante cost analysis was the addition of exhaust controls to spray booths (EPA 2004a). Interestingly, this compliance strategy also had the highest estimated average annual control cost of all four strategies.[11]

For the ex-ante cost analysis, capital and operating costs for each of these strategies were drawn from the literature, from industry data reported to the EPA, as well as other industry sources (EPA 2002).[12] For plants expected to implement one or more compliance strategy, total annualized capital and operating costs (excluding administrative costs from monitoring, recordkeeping, and reporting) ranged from $1,800 to $13 million per plant, with an average annualized cost of $2.6 million.[13] Eleven plants were expected to incur annualized costs of less than $1 million, while six plants were expected to have annualized capital and operating costs in excess of $5 million.

Most of the plants above the MACT standard were expected to add an oxidizer and/or exhaust controls, which have capital and operating costs associated with them.[14] These plants were estimated to have a

[11] The EPA estimated that "it costs $10,000/ton to reduce VOC emissions from automated zones of spray booths. For Strategy 4, it is assumed that annual VOC control costs of $10,000/ton imply annual HAP control costs of $40,000 per ton. This cost is split evenly between annual capital and operating expenses" (EPA 2004a).
[12] Control costs for a regenerative thermal oxidizer were based on a system that had been recently installed by Daimler Chrysler. The cost of reformulating the primer-surfacer or top coating to substitute non-HAP for HAP solvents was based on the per pound cost differential between aromatic solvents such as toluene and xylene and non-HAP solvents such as ethyl acetate and butyl acetate. The cost of installing a capture and control system on the exhaust from the spray booth was based on estimates provided in permit applications for similar controls at new paint shops but adjusted to account for the cost of retrofitting them into an existing spray booth.
[13] A small subset of plants (about five) had more than one paint line at the same geographic location subject to the 2004 NESHAP. We refer to each of these paint lines as a separate plant, each with one paint shop.
[14] The EPA (2004a) states that "adoption of strategy 1 and/or strategy 4 will necessitate extra fan horsepower to convey additional air streams to add-on control devices (which are assumed to be regenerative thermal oxidizers).The operation of such abatement equipment is estimated to require an additional $4.9\text{x}10^9$ standard cubic feet per year of natural gas and $1.8\text{x}10^8$ kilowatt hours per year of electricity nationwide at a cost of $3.20 per thousand cubic feet of natural gas and $0.06 per kilowatt of electricity…This incremental energy cost was included in the operation and maintenance component of the engineering cost estimates."

wide range of compliance costs (from about $150,000 to $13 million). In addition to the cost of controlling HAP emissions, the EPA assumed that existing plants that installed add-on controls would incur performance testing costs, estimated at $9,240 per strategy once every 15 years. Plants that only reformulated coatings were not expected to incur these costs (EPA 2004a).

Administrative costs in the ex-ante estimate included recordkeeping, monitoring, and reporting. The EPA recognized that plants already had a detailed recordkeeping system in place to comply with pre-existing VOC regulations (EPA 2004a). It assumed a one-time cost to modify these systems to include HAP emissions of $20,000 per plant. Every plant also was assumed to incur recordkeeping and reporting costs of $18,000 per year. The EPA assumed that plants not already in compliance with the 2004 NESHAP would incur $15,600 in annual monitoring costs (EPA 2002).

3.2 Main Drivers of Ex-Ante Cost Estimates

The EPA's analysis makes clear that one ex-ante driver of capital and operating costs was the degree to which a plant was emitting organic HAPs above the standard, for each high-HAP-emitting step in the surface coating process. The plants with the highest estimated annual rate of organic HAP emissions from combined operations were among those with the highest annualized cost of compliance. Those with the lowest annual rate of organic HAP emissions either had no or very low estimated direct compliance costs. On the other hand, there is no clear correlation between annualized compliance costs and the number of strategies that the EPA expected would be implemented by a plant to come into compliance. Several plants with the highest estimates of annualized compliance costs were anticipated to implement only one strategy, while some plants with relatively low estimated compliance costs were expected to implement as many as three strategies. The EPA assumed in its ex-ante analysis that only two plants would rely solely on process change, by modifying or reformulating coating materials.

Another key driver of ex-ante compliance costs is the EPA assumption that plants would sequentially adopt control strategies not already in place (i.e., beginning with strategy 1 and ending with strategy 4). However, applying control strategies in this way is equivalent to assuming that plants will not necessarily implement the lowest cost strategy first, contradicting what we might expect based on economic theory. Based on the average cost information available at the time (Table 1), strategies 2 and 3 – reformulation of the primer-surfacer and top coatings – were expected to be far less costly on a per ton of HAP controlled basis than installing controls. And yet, the EPA estimated that 14 plants would install a higher cost regenerative thermal oxidizer before pursuing reformulation. If, in fact, firms minimized these costs we might expect ex post that fewer thermal oxidizers would be installed and that more coatings would be reformulated than the EPA predicted ex ante. A possible caveat to this, which is mentioned by the EPA in its regulatory analysis, is the possibility of hard to quantify indirect costs such as loss of market share over time due to the use of lower quality (i.e., less durable) coatings. If the EPA anticipated that reformulated coatings might suffer from these types of quality concerns, particularly in the early stages of development, then the installation of control technologies with higher direct costs might necessarily be at odds with what economic theory would predict.

The EPA assumed that new paint shops would incur few additional compliance costs because of their use of bake oven controls, powder or low-HAP primer-surfacer operations, and partial spray booth exhaust controls to control VOCs and odors from topcoat systems that rely on water- or solvent-based materials (EPA 2002, 2004a). However, the regulatory analysis acknowledges that even with these controls in place new plants may still need to lower the HAP content of their coating materials to meet the emissions limit (EPA 2004a). It was assumed that new plants would not incur additional testing and monitoring costs, as this would already be required under existing VOC regulations, though new plants would incur annual recordkeeping and reporting costs (EPA 2002).

3.2 Main Sources of Uncertainty

As previously mentioned, the EPA had fairly accurate information on the degree to which plants were emitting HAPs at rates above the MACT standard and to which step of the coating process the standard would apply.[15] The key sources of uncertainty with regard to compliance costs therefore related to how each plant would actually comply with the standard and the per unit cost of doing so. As discussed in section 3.1, the EPA expected facilities to pursue a higher cost compliance strategy, installing a thermal oxidizer on the electrodeposition oven, before implementing the lowest cost approach, reformulating coatings. MACT standards are performance-based, which means that firms can choose the way in which they comply with emission limits. However, one might expect firms to pursue lower cost and/or more effective techniques than those evaluated by the EPA if they are available. Compliance costs attributable to the rule would also hinge on already planned equipment and material upgrades. The EPA's ex-ante analysis did not address whether plants were already planning to replace equipment in their painting shops prior to the rule, though it acknowledged that plants made regular upgrades.

[15] While the annual organic HAPs emission rate of a plant at the time the rule was promulgated was likely fairly accurate, the EPA noted that some plants were not able to provide estimates of the overall efficiency of the control systems in place. The largest source of uncertainty with regard to existing operations and the organic HAPs emissions associated with them pertains to the cleaning and purging of emissions from spray booths. These estimates were derived from information on the volume of materials used and the organic HAP content reported for these materials, adjusted for control devices when appropriate. In particular, the degree to which an existing purge recovery system reduced emissions was not always reported. Because the descriptions of the purge systems were very similar across plants, the EPA used midrange estimates from plants that reported this information to estimate purge control efficiencies for plants where this information was missing.

3.3 Exogenous Factors

A major unknown, potentially exogenous, factor that is discussed but not explicitly accounted for in the EPA's assessment of compliance options is the role of technological change. Emissions from coatings are determined by a combination of factors including the HAP content of the coating, transfer efficiency (i.e., how much of the sprayed paint adheres to the surface), and the type of control equipment in a paint shop. Liquid coatings can be water or solvent-based; both result in the release of HAPs albeit at different levels. At the time the EPA conducted its analysis, it recognized that it was possible to (1) reformulate liquid coatings to rely on low or non-HAP chemicals (e.g., use water or lower-HAP solvents), (2) switch to powder coatings, which do not release HAPs, (3) raise the solids content of the coating, which reduces the "amount of solvent carrier needed" and therefore reduces HAP emissions, or (4) modify the way coatings are applied to achieve a higher transfer efficiency (EPA 2002).[16]

The options discussed in greatest detail in the EPA analysis are (1) and (2). Water-based and powder coatings represented almost 20 percent and less than 10 percent of coatings (by weight) applied to motor vehicles in 1998, respectively (EPA 2004a). Of the plants used to calculate the MACT floor, half relied on powder coatings, though in several cases they had also recently undergone major renovations or installed new paint shops. One industry publication projected only a moderate increase in the use of water-based or powder coatings - to 25 percent and 13 percent, respectively - by 2008 absent the standard (Freedonia Group 1999).[17] In addition, the EPA briefly mentioned an already existing joint effort between automobile manufacturers and their suppliers to develop low- or no-HAP coatings, with an initial focus on powder coatings, though it recognized barriers to their use (e.g., changes in the

[16] The EPA noted that low-emission powder or water-based coatings require adjusting existing, or investing in new, paint shop equipment and/or application methods to ensure that coating quality was maintained.

