United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park, NC 27711

EPA-453/R-94-034
July 1994

Air

EPA

Economic Impact Analysis for the Polymers and Resins II NESHAP

DRAFT

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SECTION 9

ECONOMIC IMPACT ANALYSIS

9.1 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is reviewing National Emission Standards for Hazardous Air Pollutants (NESHAP) for the basic liquid epoxy resin and wet strength resin industries. These industries emit several of the hazardous air pollutants (HAPs) identified by the Clean Air Act Amendments of 1990.[1]

Section 317 of the Clean Air Act requires EPA to evaluate regulatory alternatives through an Economic Impact Analysis (EIA). Accordingly, this EIA has been conducted to satisfy the requirements of the Clean Air Act.

9.1.1 EIA Objectives

There are two primary objectives of this EIA. The first objective is to describe the distribution of adverse impacts associated with the NESHAP among various members of society. The second objective is to adjust estimated emission control costs so that these reflect the economic costs associated with the standard.

Neither the benefits nor the costs associated with the NESHAP will be distributed equally among different members of society. Since this study is focused on costs, emphasis is placed on estimating and describing the adverse impacts associated with the NESHAP. Those members of society who could potentially suffer adverse impacts include:

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[1] These HAPs are MeOH, HCl and EPI.

- Producers whose facilities require emission controls.
- Buyers of goods produced by industries requiring controls.
- Employees at plants requiring controls.
- Individuals who could be affected indirectly such as residents of communities proximate to controlled facilities, and employees of industries that sell inputs to or purchase inputs from directly affected firms.

Because of potential distributional impacts, and because of other policy issues, impacts on both energy consumption and foreign trade are also considered in this study.

Economic costs generally do not correspond to emission control costs because the latter do not reflect market adjustments that occur because of higher production costs caused by the installation, operation and maintenance of emission controls. A second purpose of this EIA is to make appropriate adjustments to estimated emission control costs so that they reflect the economic costs of the NESHAP.

9.1.2 Background

9.1.2.1 Affected Markets

EPA expects the NESHAP to affect two of the industries included in Standard Industrial Classification code 2821. They are:

- Basic Liquid Epoxy Resin (Diglycidyl Ether of Bisphenol A or DGEBPA).
- Wet Strength Resin (Epichlorohydrin Cross-Linked Non-Nylon polyamide resins).

9.1.2.2 Regulatory Alternatives

The Clean Air Act Amendments of 1990 stipulate that HAP emission standards for existing sources must at least match the percent reduction of HAPs achieved by either a) the best 12 percent of existing sources, or b) the best five sources in a category or subcategory consisting of fewer than 30 sources. This minimum standard is called a MACT floor.

The NESHAP considered in this EIA is the MACT floor for wet strength resin plants. The MACT floor for these plants requires controls on storage tanks and process vents. This EIA considers an alternative to the MACT Floor for wet strength resin plants. This alternative, which we refer to as Option I, requires controls only on equipment leaks. The NESHAP for DGEBPA plants is the MACT floor for storage tanks and process vents, but requires more stringent controls than the MACT floor for equipment leaks.

Both the DGEBPA and The Wet Strength resin industries consist of fewer than 30 sources. Thus, definition b) was used in both cases to construct the MACT floor for existing sources. For new sources the Amendments stipulate that the MACT floor be set at the highest level of control achieved by any similar source.

There are currently three facilities producing substantial amounts of DGEBPA. The MACT floor for existing sources was constructed by averaging the percentage reduction of HAPs achieved for each source type by each facility. A source type is a piece of equipment or component of production which produces HAPs. The MACT floor requires controls on the following DGEBPA source types: process vents, storage tanks and equipment leaks. As noted above, the NESHAP considered in this EIA requires controls at DGEBPA plants more stringent than the MACT floor for equipment leaks.

There are 17 existing wet strength resin plants. The MACT floor was constructed by averaging the percentage reduction of HAPs achieved by the five best controlled sources for each source type. The MACT floor for wet strength resin plants requires controls on storage tanks and process vents, but no additional controls on equipment leaks.

As noted earlier, Option I, which is an alternative to the MACT Floor for the wet strength resin industry, requires controls on equipment leaks, but no controls on either storage tanks or process vents. We consider Option I because it results in larger emission reductions at considerably lower costs than the MACT floor.