[17] For instance, the EPA reported that switching to a powder coating required the installation a new primer-surfacer system, estimated to cost between $26 million and $30 million, and removal of previous coating equipment, estimated to cost between $8 million and $10 million (EPA 2004a). Switching from solvent- to water-based coatings also requires a significant investment: one paint supplier estimated that it would cost between $10 million and $20 million because all of the piping and equipment needs to be replaced.

method and equipment used to apply coatings would be required to achieve the coating quality needed) (EPA 2002). The EPA also noted that companies sometimes experimented with new technologies or coating formulations in new plants or during paint shop retrofits, which occur approximately every 10 to 15 years (EPA 2004a).

4. Data Available to Conduct Ex-Post Evaluation

This section describes the data used to conduct an ex-post evaluation of the 2004 NESHAP. In particular, we focus on identifying data or methods related to the previously described key drivers of differences in ex ante versus ex post cost estimates, while accounting for sources of uncertainty and possible exogenous factors. The literature contains some information on technological change in the automobile coating process (e.g., Akafush, et al. 2016; Freedonia Group 2008) and the nature of the manufacturer-supplier relationship when developing new processes or technologies to reduce emissions in paint shops (Geffen and Rothenberg 2000). While these papers provide helpful background and context on the industry, they do not attempt to assess compliance costs retrospectively nor do they yield specific data on the key drivers of compliance costs.

Given the lack of published literature related to ex-post assessment in the surface coating industry, we focused on identifying data from existing sources, collecting new information from a sample of plants that were subject to the 2004 NESHAP via survey and interview, and generating an independent cost estimate based on contractor expertise.[18]

4.1 Publicly Available Data

Limited ex-post data are available on surface coating operations at automotive assembly plants. The Freedonia Group publishes a biennial report on the U.S. automotive coatings, adhesives, and sealants

[18]Note that the sample of plants included in this study is not (and was not intended to be) representative of the industry. The sample is small by design to stay in compliance with the Paper Work Reduction Act.

market that includes information on the latest trends in surface coating technologies and pricing, as well as a discussion of major market suppliers, and environmental and regulatory considerations. However, data on specific methods used by automotive manufacturers and the cost of compliance with the 2004 NESHAP are not included. In addition, we examined Securities and Exchange Commission (SEC) 10-K filings for two publically listed companies, GM and Ford, between 1998 and 2005 but the NESHAP regulatory requirements and their associated costs were not discussed in detail.[19]

4.2 Facility Survey and Interviews

The survey and interview approach pursued here is motivated by lessons learned from an initial set of EPA retrospective cost case studies. A key interest is to demonstrate its viability as a retrospective cost assessment tool (EPA 2014). In particular, the authors of the 2014 retrospective study concluded that "all of the case studies suffer from a lack of comprehensive cost information on treatment technologies and mitigation strategies at the plant level, limiting our ability to make definitive statements on the reasons for differences between ex-ante and ex-post cost estimates" (Kopits, et al. 2014).

The interview approach was originally intended to mimic the information collection strategy used in the Pollution Abatement and Cost Expenditures Survey (Gallaher, et al. 2006): the completion of initial surveys on plant-level compliance strategies were to be followed by site visits to gain a better understanding of the industrial processes at play. Responses to the survey, however, revealed that compliance was achieved primarily through the reformulation of coatings and associated process changes rather than the installation of capital equipment. As such, site visits were deemed unnecessary

[19] The bulk of the discussion regarding environmental requirements in the 10-Ks focused on vehicle emission requirements. Ford began to include a section on stationary emission control requirements in its 2003 filing that mentioned both hazardous air pollutants and requirements related to surface coating operations, but did not include specific compliance cost estimates. GM stated in its 2002 and 2003 filings that it expected to spend about $500 - $700 million to meet all HAP requirements, and compliance assurance and other monitoring requirements through 2005. In its 2004 and 2005 filings, this amount was lowered to $300 - $500 million in corporate-level expenses through 2007. The 2004 NESHAP requirements were not specifically discussed.

and were replaced with telephone interviews to discuss the survey responses in more detail and gain a better understanding of the costs of reformulation.

Survey participants

To supplement available information from the literature, we designed and administered a survey to a small set of automotive assembly plants operating in the United States.[20] Criteria used to select a plant for participation in the survey were:

- responded to the EPA's original data collection request for the rulemaking;
- had an operating paint shop;
- was still owned and operated by the same company as at the time of rule promulgation; and
- did not have an open enforcement investigation with the EPA at the time of the study.

Approximately 30 (three of which have multiple production lines/facilities) of the 60 assembly plants that the EPA had identified as subject to the 2004 NESHAP met these criteria, representing 11 different automobile and light-duty truck manufacturers. Twenty of the plants were located in the Midwest (i.e., Michigan, Ohio, Illinois, Indiana, and Kansas), seven in the Southeast (i.e., Kentucky, Tennessee, Missouri, and South Carolina) and three in the South (i.e., Louisiana, Alabama, and Texas). Annual production at these plants averaged 211,000 vehicles in 2003, with the smallest plant producing about 20,000 vehicles and the largest producing more than 450,000 vehicles. About eight of these plants were expected ex-ante to be in compliance with the regulation at the time of promulgation and therefore to only incur monitoring and reporting costs.

[20] The Paperwork Reduction Acts prohibit federal agencies from administering surveys to more than nine individuals or entities without prior approval from the Office of Management and Budget (OMB). That said, this survey is covered by Information Collection Request approval, OMB Control No: 2090-0028.

The EPA's Office of Air Quality Planning and Standards (OAQPS) recommended that we contact the trade association, Auto Industry Forum, which had been actively involved in the development of the 2004 NESHAP, to help us facilitate contacts within the industry. The director of the Auto Industry Forum shared project information with members and provided us with contact information for manufacturers willing to participate in the case study. To maximize the representativeness of the universe of regulated paint shops, we aimed for diversity in company ownership, geography, sales volume and the degree to which a plant was expected to be above the MACT standard in the selected facilities. Information that could be used to connect specific responses to individual plants or companies is kept confidential.

Nine facilities, owned by six different manufacturers, were selected for participation in the survey, with no single manufacturer responding for more than two facilities. Four respondents are located in the Midwest, while the remainder are located in the Southeast. In one case, the firm provided responses for two production facilities at the same plant with potentially different surface coating HAP emissions. In only one case had a production line/facility permanently ceased production since the promulgation of the NESHAP. Two of the selected paint shops were used to set the MACT floor, and therefore needed no additional HAP reductions to meet the 2004 NESHAP requirements. Plants ranged in age from 17 to 35 years with an average age of 28 years. Six of the nine plants had undergone a major update, renovation or expansion of their paint shop since they first were established, though these were reported by the facilities to not be HAP-related upgrades. Respondents had slightly larger production volumes (about 250,000 vehicles) in 2003, on average, compared to the larger sample of qualifying plants (from above, 211,000 vehicles). In addition, the plants in our sample represented about 25 percent of total annualized ex-ante compliance costs.

Survey description

The survey was designed to ask questions relevant to 2004 NESHAP compliance in five general areas: basic plant information, pollution abatement activities, capital expenditures, operating costs, and depreciation of capital. It is modeled after the 2005 redesign of the Pollution Abatement and Capital Expenditures (PACE) survey jointly administered by the EPA and the Census Bureau.[21] We used the PACE survey as a starting point because of its emphasis on improving identification of production process changes associated with regulatory requirements. The survey instrument that we sent to our sample of plants is available in its entirety in the Appendix.

The first section of the survey asks for plant location and age, and the date of its last major update, renovation or expansion. The second section asks respondents which pollution abatement activities were underway in the paint shop prior to 2004 and which were newly installed or implemented between 2004 and 2007.[22] We asked about both the use of abatement control devices and coatings that would lower HAP or VOC emissions by major coating stage. We also asked respondents to identify other regulations at the Federal, state, or local level that influenced decisions to newly install or implement lower HAP or VOC abatement strategies between 2004 and 2007. The third section of the survey asks about capital expenditures associated with each major HAP or VOC pollution abatement activity between 2004 and 2007. The fourth section asks respondents to report operating costs for a single year between 2004 and 2007 by type of pollution abatement device, or product redesign or reformulation activity. In addition, we ask for estimates of energy and waste disposal costs, monitoring, recordkeeping, and reporting costs and one-time shutdown costs associated with compliance activities. The final section

[21] For more information, see https://www.epa.gov/environmental-economics/pollution-abatement-costs-and-expenditures-2005-survey .

[22] Recall that facilities that were subject to this NESHAP had three years to comply with the rule in accordance with Section 112 the Clean Air Act. Thus, facilities had to comply with this rule by 2007.

of the survey asks several questions about depreciation expenses associated with newly installed pollution abatement equipment. The survey was administered in 2013 by Abt Associates.

Interview description

As noted above, we originally planned to conduct in-person site visits following the completion of the survey to verify the use of the reported pollution abatement equipment. However, the survey responses indicated that no new pollution abatement equipment had been installed due to the 2004 NESHAP and no other visible modifications to the production process were put in place to meet the standard. Rather, compliance with the standard was achieved primarily through reformulation of the primer-surfacer and top coatings and other process changes. For this reason, we decided follow-up phone interviews with each of the six participating auto manufacturers would be sufficient to gain better understanding of changes to the surface coating process and the costs incurred to meet the 2004 NESHAP. Generally speaking, interview participants were either plant managers or corporate engineers. The interviews were approximately 45 minutes in length and were administered by Abt Associates, and included an engineer with expertise in the automobile manufacturing and abatement process. A list of potential interview questions is included in the appendix.

In the course of conducting these interviews, we encountered a somewhat unanticipated challenge: the passage of time. The 2004 NESHAP was promulgated and actions taken to reach compliance occurred more than a decade ago. Staff, recordkeeping, and even ownership at some plants changed substantially over this time period. While staff could often tell us what actions the plant took to comply, it was more difficult to find and supply data on the cost of complying. Because of the difficulty in estimating certain elements of the cost of compliance, we extended the interviews to representatives from two major paint suppliers with the permission of the auto manufacturers they serve. Again, information that could be used to connect specific responses to individual plants is kept confidential.

Independent cost analysis

The final source of information for the ex-post cost assessment of the 2004 surface coating NESHAP is analysis we commissioned from Abt Associates. While the contractor relied on confidential facility-level survey information regarding the specific actions taken to comply, the estimated cost of those actions were generated independent of the survey or follow-up interviews using published sources.

5. Assessing Costs Retrospectively

This section compares the EPA's ex-ante estimates to ex-post estimates for each cost component for the nine plants in our sample, identifying possible key drivers of substantial differences when possible. Table 8 summarizes the main sources of information and findings for each cost category. As previously mentioned, because the EPA ex-ante analysis focused on direct compliance costs associated with the 2004 NESHAP, that is also the focus of our assessment.

5.1 Regulated Universe

As previously stated, the EPA determined that 60 plants would be subject to the NESHAP regulation.[23] Since that time, substantial restructuring and consolidation has occurred in U.S. vehicle manufacturing, resulting in the closure of 23 of these facilities.[24] Web searches confirm that seven of these plants closed before or during the period in which controls would have had to be put in place to comply with the 2004 NESHAP (i.e., plants had up to three years to comply) and therefore would likely have not incurred compliance costs. In its regulatory analysis, the EPA estimated that the impact of the regulation on

[23] In addition, after the 2004 NESHAP, the EPA issued two direct final rules in 2006 and 2007 affecting and expanding the regulated universe. The 2006 rule provided the option of including surface coating of heavier motor vehicles (NAICS 336210 Heavy Duty Truck Manufacturing and NAICS 33211 Motor Vehicle Body Manufacturing) under the 2004 NESHAP, instead of under other NESHAPs for Miscellaneous Metal Parts (40 CFR part 63, subpart MMMM) or Plastic Parts (40 CFR part 63, subpart PPPP). The 2007 rule clarified rule interactions and corrections to the text of the 2006 rule. See https://www.epa.gov/stationary-sources-air-pollution/surface-coating-automobiles-and-light-duty-trucks-national-emission .

[24] Though one of these plants was subsequently reopened as a Tesla plant.

market prices would be small (EPA 2004a). Therefore, the EPA concluded ex-ante that no plant would close as a result of the regulation. Newspaper reports confirm that the decisions to close these facilities had little to do with EPA's HAP (or VOC) regulations. For instance, Ford and GM both announced schedules of planned closings in the mid-2000s in response to increased competition from Japanese manufacturers and an inability to decrease labor costs (Kropko 2006, Taylor 2007) [25]

The EPA did not explicitly account for potential plant openings in its analysis. Aside from an existing plant that was retooled for Tesla production, three new U.S. light-duty vehicle manufacturing plants have opened in the U.S. over the past decade: Hyundai opened a plant in 2005, Kia opened one in 2009, and Volkswagen opened a plant in 2011. However, recall that since new paint shops would need to install technologies to meet existing VOC regulations, compliance with the 2004 HAP regulations was expected to occur at little additional cost.

5.2 Baseline Information

Characterizing the baseline for a cost analysis typically involves identifying what emission-reducing technologies or process changes had already been adopted by plants prior to promulgation of the new regulation. The EPA's *Guidelines for Preparing Economic Analyses* recommends that voluntary adoption of emission-reducing practices by industry not be attributed to the cost of regulation (EPA 2010).

To characterize the baseline ex-ante, the EPA relied on 1996, 1997, and 1998 calendar year data from a questionnaire called an information collection request (ICR) on the types of emission control devices already in place and the composition of its surface coatings, including whether the plant recently made significant changes to its coatings or solvent mixture (EPA 2002). The EPA also provided an overview of technologies used in the automobile industry to control paint shop HAP and VOC emissions prior to the

[25] Ford announced its intent to close 16 plants by 2012, while GM announced plans to shutter 12 plants between 2006 and 2009.

2004 NESHAP in its regulatory analysis, though it did not identify which specific technologies were used at particular plants.

To gain a better understanding of how baseline HAP emission profiles map to abatement technologies already in place, we asked the nine plants we surveyed to identify specific control devices installed or abatement-related process changes implemented prior to promulgation (i.e., before 2004). We asked follow-up questions during interviews with plant and corporate managers regarding the reasons these technologies or process changes were implemented if they took place in the 2000 to 2004 timeframe.[26] In total, we asked about six specific control technologies (consolidated to four in Table 3) and eight specific process changes known to reduce HAP and VOC emissions. While plants were given the option of identifying additional control strategies, none did so.

The EPA's ex-ante analysis identifies thermal oxidation, which destroys organic HAP or VOC emissions in the waste stream over a fairly wide range of concentrations, as the most common abatement approach in use at automotive paint shops prior to promulgation of the 2004 NESHAP (EPA 2002). At times, installation of a carbon-based system was also used to concentrate the waste stream prior to feeding it into the oxidizer. The EPA's regulatory analysis characterized solvent-recovery systems as relatively rare in the baseline, noting the economic infeasibility of recovering solvent for reuse.

With regard to abatement control devices already in place prior to 2004 (Table 2), the results of the ex-post survey confirm that thermal oxidizers, often in combination with a carbon-based concentration system, were relatively common among the plants in our sample prior to 2004. We did identify one discrepancy between ex-ante and ex-post information – for one plant in our sample, the EPA assumed ex-ante it did not have a thermal oxidizer, but in the ex-post survey the plant responded that it had one

[26] Note that the ICR occurred in 1999 and the rule was proposed in 2002, so it is possible that some early actions could still be potentially attributable to the regulation.

in place prior to promulgation. As expected, alterations to the design of the paint shop to accommodate low emission coatings was relatively rare before 2004. However, unlike EPA's ex-ante assessment that solvent recovery systems were not economically viable, all but one of the paint shops in our sample stated that they already utilized this approach for controlling HAPs prior to promulgation.

Table 2: Survey Results on Baseline Control Devices Operating in a Plant's Paint Shop

Control device	Proportion of paint shops in which it was operating prior to 2004
Thermal oxidizer	6/9
Carbon-based concentration system	4/9
Solvent-recovery system	8/9
Paint shop design alterations to alter coating used	1/9

Note that a thermal oxidizer can be regenerative or non-regenerative, and a regenerative thermal oxidizer can by catalytic or non-catalytic. The vast majority of plants that had a thermal oxidizer already in place prior to 2004 relied on a regenerative, non-catalytic variant.

We also asked about the use of alternative solvents or coatings, which we characterize as process changes that may not necessarily require capital expenditures, prior to 2004. As already noted, the EPA observed that use of water- and powder-based coatings in primer-surfacer operations was increasing prior to 2004 and expected their use would continue to grow slowly over time even absent regulation. Reformulating solvent-based coatings to lower HAP and VOC content was described in the ex-ante analysis as a current approach but also an area of active research due to quality concerns (EPA 2002).[27]

Four of the nine plants in our sample reported using lower HAP or VOC coatings at every stage in the paint shop process prior to 2004. Table 3 shows that four of the nine plants we surveyed used water-

[27] The top-performing 8 facilities used to set the MACT floor were described by a public commenter on the rule as a good representation of diversity in technologies currently used, which included facilities using powder primer-surfacers, or some combinations of low-HAP solvent-borne coatings, low-HAP waterborne coatings, and/or add-on control systems to reduce emissions (EPA 2004c).

based or powder coatings, while all but one plant reported that it had reformulated one or more coatings to lower HAP or VOC emissions. (The one plant that did not use this approach relied on powder or water-based coatings prior to 2004.) Use of lower HAP or VOC materials was also relatively common in primer and in sealer, sound deadener, or bonding adhesive prior to 2004.