9.1.3 Summary of Estimated Impacts

9.1.3.1 Primary and Secondary Impacts

Table 9-1 summarizes the estimates of the primary and secondary economic impacts associated with the NESHAP.[2] Primary impacts include price increases, reductions in market output levels, changes in the value of shipments by domestic producers, and plant closures. Secondary impacts include employment losses, reduced energy use, changes in net exports, and potential regional impacts.

The estimated primary impacts on the DGEBPA market are small. For example, we estimate that the market price will increase by just 0.05 percent, and that market output will fall by about 0.08 percent. The estimated impacts of the MACT Floor on price and output in the wet strength resin market are somewhat larger than those for the DGEBPA market. We estimate an increase

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[2] Table 9-1 summarizes the results of the MACT floor for the wet strength resin industry. We describe the impacts of Option I in the text that follows.

Table 9-1

SUMMARY OF ESTIMATED ECONOMIC IMPACTS[3]

Analysis	Estimated Impacts
Primary Impacts	
Price Increases	Estimated price increases are 0.05 percent for DGEBPA and 4.19 percent for wet strength resins.
Market Output	Estimated reductions in market output are 0.08 percent for DGEBPA and 3.73 percent for wet strength resins.
Value of Domestic Shipments	Estimated changes range from a decline of 0.03 percent for DGEBPA to an increase of 0.31 percent for wet strength resins.
Plant Closures	No plant closures are expected in the DGEBPA industry and one plant closure is predicted for the wet strength resin industry.
Secondary Impacts	
Employment	No significant employment losses are expected.
Energy Use	Estimated industry-wide use to decline by 0.08 percent ($8,500) in the DGEBPA industry and by 3.73 percent ($45,000) in the wet strength resin industry.
Net Exports	Estimated trade impacts are small. Net exports of DGEBPA predicted to decline by about $25,000. Lower volume of wet strength resin exports expected to be offset by higher post-control prices.
Regional Impacts	No significant regional impacts are expected.

[3] Results reported for wet strength resin industry are for the MACT floor. Results for Option I are described in the text.

in price of 4.19 percent and a decrease in U.S. production of 3.73 percent. Note, however, that we expect a slight increase in the value of shipments by domestic wet strength resin producers. This occurs because the estimated price increase more than offsets the lower production volume. Our analysis predicts no plant closures in the DGEBPA industry, but one wet strength resin plant closure is possible. This predicted closure, however, may be due to some "worst case" assumptions adopted in our analysis.

The analysis of the primary impacts on the wet strength resin market under the implementation of Option I yields substantially less adverse impacts than the MACT floor. The increase in wet strength resin price is estimated at 0.22 percent (compared to a 4.19 percent increase under the MACT floor). We estimate that market output will decrease by just 0.20 percent under Option I, with an associated increase (due to the slight increase in price) in the value of domestic shipments of $7,000 (0.02 percent). While one plant closure is possible under the MACT floor, none is expected under Option I.

The estimates of secondary impacts reported in Table 9-1 follow the estimates of primary impacts described above. We expect only small employment losses and reductions in energy use. These findings, of course, are consistent with our estimates of small impacts on market output. We estimate that the reduction in net exports of DGEBPA will be small, about $25,000, and that higher post-control prices will offset a slightly lower volume of wet strength resin exports. Finally, we expect no significant regional impacts.

The secondary impacts of Option I on the wet strength resin industry are also smaller than those those of the MACT Floor. Employment (production job) losses are almost negligible (0.10 production jobs) and energy use is expected to decline by 0.20 percent. The estimated trade impacts are negligible. Wet strength resin exports are estimated to fall by .21 percent. Also, no significant regional impacts are expected.

9.1.3.2 Financial Analysis

Our financial analysis indicates that capital and annual emission control costs are small relative to the financial resources of the firms producing DGEBPA and wet strength resin. As a result, we do not expect that it will be difficult for these firms to raise the capital required to purchase and install emission controls.

9.1.3.3 Sensitivity Analyses

In Appendix D of the report, we examine the sensitivity of the estimated primary impacts to our estimates of market demand elasticities. The results reported in Appendix D indicate that the primary impacts summarized in Table 9-1 are relatively insensitive to reasonable ranges of demand elasticity estimates. However, analysis conducted assuming a "low" elasticity of demand yields slightly less adverse impacts, including no plant closures in the wet strength resin industry.