Table 3: Survey Results on Baseline Coating Process Changes

Coating Process Change	Proportion of paint shops with coating process changes prior to 2004
Lower HAP or VOC primer	7/9
Lower HAP or VOC primer-surfacer	4/9
Lower HAP or VOC topcoat or clearcoat	5/9
Lower HAP or VOC sealer, sound deadener, or bonding adhesive	8/9
Lower HAP or VOC cleaning agents	5/9
Powder or water-based coatings	4/9

In follow-up interviews, several manufacturers opined on the reasons for investing in abatement technologies or process changes that lowered HAP emissions prior to the 2004 NESHAP. Water-based coatings were used in some plants prior to 2004 as a replacement for old solvent-based paint lines at the end of their natural life, due to global initiatives at the corporate level, to comply with state-level regulations (i.e., New Jersey and California), or by design from the very beginning for new plants. Reformulation of solvent-based coatings to lower HAPs was driven by global, corporate-level initiatives prior to 2004. Investments in abatement technologies that lower HAPs prior to 2004 were reportedly to control VOC emissions or replace old devices that had reached the end of their life.

5.3 Methods of Compliance

As described in section 3.1, a subset of plants was expected to already be in compliance with the MACT standard and therefore would not install new abatement equipment or make further modifications to their coating processes. Recall that for plants not yet in compliance with the 2004 NESHAP, the EPA anticipated that they would comply using one or more of four strategies: (1) install a regenerative thermal oxidizer on the electrostatic oven used in the first primer coating process, (2) substitute non-HAP for HAP solvents in primer surface coating, (3) substitute non-HAP for HAP solvents in top coating, or (4) install exhaust controls in the spray booth. The EPA evaluated which approaches would be used to comply plant-by-plant based on the extent to which a given facility was above the MACT standard.

Ex-post evidence from the surveys and follow-up interviews suggest that manufacturers often pursued corporate-level strategies to compliance with the 2004 NESHAP, which would substantially reduce heterogeneity in compliance strategy relative to the plant-by-plant estimation approach used by the EPA in its ex-ante analysis.[28] Table 4 compares the compliance strategies expected in the EPA ex-ante analysis with the compliance strategies reported ex-post for the nine plants that we surveyed.[29] While the EPA anticipated that only one of the nine plants was already in compliance with the 2004 NESHAP, survey results indicate that three plants did not take further action (i.e., install new abatement equipment or change their coating processes) to comply with the regulation. For the six plants that needed to reduce HAPs emissions to comply with the NESHAP, none reported installing an abatement control device, even though this was anticipated to be a common compliance strategy ex-ante. Instead, they relied on process changes to comply with the NESHAP. At least two manufacturers stated that

[28] Swift (2001) also observed that many electric utilities used corporate level strategies to bring plants into compliances with Phase I of the SO2 cap-and-trade program.

[29] Compared to the full sample, ex-ante installation of thermal oxidizers is over-represented (only 24 percent of all 58 plants were expected to install thermal oxidizers compared to 44 percent of the surveyed sample). The proportion expected to install exhaust controls in paint booths is the same across the two groups. For the remaining options (i.e., no additional controls, lower HAP or VOC primer-surfacer or top coatings), the proportion of plants in the sub-sample are reasonably close to the full sample (i.e., within 4 to 8 percentage points).

these process changes were applied to all of their facilities, even when they could demonstrate compliance with the 2004 NESHAP using pre-existing control systems.

Table 4: Comparison of Ex-Ante and Ex-Post Compliance Strategies for Surveyed Plants

Compliance Strategy	Proportion of Plants Adopting	
	Ex-Ante	Ex-Post
No additional controls	1/9	3/9
Add regenerative thermal oxidizer to electrostatic oven for first primer coat	4/9	0/9
Substitute non-HAP for HAP solvents in primer-surfacer coating	4/9	6/9
Substitute non-HAP for HAP solvents in top coating	2/9	6/9
Install exhaust controls in spray booth	7/9	0/9
Other	0/9	6/9

While the EPA estimated that five of the nine plants surveyed would either use lower HAP or VOC solvent coatings in their primer-surfacer coating or topcoats (only one was predicted to rely on both), the EPA predicted that these compliance strategies would almost always be accompanied by installation of a thermal oxidizer, exhaust controls, or both. Ex-post information indicates that all six plants that took action to comply with the 2004 NESHAP relied entirely on lower HAP and VOC solvent coatings, and that they used them in both the primer-surfacer and topcoat stages.[30] In addition, all six plants reported

[30] As expected, the use of water-based and powder coatings did not increase significantly from what had been projected ex-ante. In 2007, water-based coatings were used by about 22 percent of the market while powder coatings were characterized as representing a minor part of the market. The main barriers to increased adoption of water-based coatings were performance issues; testing requirements and significant capital investments were listed as barriers to adoption of powder coatings (Freedonia 2008).

compliance strategies not quantified by the EPA ex-ante: three of the plants reported using lower HAP or VOC cleaning agents, one reported using lower HAP or VOC primer, and two reported actions to lower solvents in the surface coating process more generally.[31]

Many manufacturers reportedly started to work on lowering HAP emissions from coatings before the 2004 NESHAP was promulgated, even though they described significant uncertainty regarding the ultimate standard. More than one manufacturer noted that the data request made by the EPA in 1999 gave them time to strategize regarding how they might meet the NESHAP. Another manufacturer mentioned that as new colors were introduced, it simultaneously reformulated the coating to reduce HAPs; some of these reformulations occurred as early as 2002. (Existing colors were not reformulated until promulgation of the NESHAP.)

Because manufacturers also reformulated their existing paint colors to lower HAP emissions, implementation typically took several years (e.g., reformulation began in 2004/2005 with full conversion by 2007) and proceeded in stages. One manufacturer introduced lower-HAP coatings for higher-volume colors first, followed by lower-volume colors. Another manufacturer reformulated darker colors first, which were viewed as more forgiving, before moving onto lighter colors.

Why did reformulation of coatings dominate as a compliance strategy among survey respondents? Manufacturers mentioned several reasons. First, major manufacturers (as well as paint suppliers) were already cooperatively exploring low-HAP paint formulations prior to promulgation of the NESHAP. For instance, Chrysler, Ford, and General Motors formed a consortium in 1993 to share the technology and costs of developing a low-VOC emission coating for automobiles (Freedonia 1999). This was reportedly

[31] Note that the EPA delisted methyl ethyl ketone (MEK) as a HAP in 2005. The EPA's regulatory analysis for the 2004 NESHAP noted that MEK is released during the surface coating process for light-duty vehicles (specifically, during the electrodeposition primer, primer-surfacer, and basecoat steps) and that it had been proposed for delisting in 2003 (EPA 2004). However, while it is possible the delisting could have affected manufacturers' compliance strategies, none of the plants we surveyed or managers we interviewed mentioned this as a factor in how they complied with the 2004 surface coating NESHAP.

in response to increased competition by foreign automobile manufacturers as well as passage of the 1990 Clean Air Act Amendments (New York Times 1993; Meschievitz, et al. 1995).[32] Second, the automotive coatings industry is fairly concentrated; there were three major suppliers in the United States at the time (EPA 2004a). Pursuing a corporate-level reformulation approach was therefore attractive because it yielded substantial economies-of scale; as one manufacturer stated, eventually non-compliant paints would become more expensive than reformulated paint. In addition, another manufacturer observed that, while coating specifications are unique to a manufacturer, paint suppliers received similar requests from multiple manufacturers to develop compliant coatings. While we also asked plants whether Federal, state, or local regulations aside from the 2004 NESHAP influenced the strategies they pursued to lower HAP or VOC emissions between 2004 and 2007, they did not identify any additional regulatory factors.

5.4 Compliance Costs

In this section, we examine the ex-post evidence on compliance costs. In particular, what were the initial or one-time costs of compliance (fixed or variable components)? What were the ongoing costs of compliance (operation and maintenance)? For the automobile manufacturers, these types of compliance costs can be classified into three categories: the cost of installing capital (i.e., abatement equipment); on-going annual operating costs; and on-going administrative costs (e.g., monitoring, testing, recordkeeping, and reporting).[33] For process changes, one-time R&D costs incurred by paint suppliers are also relevant, though these should eventually manifest as a change in a manufacturer's operating costs and thus are discussed in section 5.4.2.

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[32] The Low Emissions Paint Consortium operated out of a Ford plant under the auspices of the United States Council for Automotive Research (USCAR). It initially focused on powder coatings (Meschievitz, et al. 1995).
[33] While we asked about energy and waste disposal costs on the survey, no plant entered a value other than zero.