9.1.3.4 Potential Small Business Impacts

All of the affected DGEBPA and wet strength resin producers are large companies and none satisfies the criteria for a small business. Consequently, we do not expect any significant small business impacts to result from implementing the NESHAP.

9.1.3.5 Economic Costs

Table 9-2 reports estimates of the economic costs associated with the NESHAP. The estimated annualized economic costs are $120 thousand for the DGEBPA industry and $465 thousand for the wet strength resin industry under the MACT floor. The economic costs associated with Option I, $51 thousand, are considerably lower than those of the MACT floor. These estimates measure changes in economic surplus and include the costs associated with higher prices of imports to the U.S. economy.

Table 9-2

ESTIMATES OF ANNUALIZED ECONOMIC COSTS
(thousands of 1992 dollars)

Industry	Loss in Consumer Surplus	Loss in Producer Surplus	Loss in Residual Surplus	Loss in Surplus Total
DGEBPA	141	-3	-19	120
Wet Strength Resin MACT Floor	1,607	-841	-300	465
Option I	87	-22	-13	51

[a] Economic costs are computed as the change in economic surplus associated with the NESHAP. The estimates include the costs of higher prices of imported products.

9.1.4 Organization of EIA

We describe the analytical methods employed to estimate the economic impacts associated with the NESHAP in Section 9-2. Section 3 contains profiles of the two affected industries. We report in Section 9-4 estimates of primary economic impacts, including those on market prices, market output levels, value of shipments by domestic producers, and plant closures. Section 9-5 presents estimates of secondary impacts, including the effects on employment, foreign trade, energy use and regional economies. We describe potential adverse impacts of small businesses in Section 9-6. In Section 9-7, we report estimates of the economic costs associated with the NESHAP.

There are four appendices to this section. We describe the model plants used in the analyses and report estimates of emission control costs and other baseline data in Appendix A. Appendix B provides a detailed technical description of the analytical methods employed to estimate economic impacts and costs. We describe an econometric model of the resin industry in Appendix C. We report in Appendix D the results of sensitivity analyses in which we consider ranges of demand elasticity estimates.

9.2 OVERVIEW OF ECONOMIC IMPACT ANALYSIS

We assess the economic impacts associated with the NESHAP by conducting studies of the affected industries. These industries are the DGEBPA and the wet strength resins. We describe the analytical methods employed in these studies below.

9.2.1 Overview of Distributional Impacts

As noted earlier in the introduction to this section, several groups might potentially suffer from adverse impacts associated with the NESHAP. These groups include:

- Resin producers.
- Resin buyers.
- Employees at affected plants.
- Individuals affected indirectly by the NESHAP.

We describe the potential adverse impacts affecting each of these groups below.

9.2.1.1 Impacts on Producers

The emission control costs associated with the standard are likely to reduce the profitability of at least some of the affected plants. Indeed, some affected plants may be forced to shutdown operations in the face of emission control costs. Ultimately, the magnitude of the adverse impacts incurred by affected plants will depend on the extent to which emission control costs can be passed on to buyers. In addition, operators of some affected plants might have difficulty acquiring the capital necessary to purchase and to install emission control equipment.

Some plants in affected industries may not suffer adverse impacts as a result of the implementation of an emission control standard. The post-control profitability of an affected plant will improve if post-control price increases more than offset the plant's emission control costs. This could occur if control costs for some plants are substantially higher, per unit of output, than those for other plants in the industry.

9.2.1.2 Impacts on Consumers or Buyers

Both DGEBPA and wet strength resin are purchased primarily by firms which use these products as inputs to produce other goods. These firms and the consumers of the goods which they produce are likely to suffer from two related adverse impacts. First, post- control prices for resins produced at the affected plants are likely to be higher as sellers attempt to pass through some of the costs of emission controls. This will cause profits to be smaller, at least in the short run, for firms which purchase DGEBPA and wet strength resin as inputs. It will also cause prices of final goods to be higher as firms attempt to pass through some of the increase in production costs. Second, the shift in supply caused by emission control costs is likely to reduce the amount of resin sold in affected markets, as well as the level of output sold in markets which use the resin as an input. These two effects are related in that post-control equilibrium prices and output levels in affected markets will be determined simultaneously.

9.2.1.3 Indirect or Secondary Impacts

Two countervailing impacts on employees of affected plants are likely to result from the implementation of the NESHAP. Employment will fall if affected plants either reduce output or close operations altogether. On the other hand, increases in employment associated with the installation, operation, and maintenance of emission controls are likely.

A number of other indirect or secondary adverse impacts may be associated with the implementation of a standard. The indirect impacts we consider in this study include: foreign trade effects; impacts on regional economies; and, effects on energy consumption.

9.2.2 Economic Impact Studies

The industry segment studies that follow in this report include six major components of analysis. These components or phases of analysis, which are designed to measure and describe economic impacts, are:

- Industry profile.
- Direct impacts (market price and output, domestic production and plant closures).
- Capital availability analysis.

- Evaluation of secondary impacts (employment, foreign trade, energy consumption, and regional and local impacts).
- Analysis of potential small business impacts.

Each of these phases of analysis is described below.

9.2.3 Industry Profile

The industry profile provided in Section 9-3 describes conditions in affected industries that are likely to determine the nature of economic impacts associated with the implementation of the NESHAP. We discuss the following seven topics in the industry profile:

- Product descriptions.
- Prices and output.
- Market outlook.
- Market structure.
- Foreign trade.
- Financial conditions.
- Employment and energy use.

9.2.4 Primary Impacts

We employ a partial equilibrium model of the DGEBPA and wet strength resin industries to estimate the primary impacts of emission control costs, including market equilibrium price, market output, the value of domestic shipments, and the number of potential plant closures.[4] This analysis is so named because the predicted impacts are driven by estimates of how the affected

[4] The results of the partial equilibrium analyses are also used to estimate employment, energy and foreign trade impacts and the economic costs associated with the regulatory alternatives.

industries achieve market equilibrium after the air quality standard is implemented.

In a competitive market, equilibrium price and output are determined by the intersection of demand and supply. The supply function is determined by the marginal (avoidable) operating costs of existing plants and potential entrants. A plant will be willing to supply output so long as market price exceeds its average (avoidable) operating costs. The installation, operation, and maintenance of emission controls will result in an increase in operating costs. An associated upward shift in the supply function will occur.

The procedures employed in the market analysis are illustrated in Figure 9-1. Constructing the model and predicting impacts requires completing the following four tasks.

- Estimate pre-control market demand and supply functions.
- Estimate per unit emission control costs.
- Construct the post-control supply function.
- Solve for post-control price, output and employment levels, and predict plant closures.

We briefly describe each of these tasks below.[5]

9.2.4.1 Pre-Control Market Demand and Supply Functions

Pre-control equilibrium price and output levels in competitive markets are determined by market demand and supply. Because estimates of demand and supply for the relevant industries are unavailable from the literature, we estimated these functions as

[5] See Appendices A, B, and C for more detailed descriptions of the data and methods employed in the partial equilibrium analysis.