5.4.1 Capital Costs

Because none of the plants that we surveyed invested in abatement control technology, ex-post capital costs associated with the 2004 NESHAP were essentially zero.[34] One manufacturer indicated that its goal was to satisfy the NESHAP requirements while avoiding the costs of installing control equipment. This contrasts with what the EPA anticipated ex-ante. It expected that only two of the nine plants would have zero capital costs since they were largely already in compliance. For the remaining seven plants, the EPA estimated upfront total capital costs to comply with the 2004 NESHAP ranging from $6 million to $60 million per plant, with a median cost of almost $19 million (in 1999 U.S. dollars). In addition to the cost of purchasing and installing abatement equipment, the EPA included a one-time cost of $9,000 to $18,000 per plant in its ex-ante analysis to account for performance testing of add-on control device systems. Since no plant installed pollution abatement equipment to comply with the 2004 NESHAP, ex-post testing costs are also zero.[35]

5.4.2 Operating Costs

Generating ex-post estimates of operating costs due to compliance with the 2004 NESHAP proved challenging. From the perspective of an individual plant, adopting lower-HAP formulations was seen as very similar to introducing a new paint color; the calibration and testing process is reportedly the same. As such, plants often did not view this process change as resulting in additional operating costs. In addition, at least one manufacturer noted that it did not work directly with paint suppliers to develop new low-HAP coatings, instead piggy-backing on work that had already been performed for other

[34] We asked about one-time shutdown costs associated with the installation of new pollution abatement equipment, but since no equipment was installed there were no shut down costs.

[35] It is interesting to note that all but one of the nine plants we interviewed responded that capital expenditures to reduce HAPs emissions were about what they expected ahead of time. The one plant that responded differently stated that capital expenditures were significantly lower than expected.

manufacturers. Thus, most manufacturers either included an estimate of zero on the survey or offered a qualitative explanation that implied very low annual costs.[36] [37]

Several manufacturers observed that most of the cost of developing new coatings was incurred by the paint suppliers. The paint suppliers conducted R&D over multiple years to design and refine lower HAP formulations prior to introducing them into a manufacturer's product line, which ultimately should have manifested as a change in the cost of coatings to the manufacturer. One manufacturer we interviewed noted that because the decision to comply with the NESHAP by reformulating coatings was made at the corporate level, any costs passed along by the paint suppliers were not obvious. Another manufacturer added that any changes in the cost of the coatings passed along to them due to reduced HAP content would have been difficult to separate out from other factors but were minimal if present at all. The amount of time that had passed between promulgation and the conduct of our survey also made it difficult for manufacturers to determine the actual costs incurred. Thus, it should not be surprising that only one manufacturer - in a follow-up interview - attempted to roughly quantify incremental operating costs of reformulating its topcoat (specifically, the basecoat).

Because of the paucity of detailed information from manufacturers on their cost of compliance with the 2004 NESHAP, we followed up directly with two of the manufacturers' main U.S. paint suppliers, with the manufacturer's permission, regarding the R&D costs associated with developing low-HAP emission coatings. The paint suppliers indicated that development of any new formulation requires two to three years of lead time before it can be introduced into the paint line at a manufacturing facility. For the response to the NESHAP, the new formulations were developed to achieve the necessary reduction in

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[36] The challenge of collecting estimates of process-related pollution expenditures was also acknowledged during the redesign of the Pollution Abatement and Cost Expenditures survey (Ross, et. al 2004).

[37] As previously mentioned, the costs of work practice standards were not analyzed in the EPA's ex-ante cost analysis. While two manufacturers mentioned in follow-up interviews that they developed a work practice plan to meet these requirements they also noted that this resulted in fairly minimal costs.

solvent content and the performance of the paint was validated through testing (e.g., weather and durability testing and chip resistance). The two suppliers agreed that the testing process for a reformulated topcoat – in particular, the basecoat, the first step in the finishing process - is identical to what would have occurred for a new color.[38] However, one supplier noted that additional quality testing was required to reformulate the primer-surfacer but offered no additional details.

One paint supplier noted that the R&D cost to reformulate coatings was quite low: it estimated that it took one person-year to develop a new primer-surfacer and 0.5 person-year to develop a new topcoat (the basecoat), with each person-year valued at about $100,000. The main reason for the low cost was that the supplier only had to reformulate the delivery solvent (i.e., the resins in the paint were left alone) to meet the new requirements. In 80 to 90 percent of the cases, HAP reductions were achieved by substituting butyl acetate for xylene (the supplier noted that ethyl glycol acetate was more expensive and therefore rarely used). The supplier confirmed that these costs were passed onto manufacturers indirectly via paint prices. Both paint suppliers offered rough estimates of the change in the per-gallon cost of reformulating a NESHAP compliant topcoat (i.e., specifically, the basecoat), which is equivalent to the increase in the price of the paint to the manufacturer once all the reformulation costs have been passed through (see Table 5). In general, the estimates provided by the suppliers are significantly lower than those from the manufacturers, who are one step removed from the actual reformulation process.

[38] The electrodeposited primer and clearcoat were reportedly not reformulated.

Table 5: Estimated Incremental Operating Costs of a Reformulated Topcoat (1999$)

Incremental Cost Increase	Ex-Post				Ex-Ante
	Manufacturer Estimate[39]	Paint Supplier Estimate[40]	Paint Supplier Estimate[41]	Independent Estimate	EPA Estimate[42]
Per Gallon of Paint	$1.25 - $4.13	$0.26 – $0.71	$0.21 - $0.84	$0.17 - $0.39	--
Average per Plant ($1,000s)	$152 - $501	$65 - $172	$51 - $204	$21 - $47	$53

In addition, since so few manufacturers were able to offer a quantifiable estimate we commissioned an independent cost estimate from a contractor for comparison purposes (see Table 5). The contractor used publicly available historical information on the cost of two possible substitute solvents– ethyl acetate and butyl acetate – to develop bottom up estimates of the incremental cost per gallon of basecoat paint.[43] The per gallon cost estimates developed through this process are lower than either the manufacturer or supplier estimates. This may be due to the fact that they are based solely on the replacement cost of the solvent and do not account for the cost of validation and testing.

[39] The manufacturer indicated that a high HAP paint cost between $30 - $100/gallon in 2006 dollars with about 10 percent of the cost due to solvents prior to reformulation. The manufacturer estimated that about 15 percent of the current cost is due to solvents, which results in an incremental increase in costs of approximately $1.50-$5/gallon. A vehicle requires about ½ gallon of paint. In 2006 dollars, this is $0.75-$2.50/vehicle.

[40] The first supplier estimated an additional cost of $0.30 to $0.80 per gallon to comply, depending on whether the coating was solvent- or water-based, respectively. The supplier cited two internal case studies as the main source of this information. We assume these studies are expressed in 2004 dollars (the first year of compliance), though the supplier did not indicate the year of the studies.

[41] The second supplier indicated that reformulating the basecoat resulted in a one to two percent increase in the cost of the coating, with a gallon of basecoat costing $30 - $60 per gallon (in 2014 dollars), depending on the color.

[42] We report the average cost for the subset of plants participating in the survey that the EPA expected would use this compliance strategy. In the regulatory analysis, the EPA mentioned that it used an incremental cost of $0.23 per pound of solvent to switch from xylene to ethyl acetate as an input into its analysis, but it did not provide enough information to translate this into a per gallon of paint estimate (EPA 2004a).

[43] The main source of information for the cost of xylene and its low-HAP substitutes was ICIS (2008). The weight and density of solvent in the paint was taken from the EPA (1995) and Papasavva et al. (2001). The cost per gallon for each solvent was derived by multiplying the density of the paint (8.5 pounds per gallon) by the percent of solvent by weight (18 percent) by the unit cost of the solvent ($0.53 per pound for xylene; $0.69 per pound for ethyl acetate; and $0.89 per pound for butyl acetate in 2013 dollars). The incremental cost was then derived by taking the difference between the cost of xylene and its low-HAP substitute.

Comparison of Ex Post and Ex Ante Operating Cost Estimates

To compare the various ex-post estimates to the EPA ex-ante estimates, it is necessary to calculate compliance costs at the plant level. If we rely on the manufacturer-provided estimate that a vehicle requires about 1/2 gallon of paint on average, we can calculate the increase in costs on a per-vehicle basis and combine this information with sales data to calculate the average ex-post compliance cost per plant (see Table 5).[44] The ex-post basecoat reformulation estimates from paint suppliers, which we think likely to be the most accurate, range from about $50,000 to $250,000 per plant. The EPA's ex-ante estimate falls at the low end of the range of these ex-post estimates.[45]

Only one supplier provided an estimate of the cost of reformulating the primer-surfacer coating. Similar to its estimate for reformulating the basecoat, it indicated that the cost of primer-surfacer increased one to two percent after compliance with the NESHAP.[46] Using a similar methodology to what was used for the basecoat cost estimate, we commissioned an independent cost estimate for the reformulated primer-surfacer coating (see Table 6).[47] As with the basecoat estimate, the independent cost estimate is low and likely missed important validation and testing costs. The EPA's estimate of operating costs associated with reformulating the primer surfacer coating for the plants we surveyed is well within the estimated ex-post range offered by the paint supplier.

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[44] We use 2004 production levels. While the EPA used 1999 production levels in its ex-ante analysis, they are very similar to 2004 production levels. By 2008, production levels declined slightly.

[45] Recall that the EPA estimated annual operating costs for each plant based on the mix of compliance strategies expected. For the plants we surveyed, ex-ante median annual operating costs were about $2 million (in 1999 dollars). However, the majority of those expenses were for installation of abatement control equipment.

[46] Since the supplier indicated that primer-surfacer costs about $25 per gallon (in 2014 dollars), this implies an increase in the cost of $0.25 - $0.50 per gallon in 2014 dollars, or $0.18 - $0.35 per gallon in 1999 dollars.