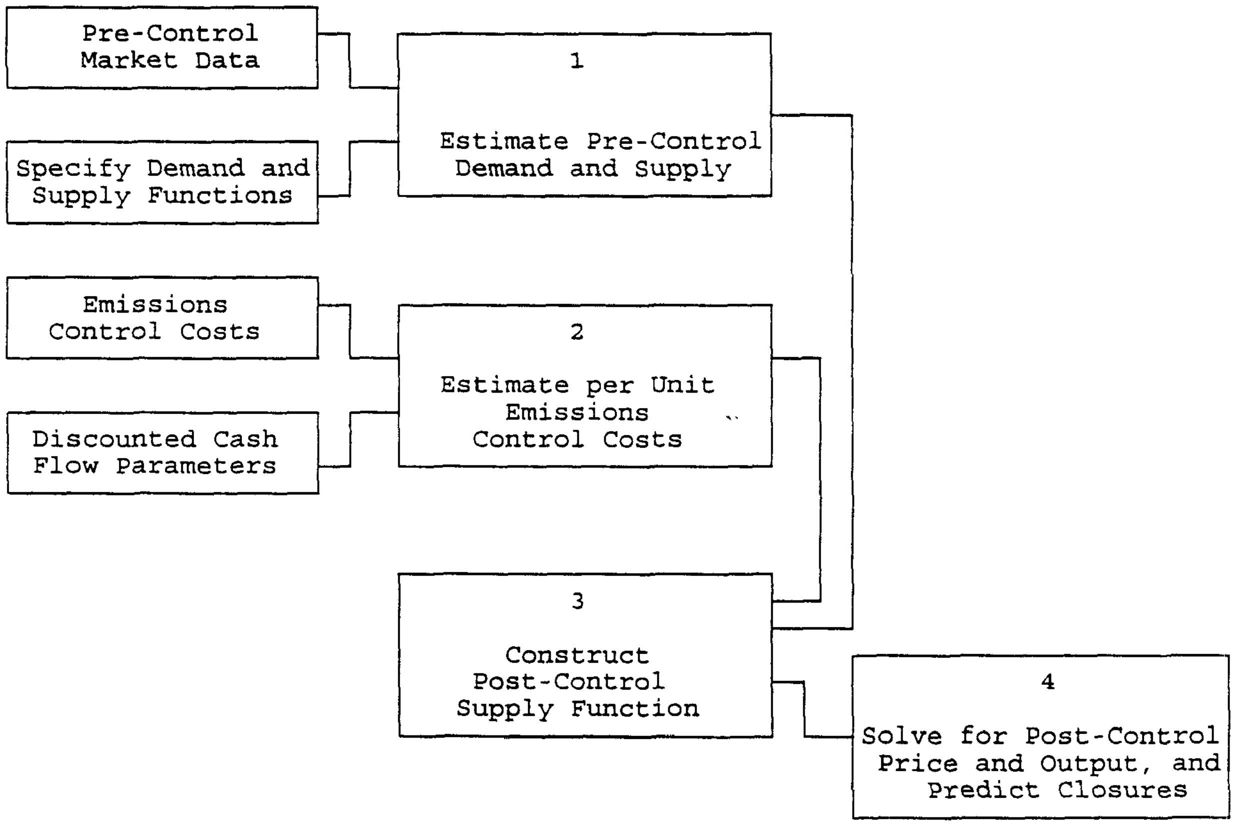

Figure 9-1

Partial Equilibrium Analysis of DGEBPA and
Wet Strength Resin Industries

part of this study. Both the market demand and domestic supply functions were estimated econometrically using time-series data.[6]

Market demand in the household segment was specified as a function of product price and a time trend to capture structural change in demand over time.[7] However, because of uncertainty regarding the demand elasticity estimates, we report the results of sensitivity analyses in Appendix D.

Market supply includes domestic supply and foreign supply of imports. We derived our estimate of domestic supply elasticity from a production function in which output of is expressed as a function of capital stock held by the industry, material and labor inputs, and time. We assume, in the absence of other information, that the supply elasticity of imports (foreign supply) is the same as that for domestic supply.[8]

9.2.4.2 Per Unit Emission Control Costs

Emission control costs will cause an upward vertical shift of the supply curves in affected markets. The height of the vertical shift for each affected plant is given by the after-tax cash flow required to offset the per unit increase in production costs resulting from the installation, maintenance, and operation of emission control equipment.

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[6] See Appendix C for detailed descriptions of the data and methods employed to estimate these functions. Appendix C also reports the estimated parameters of the functions.

[7] Our estimates of demand elasticities are -1.50 for DGEBPA and -0.92 for wet strength resin.

[8] Given this assumption, a one percent change in price causes the same percentage increase in both domestic and foreign supply.

Estimates of the capital, operating and maintenance costs associated with emission control equipment for affected plants were obtained from the draft BID document. Per unit, after-tax costs are estimated by dividing after-tax annualized costs by annual output. This cost reflects the offsetting cash flow requirement which, in turn, yields an estimate of the post-control vertical shift in the supply function.

Computing per unit after-tax control costs requires, as inputs, estimates of the following parameters:

- The useful life emission control equipment.
- The discount rate (marginal cost of capital).
- The marginal corporate income tax rate.

Estimates of the expected life of emission control equipment were obtained from the draft BID document. The results presented in this report are based on a 10 percent real private discount rate[9] and a 25 percent marginal tax rate.