[47] The cost per gallon for each solvent was derived by multiplying the density of the paint (8.5 pounds per gallon) by the percent of solvent by weight (9 percent) by the unit cost of the solvent ($0.53 per pound for xylene; $0.69 per pound for ethyl acetate; and $0.89 per pound for butyl acetate in 2013 dollars). The incremental cost was then derived by taking the difference between the cost of xylene and its low-HAP substitute.

Table 6: Estimated Incremental Operating Costs of a Reformulated Primer-Surfacer Coating (1999$)

Incremental Cost Increase	Ex-Post		Ex-Ante
	Paint Supplier Estimate	Independent Estimate	EPA Estimate[48]
Per Gallon of Paint	$0.18 - $0.35	$0.09 - $0.20	--
Average per Plant ($1,000s)	$15 - $29	$7 - $16	$22

In addition to the costs incurred by paint suppliers to reformulate coatings, two manufacturers noted that a small amount of their staff's time was periodically dedicated to coordinating with paint suppliers, particularly during the testing and paint-line conversion stages. One manufacturer offered specific estimates: two staff engineers spent about 10 percent of their time during the R&D stage (which lasted several years), 25 percent of their time during the testing or trial stage (about one year in length), and about 40 percent of their time at the conversion stage (about one year in length). When combined with wage rate information from the Bureau of Labor Statistics, this amounts to about $150,000 in additional costs per plant (in 1999 dollars).[49]

5.4.3 Administrative Costs

Automobile assembly plants also were expected to incur costs to meet the monitoring, recordkeeping, and reporting requirements of the 2004 NESHAP. We asked the plants we surveyed to provide estimates of these additional costs in any given year between 2004 and 2007. Most of the plants were

[48] Note that the EPA estimate to reformulate the primer-surfacer coating ranged widely for the four plants it anticipated would use this approach. We do not report the range to avoid identifying the specific plants that participated in the survey.

[49] In one case, the manufacturer stated that it took a programmer working part time about 6 months to develop a new database. We used BLS wage information to translate this into a quantitative estimate. Others described developing new measurement protocols, modifying annual databases to allow for monthly tracking, or adding a HAPs module to existing VOC databases.

not able to supply quantitative estimates due to the amount of time that had passed since implementation, and the fact that many of the systems put in place were designed at the corporate level. Follow-up interviews with the manufacturers yielded more information.

Of the five manufacturers that provided quantitative estimates, representing all but one of the plants surveyed, only one incurred no additional monitoring or recordkeeping costs because it already tracked the information required by the 2004 NESHAP prior to the regulation. The remaining manufacturers described additional costs mainly associated with adapting or building a new database to track HAP emissions. Estimates for database development ranged from $26,000 to $52,000 (in 1999 dollars) at the corporate level.[50] In most cases, it is not possible to express this on a per-plant basis.[51] Annual costs of monitoring and recordkeeping for the 2004 NESHAP were described as relatively low in most cases, ranging from "nearly automatic" to a couple hours of staff time each month. Only one manufacturer stated that the plant that participated in the survey incurred significantly larger monitoring costs, of about $14,000 in 2007 (in 1999 dollars), but it is not clear if this is an annual or one-time cost.

Ex-ante, the EPA assumed that almost all plants would incur one-time costs of $20,000 (in 1999 dollars) to modify existing recordkeeping systems as well as annual costs of about $2,000 per plant, which is somewhat consistent with ex-post estimates provided by most manufacturers. However, the EPA estimated that monitoring would cost $15,600 per plant on an annual basis. Most manufacturers made no mention of these types of costs in the ex-post survey, although asked specifically about monitoring.

Three plants included annual reporting costs of $7,000 to $8,000 (in 1999 dollars) on the survey, while four indicated near-zero costs due to the automatic nature of reporting once their database system was in place. When expressed as an average, the annual cost of reporting per plant is quite close to what the

[50] The loaded hourly wage for a computer systems analyst is $69.48 in 2013 dollars ($49.69 in 1999 dollars). The range is based on whether we assume the analyst worked full or part time to develop the system over six months.
[51] In two cases, we identify per-plant data development costs ranging from $16,000 to $42,300 in 1999 dollars.

EPA assumed ex-ante ($2,300), though the EPA did not consider the potential for substantial heterogeneity in reporting costs across plants.

5.5 Total Compliance Costs

In this section, we estimate total ex-post compliance costs for the nine plants that participated in the survey and compare this estimate to the EPA's ex-ante compliance costs for the same set of plants (see Table 7). Recall that one of the main differences between the ex-ante and ex-post estimates for the nine plants we surveyed is the choice to comply by reformulating coatings instead of installing abatement control equipment. It is therefore not surprising that there is a large discrepancy between total ex-ante and ex-post compliance costs. However, once the cost of installing and operating abatement control equipment is deducted from the total, we find that the EPA's ex-ante estimate falls well within the estimated ex-post range.

With regard to administrative costs, the EPA's ex-ante estimate is more than eight times larger than estimated ex-post costs. The magnitude of the EPA's ex-ante estimate is largely driven by the assumption that plants would incur substantial annual costs for ongoing monitoring and recordkeeping, for which there is no ex-post evidence. These constitute about 93 percent of the ex-ante total annualized administrative cost estimate. Ex-ante and ex-post estimates of the cost to set up or modify an existing recordkeeping system are roughly similar. However, the EPA assumed ex-ante that plants would individually set up a recordkeeping system, while ex-post information reveals that most of the manufacturers we surveyed updated or built databases at the corporate level. It is unclear whether this difference is fully reflected in the ex-post estimates.

Table 7: Comparison of Ex-Ante and Ex-Post Compliance Cost Estimates for Surveyed Plants

	Ex-Ante EPA Estimate	**Ex-Post Estimate** (paint supplier - low)	**Ex-Post Estimate** (paint supplier - high)
Total Annualized Compliance Cost	$35.9 million	$148,000	$264,000
Annualized Capital & Operating Cost for Abatement Controls	$35.7 million	$0	$0
Annualized Cost to Reformulate Coatings	$192,000	$148,000	$264,000
Total Annualized Administrative Costs	$321,000	$38,000	$38,000
Annualized Cost of One-Time Recordkeeping Costs	$20,000	$15,000	$15,000
Annualized Ongoing Administrative Costs	$301,000	$23,000	$23,000

6. Overall Implications and Study Limitations

In this paper, we compare ex-ante estimates of the costs of compliance with the 2004 NESHAP for surface coating of light-duty automobiles and trucks to ex-post cost estimates based on data collected mainly through a survey and follow-up interviews administered to nine assembly plants subject to the regulation. Analysis of the data indicates that the EPA likely substantially overestimated the cost of complying with the 2004 NESHAP for the plants we surveyed. This is primarily because the plants chose to reformulate their coatings to emit fewer HAP emissions rather than install expensive abatement control technology. Importantly, managers often had difficulty estimating compliance costs for a variety of reasons, including loss of documentation due to the passage of time and difficulty identifying costs associated with process changes. We supplemented the information supplied by the plants with additional data from two paint suppliers that performed R&D to reformulate coatings for several of the leading manufacturers.

Because we only have ex-post information for a subset of plants subject to the 2004 NESHAP, it is not possible to produce an ex-post aggregate compliance cost estimate for the automobile industry. However, there are several reasons why we might expect that the EPA also overestimated compliance costs for the sector as a whole. First, fewer plants likely incurred compliance costs than expected since they closed prior to 2007 for reasons unrelated to the regulation. Second, many companies pursued a corporate-wide strategy of reformulating coatings to comply with the 2004 NESHAP as well as international standards. If process change dominated for other facilities as well, then ex-post compliance costs were likely lower than expected. Third, by design the MACT standards are performance-based standards, which means that firms can choose the way in which they comply with emission limits. If lower cost and/or more effective techniques than those evaluated by the EPA were available, it seems likely, that firms would pursue those abatement options.

Finally, many manufacturers noted that they were already taking action or actively supporting R&D to reduce HAP emissions from their paint shops prior to the 2004 NESHAP either as part of global and/or corporate-level initiatives, in response to state regulations, or as part of major upgrades of outdated equipment. While many of these pre-existing efforts were accounted for in the EPA's ex ante baseline (e.g., the use of water-based coatings), interviews suggest that the 2004 NESHAP may have accelerated the technological change already under way in the industry.

Table 8: Summary of Findings

<table>
<tr><td colspan="3">Components of Cost Estimate</td><td>Source of Ex-Post Information</td><td>Assessment (Compared to Ex-Ante)</td></tr>
<tr><td>Regulated Universe</td><td colspan="2">Number of automobile manufacturers with paint shops</td><td>Annual production by automotive plant, 2003-2008</td><td>Smaller than expected – nearly one third of plants closed for reasons unrelated to environmental regulation</td></tr>
<tr><td colspan="3">Baseline use of abatement controls and process changes to lower HAPs</td><td>Survey results</td><td>Abatement controls – reasonable
Process change – used more than expected</td></tr>
<tr><td rowspan="2">Methods of Compliance</td><td colspan="2">Abatement controls</td><td>Survey results</td><td>Smaller use than expected – EPA predicted this as main method of compliance but no one used</td></tr>
<tr><td colspan="2">Process Changes</td><td>Survey results</td><td>Large use than expected – main compliance strategy compared to moderate uptake predicted</td></tr>
<tr><td rowspan="4">Compliance Costs</td><td>Direct, One-Time</td><td>Capital</td><td>--</td><td>Smaller than expected – no one used, so no costs</td></tr>
<tr><td rowspan="2">Direct, On-Going Cost</td><td>Reformulating paints</td><td>Survey results and interviews; indep. cost assessment</td><td>Possibly somewhat larger than expected for basecoats; reasonable for primer-surfacer</td></tr>
<tr><td>Monitoring, recordkeeping, reporting</td><td>Survey results and interviews</td><td>Lower than expected</td></tr>
<tr><td colspan="2">Indirect</td><td>--</td><td>--</td></tr>
<tr><td colspan="3">Opportunity Costs</td><td>--</td><td>--</td></tr>
<tr><td>PER PLANT NET COSTS</td><td colspan="4">Likely lower than expected – driven mainly by different methods of compliance rather than substantial mis-estimation of abatement costs associated with a given method of compliance</td></tr>
<tr><td>TOTAL COSTS</td><td colspan="4">Difficult to assess since we only have information for a subset, but if process change dominated for other facilities as well, then likely lower than expected</td></tr>
</table>

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OMB No. 2090-0028: Approval Expires 06/30/2015

Emission Reduction Strategies and Costs related to 2004 National Emission Standard for Hazardous Air Pollutants for Automobile and Light-Duty Truck Surface Coating

NOTICE – All information provided on this survey will remain confidential.

IMPORTANT

Please read guidelines, definitions, and examples before completing this survey form.

Report for the specified paint shop in the facility located at the address below.

Please correct errors in name, address, and ZIP code. ENTER street and number if not shown.

Item 1 FACILITY INFORMATION

A. For the specified paint shop, check ONE box that best describes current status.

Paint shop :

- ☐ In operation as of July, 31, 2013.
- ☐ Temporarily idle (intend to resume operations)
- ☐ Permanently ceased operations

B. For the specified paint shop within the facility, provide information on age of the paint shop and timing of major updates or expansions.

Year first built or installed: ______

Year of most recent major update, renovation, or expansion: ___

Item 2 POLLUTION ABATEMENT ACTIVITIES

The questions in this section are specific to the paint shop in your facility identified above and refer to pollution abatement activities to reduce HAP or related VOC emissions from surface coating.

A. What pollution control devices for reducing HAP or VOC emissions from your paint shop were operating <u>prior to 2004</u>? What devices for controlling HAP or VOC emissions were newly installed between the beginning of 2004 and <u>the end of 2007</u> to help comply with the 2004 NESHAP? If no control devices were installed or operating, check the box in the "No" column.

Control Device	Control Devices Operating in Paint Shop Prior to 2004		Control Devices Newly Installed in 2004 - 2007	
	Yes	No	Yes	No
a. Regenerative thermal oxidizer (catalytic)	☐	☐	☐	☐
b. Regenerative thermal oxidizer (non-catalytic)	☐	☐	☐	☐
c. Non-regenerative thermal oxidizer	☐	☐	☐	☐
d. Carbon-based concentration system	☐	☐	☐	☐
e. Solvent recovery system	☐	☐	☐	☐
f. Paint shop design alterations to alter coating used	☐	☐	☐	☐
g. Other *Describe:*______________________	☐	☐	☐	☐

B. Were lower HAP or VOC solvents and coatings used in your paint shop prior to 2004? Were lower HAP or VOC solvents or coatings newly adopted between the beginning of 2004 and the end of 2007 to help comply with the 2004 NESHAP?

Solvents or Coatings	Solvents and Coatings Used in Paint Shop Prior to 2004		Solvents and Coatings Newly Used in 2004 - 2007	
	Yes	No	Yes	No
a. Lower-HAP or VOC primer (e.g., w/acetate instead of toluene or xylene)	☐	☐	☐	☐
b. Lower-HAP or VOC primer surfacer	☐	☐	☐	☐
c. Lower-HAP or VOC topcoat or clearcoat	☐	☐	☐	☐
d. Lower-HAP or VOC sealer	☐	☐	☐	☐
e. Lower-HAP or VOC sound deadener	☐	☐	☐	☐
f. Lower-HAP or VOC glass bonding primer or bonding adhesive	☐	☐	☐	☐
g. Lower-HAP or VOC cleaning agents	☐	☐	☐	☐
h. Powder or waterborne coatings	☐	☐	☐	☐
i. Other *Describe:*_________________________	☐	☐	☐	☐

C. **Please describe any other regulations (Federal, State, or Local) for HAPs or VOCs that applied to your paint shop and resulted in new installations or use of lower HAP or VOC solvents and coatings between the beginning of 2004 and end of 2007.** *Circle the regulation that was the most stringent during this time period.*

	Federal	State	Local
a. *Describe:*____	☐	☐	☐
b. *Describe:*____	☐	☐	☐
c. *Describe:*____	☐	☐	☐
d. *Describe:*____	☐	☐	☐
e. *Describe:*____	☐	☐	☐

Item 3 POLLUTION ABATEMENT CAPITAL EXPENDITURES

The questions in this section ask about capital expenditures associated with HAP and related VOC pollution abatement for the paint shop between the beginning of 2004 and the end of 2007. Report capital expenditures by type of HAP or VOC pollution control device. Add these values together to determine TOTAL CAPITAL EXPENDITURES of pollution abatement in 3B. **Provide an estimate of TOTAL CAPITAL EXPENDITURES even if you are unable to provide separate estimates for each component of pollution abatement capital expenditures in 3A.**

- Report only incremental capital expenditures for HAP and VOC pollution abatement activities. (See page 2 in the guidelines for a discussion of "incremental" costs.)
- For facility/process upgrades/modifications, report only the incremental cost for which the primary purpose is pollution abatement.
- Do NOT report pollution abatement capital expenditures from previous years.
- Do NOT include depreciation expense.
- Include installation and start-up costs for pollution abatement expenditures. Include labor only when contracted specifically for installation.
- Include capital expenditures related to monitoring and testing.

If the paint shop in your facility had no capital expenditures or capital expenditures less than $500 for HAP or VOC pollution abatement from 2004 to 2007 in a specific category, check the box in the "Zero" column.

1. **Provide estimates of capital expenditures for your newly installed HAP and/or VOC pollution abatement methods during 2004-2007 to help comply with the 2004 NESHAP.** [Fill in dollar amount or check "zero"]

		Zero
a. Regenerative thermal oxidizer (catalytic)	$	☐
b. Regenerative thermal oxidizer (non-catalytic)	$	☐
c. Non-regenerative thermal oxidizer	$	☐
d. Carbon-based concentration system	$	☐

e. Solvent recovery system	$	☐
f. Paint shop design alterations to alter coating used	$	☐
g. Other *Describe:*________________________	$	☐

2. **Add Items 3Aa–h to calculate TOTAL CAPITAL EXPENDITURES for pollution abatement in 2004-2007.** Provide an estimate of TOTAL CAPITAL EXPENDITURES for pollution abatement even if you are unable to provide separate estimates for 3Aa–h.

		Zero
TOTAL POLLUTION ABATEMENT CAPITAL EXPENDITURES	$	☐

3. **Were capital expenditures to reduce HAP or VOC emissions substantially higher, lower, or about as expected?** (check the appropriate box)

HIGHER	**LOWER**	**AS EXPECTED**
☐	☐	☐

If capital expenditures were substantially higher or lower than expected, please describe the main reasons why:

Item 4	**POLLUTION ABATEMENT OPERATING COSTS**

Report your operating cost by type of pollution abatement activity to lower HAP or related VOC emissions for a given year between 2004 and 2007. Report only new operating costs for HAP or VOC-related abatement activities incurred to help comply with the 2004 NESHAP. Add these values together to determine TOTAL OPERATING COSTS of pollution abatement. **Provide an estimate of TOTAL POLLUTION ABATEMENT OPERATING COSTS in 4E even if you are unable to provide separate estimates for each component of operating costs in 4A-4D.**

- Report only incremental operating costs for HAP and VOC pollution abatement activities. (See page 2 in the guidelines for a discussion of “incremental” costs.)
- For facility/process upgrades/modifications, report only the incremental cost for which the primary purpose is pollution abatement.
- Operating costs include salaries/wages for time spent by professional administrative, operating, and maintenance employees on pollution abatement activities (including training to operate new equipment), material and supply costs, contract work, leasing, and other purchased services, fuel, electricity and other energy costs, and waste disposal costs.