9.2.4.3 The Post-Control Supply Function

Estimated after-tax per unit control costs are added to pre-control supply prices to determine the post-control supply prices for domestic producers. We construct the post-control domestic supply function by sorting affected plants, from highest to lowest, by per unit post-control costs. We assume that plants with the highest per unit emission control costs are marginal

[9] The discount rate referred to here measures the private marginal cost of capital to affected firms. This rate, which is used to predict the market responses of affected firms to emission control costs, should be distinguished from the social cost of capital. The social cost of capital is used to measure the economic costs of emission controls. See Section 9.7 for a more detailed discussion of this issue.

(highest cost) in the post-control market.[10] Because per unit control costs differ across affected plants within an industry segment, the post-control domestic supply function is segmented. Total market supply is given by the sum of domestic and foreign supply. We assume, of course, that foreign supply is unaffected by emission controls.[11]

9.2.4.4 Post-Control Prices, Output, and Closures

The baseline, pre-control equilibrium output in an affected market is taken as the level of observed national consumption (shipments by domestic producers minus net exports). We compute post-control equilibrium price and output levels in affected markets by solving for the intersection of the market demand curve and the market post-control, segmented supply curve. The estimated reduction in market output is given by the difference between the observed pre-control output level and the predicted post-control output level. Similarly, the estimated increase in price is taken as the difference between the observed pre-control price and the predicted post-control equilibrium price.

Because higher market prices lead to higher imports, the reduction in domestic production is larger than the reduction in market output. Specifically, the reduction in output for domestic producers is given by the reduction in market output plus the increase in imports. We estimate the number of plant closures by dividing the predicted reduction in domestic output by the production levels at plants with post-control supply prices higher than the post-control equilibrium market price.

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[10] Note that any other construction of the post-control supply curves would result in the same or smaller vertical shifts in supply, and accordingly, the same or smaller economic impacts.

[11] This assumption means that no shift in the foreign supply function occurs as a result of emission controls on domestic producers. The quantity supplied by foreign producers, however, increases as market price increases.

9.2.4.5 Reporting Results of Market Analyses

The results of the partial equilibrium market analyses for each of the affected industries are presented in Section 9-4 of this report. In particular, estimates of the following are reported:

- Price increase.
- Reduction in market output.
- Annual change in the value of domestic shipments.
- Number of plant closures.

9.2.4.6 Limitations of the Market Analysis

The partial equilibrium model has a number of limitations. First, a single national market for homogeneous output is assumed in the analysis. However, markets may be regional. Then each region or product type will be affected primarily by cost changes of plants in the region, rather than all plants in the national market. Output reductions and price effects will vary across regions depending on locations of affected plants. In addition, the assumption of a national market is likely to cause predicted closures to be overstated to the extent that affected firms are protected somewhat by regional trade barriers.

Second, the analysis assumes that plants with the highest per unit emission control costs are marginal post-control. This assumption produces an upward bias in estimated effects on industry output and price changes because the control costs of non-marginal firms will not affect market price. Predicted closures will also be overstated.

Third, the analysis assumes that the implementation of controls does not induce any domestic producers to expand production. An incentive for expansion would exist if some plants have post-control incremental unit costs between the baseline price and the post-control price predicted by the partial equilibrium analysis. Expansion by domestic producers will result in reduced impacts on industry output and price levels. While plant closures will increase as expanding producers squeeze out plants with higher post-control costs, net closures (closures minus expansions) will be reduced.

Table 9-3 summarizes the biases discussed above. In most cases, the assumptions embedded in the market analyses produce an upward bias in estimated impacts on market quantity, market price, and net closures.

Also, statistical errors in the estimated demand and supply functions exist. We report the statistical properties of the estimates of these functions in Appendix C.[12] In addition, it is likely that uncertainty in the estimates of emission control costs exist, causing control costs for some plants to be either overstated or understated. The control costs used in this EIA are study estimates and are accurate within plus or minus 30 percent.

Table 9-3

BIASES RESULTING IF MODEL ASSUMPTIONS ARE VIOLATED

Assumption		Direction of Bias		
		Change in Industry Quantity	Change in Industry Price	Net Closures
i)	national market	+	*	+
ii)	controlled plants at margin in baseline	+	+	+
iii)	no regulation-induced expansion of domestic producers	+	+	+

* Price changes will vary depending on the locations of affected plants and the levels of regional trade barriers and degree of product differentiation.