- Do NOT include depreciation expense.
- Report operating costs (including wages, contract work, and material costs) related to the installation of new pollution control devices in 4A.
- Report changes in operating costs (including wages, contract work, and material costs) related to product redesign or reformulation in 4B.
- Separately report changes in fuels, electricity and other energy costs and waste disposal costs in 4C. Do not include these costs in your estimates for 4A and 4B.
- Include costs related to monitoring, testing, and on-site administration costs (e.g., recordkeeping and reporting) associated with environmental protection in 4D. Do not include these in your estimates for 4A – 4C.
- Separately report any one-time shutdown costs associated with a pollution abatement activity in 4F. Do not include these in your estimates for 4A - 4D.
- If the paint shop in your facility had no operating costs, or those costs were less than $500 for HAP or VOC pollution abatement from 2004 to 2007 in a specific category, check the box in the “Zero” column.

A. Provide estimates of operating costs for newly installed HAP or VOC pollution control devices for a given year between 2004 and 2007 to help comply with the 2004 NESHAP. Include wages/salaries, contract work and other purchased or leased services, and material costs. [Fill in dollar amount or check "zero"]

	YEAR ________	Zero
1. Regenerative thermal oxidizer (catalytic)	$	☐
2. Regenerative thermal oxidizer (non-catalytic)	$	☐
3. Non-regenerative thermal oxidizer	$	☐
4. Carbon-based concentration system	$	☐
5. Solvent recovery system	$	☐
6. Other *Describe:*________	$	☐

B. Provide estimates of the change in operating costs from product redesign or reformulation to lower HAPs or VOCs in a given year between 2004 and 2007 to help comply with the 2004 NESHAP. Note that the change in operating costs is the difference in costs between the new coating and the previously used coating and could be negative. Include wages/salaries, contract work and other purchased or leased services, and material costs. [Fill in dollar amount or check "zero"]

	YEAR ________	Zero
1. Lower-HAP or VOC primer (w/acetate instead of toluene or xylene)	$	☐
2. Lower-HAP or VOC primer surfacer	$	☐
3. Lower-HAP or VOC topcoat pr clearcoat	$	☐
4. Lower-HAP or VOC sealer	$	☐
5. Lower-HAP or VOC sound deadener	$	☐
6. Lower-HAP or VOC glass bonding primer or bonding adhesive	$	☐
7. Lower-HAP or VOC cleaning agents	$	☐
8. Powder or waterborne coatings	$	☐
9. Other *Describe:*________	$	☐

1. **Provide estimates of the change in energy and waste disposal costs associated with newly installed HAP or VOC pollution control devices from 4A or product redesign or reformulation to lower HAPs and VOCs from 4B in a given year between 2004 and 2007 to help comply with the 2004 NESHAP.** Note that the change in energy and waste disposal costs is the difference in costs between the new device or coating and the previously used device or coating and could be negative. [Fill in dollar amount or check "zero"]

	YEAR ________	Zero
1. Fuels, electricity, and other energy costs	$	☐
2. Waste disposal and recycling costs	$	☐

3. **Provide estimates of monitoring and testing, recordkeeping, and reporting operating costs associated with newly installed pollution control devices or new use of low HAP or low VOC coatings for a given year between 2004 and 2007 to help comply with the 2004 NESHAP.** [Fill in dollar amount or check "zero"]

	YEAR ________	Zero
1. Monitoring and testing costs	$	☐
2. Recordkeeping costs	$	☐
3. Reporting costs	$	☐

E. Add Items 4A–D to calculate TOTAL OPERATING COSTS for pollution abatement in a given year between 2004 and 2007. Provide an estimate of TOTAL OPERATING COSTS for pollution abatement even if you are unable to provide separate estimates for Items 4A–C.

	YEAR ________	Zero
TOTAL POLLUTION ABATEMENT OPERATING COSTS	$ **,000**	☐

1. Did you have any one-time shutdown costs associated with the installation of a new pollution abatement control device or product redesign to lower HAP or VOC emissions to help comply with the 2004 NESHAP that were not recovered later in the year?

Yes	No
☐	☐

If yes, please provide an estimate in terms of foregone revenues from lost output.

YEAR ____________________

	Zero
$	☐

2. **Were operating expenditures associated with newly installed HAP or VOC pollution control devices or new use of low HAP or low VOC coatings in your paint shop substantially higher, lower, or about as expected?**
(check the appropriate box)

HIGHER	LOWER	AS EXPECTED
☐	☐	☐

If operating expenditures were substantially higher or lower than expected, please describe the main reasons why:

Item 5	DEPRECIATION

Estimate depreciation expenses for all newly installed pollution abatement equipment to reduce HAP or related VOC emissions operating in this paint shop between the beginning of 2004 and the end of 2007 to help comply with the 2004 NESHAP. If your facility had no depreciation costs or depreciation costs less than $500 for the pollution abatement equipment during this time period, check the box in the 'Zero' column. (See page 6 in the guidelines for definition.)

1. **What was your depreciation expense for newly purchased pollution abatement equipment in 2004-2007?**

	Zero
$	☐

2. **What depreciation method was used to compute this estimate?** (Check only one box.)

☐ Straight-line

☐ Accelerated (e.g., double declining balance)

☐ Other Describe: ____________________

3. What length of time is used to calculate depreciation? ____________ months

4. **What was the gross book value of the pollution abatement capital used to reduce HAPs and VOCs at your paint shop at the beginning of 2004 (not adjusted for depreciations)?**

	Zero
$	☐

Item 6	BURDEN		
Estimate the number of hours spent filling out this form. Include the time you and all other staff spent completing the survey form.			hours

Item 7	CERTIFICATION		
A. Provide the following information on the person to contact regarding this survey.			
Name of person to contact regarding this report *(Please print)*	Telephone		
	Area code	Number	Ext.
E-mail address	Fax number		
B. Provide the name, title, and signature of a person who verifies that the information reported in this survey is to the best of your knowledge accurate. The authorizing official may be a plant manager, vice president, or environmental health and safety official.			
Name of authorized manager *(Please print)*	Title		
Signature of authorized manager	Date		
Feel free to add any comments about the survey in the space provided below. Thank you for your participation.			
Comments:			

The public reporting and recordkeeping burden for this collection of information is estimated to average 8 hours per response. Send comments on the Agency's need for this information, the accuracy of the provided burden estimates, and any suggested methods for minimizing respondent burden, including through the use of automated collection techniques to the Director, Collection Strategies Division, U.S. Environmental Protection Agency (2822T), 1200 Pennsylvania Ave., NW, Washington, D.C. 20460. Include the OMB control number in any correspondence. Do not send the completed form to this address.

Complete and submit the form by August 22nd, 2013 through Abt Associates' secure data transfer protocol (https://transfer.abtassoc.com/). Log in credentials will be provided separately via e-mail.

Facility Name: ______________________________ Date: _________________

Interview Checklist Items	Completed	Notes
How do you keep track of costs over time? (e.g., spreadsheet, hard copy) Do you retain costs broken out by equipment/type of change or only in aggregate?	☐	
Are the persons that worked to bring the paint line into compliance with the 2004 NESHAP still around? Did they help you identify what was done to comply? How much it cost?	☐	
Generally speaking, how did you identify the costs of compliance associated with the 2004 NESHAP? (e.g., exact figures, estimation; etc) How did you fill in the information for which you do not have specific information?	☐	

Did you install equipment/make changes unrelated to the rule around the same time? Such as? Are these excluded from your estimates? Were there cases where it was difficult to exclude them? Why? Can you make an estimate of what proportion was directly due to rule requirements?	☐	
Did you install equipment/make changes to reduce VOC emissions unrelated to the 2004 NESHAP? Are these excluded from your estimates? Were there cases where it was difficult to exclude them? Why? Can you make an estimate of what proportion was directly due to rule requirements?	☐	
Are there equipment or process changes you would have done anyway - perhaps a year or two later – if you did not have to comply with the 2004 NESHAP? Such as?	☐	

Walk through questionnaire item by item. For each item, ask: how did you interpret this question? If they interpreted it differently than we intended, discuss why and attempt to refine estimate.	☐	
Walk through questionnaire item by item. For each item, ask: how did you come up with this estimate? Can you describe the estimation approach you used? (where they had good info; key assumptions and approaches when they did not)	☐	
Walk through questionnaire item by item. For each item, confirm that changes occurred in response to the rule during the designated time frame. If not, work to exclude these costs from the estimate.		

Discuss any items left blank. Is that information unavailable? Is there a way to provide an estimate? (use examples from instructions – repeated below) Or is it close to zero? (if so, then have them indicate that on the survey.)	☐	
For the regulatory requirement question, which regulations mattered most? Did they deal with them in tandem or separately when making investment decisions? Confirm that survey responses do not include the costs of addressing regulations primarily intended to reduce VOC and not HAP emissions or regulations that precede the 2004 – 2007 timeframe.	☐	
Ask about state regulations for VOCs or HAPs if the facility is located in any of the following states or areas,: Alabama, Delaware, Illinois, Indiana, Kansas, Kentucky, Louisiana, Michigan, Mississippi, Missouri, Ohio, California's Bay Area AQMD, South Carolina, Tennessee, Texas, Wisconsin. Confirm that survey responses do not include the costs of addressing state regulations primarily intended to reduce VOC and not HAP emissions.	☐	