[12] See Appendix D for estimates of impacts associated with alternative estimates of demand elasticities.

9.2.5 Capital Availability Analysis

We assume in the market analysis that affected firms will be able to raise the capital associated with controlling emissions at a specified marginal cost of capital. The capital availability analysis, on the other hand, examines the variation in firms' ability to raise the capital necessary for the purchase, installation, and testing of emission control equipment.

The capital availability analysis also serves three other purposes. First, it provides information for evaluating the appropriateness of the selected discount rate as a proxy for the marginal cost of capital of the industry; implications for bias in the partial equilibrium analysis follow. Second, it provides information on potential variation in capital costs across firms. Third, it provides measures of the potential impacts of controls on the profitability of affected firms.

9.2.5.1 Evaluation of Impacts on Capital Availability

For each model plant[13] included in the capital availability analysis, the impact of the alternative standards on the following two measures is evaluated:

- Net income/assets.
- Long-term debt/long-term debt and equity.

Net income is measured before-tax and is defined to include all operations, continued and discontinued.

The ratio of net income to assets is a measure of return on investment. The implementation of emission controls is likely to

[13] The model plants included in the analysis are described later in this section and in more detail in Appendix A.

reduce this ratio to the extent that net income falls (e.g., because of higher operating costs) and assets increase (because of investments in emission control equipment).

The ratio of long-term debt to long-term debt plus equity is a measure of risk perceived by potential investors. Other things being the same, a firm with a high debt-equity ratio is likely to be perceived as being more risky, and as a result, may encounter difficulty in raising capital. This ratio will increase if affected firms purchase emission control equipment by issuing long-term debt.

9.2.5.1.1 Baseline Values for Capital Availability Analysis --

Baseline values for net income and net income/assets are derived by averaging data for as many years as are available between 1988 and 1991. Data from these four years are employed to reduce distortions caused by year-to-year fluctuations. Since changes in the long-term debt ratio represent actual structural changes, 1990 or 1991 data are used, whichever is the most recent year the data are available.

9.2.5.1.2 Post-Control Values for Capital Availability Analysis --

Post-control values for the two measures identified above are computed to evaluate the ability of affected firms to raise required capital. The post control values are computed as follows:

- Post-control net income – pre-control net income minus the after-tax annualized costs associated with the purchase, installation, maintenance and operation of emission control equipment.
- Post-control return on assets – post-control net income divided by the sum of pre-control assets plus investments in emission control equipment.

- Post-control long-term debt ratio — the sum of pre-control long-term debt plus investments in emission control equipment divided by the sum of pre-control long-term debt, equity, and investments in emission control equipment.

The calculations are done for a worst-case scenario of the impact of controls on the measures. First, the total investment in emission control equipment is assumed to be debt-financed. Second, it is assumed that there is no increase in the price a company receives for its output.

9.2.5.1.3 Limitations of the Capital-Availability Analysis --

The capital availability analysis has limitations. First, future baseline performance may deviate from past levels. The financial position of a firm during the period 1988-1991 may not be a good approximation of the company's position later during the implementation period, even in the absence of the impacts of emission control costs.

Second, a limited set of measures is used to evaluate the impact of controls. These measures reflect accounting conventions and provide only a rough approximation of the factors that will influence capital availability.

9.2.6 Evaluation of Secondary Impacts

The secondary impacts that we consider in this study include:

- Employment impacts.
- Energy impacts.
- Foreign trade impacts.
- Regional impacts.

9.2.6.1 Employment Impacts

As equilibrium output in affected industry segments falls because of control costs, employment in the industry will decrease. On the other hand, operating and maintaining emission control equipment requires additional labor for some control options. Direct net employment impacts are equal to the decrease in employment due to output reductions, less the increase in employment associated with the operation and maintenance of emission control equipment.

Our estimates of the employment impacts associated with the NESHAP are based on employment-output ratios and estimated changes in domestic production. Specifically, we compute changes in employment proportional to estimated changes in domestic production.[14]

Estimates of the labor hours required to operate and maintain emission control equipment are unavailable. Accordingly, the employment impacts presented in this report are overstated to the extent that potential employment gains attributable to operating and maintaining control equipment are not considered.

The estimates of direct employment impacts are driven by estimates of output reductions obtained in the market analyses. Biases in these estimates will likely cause the estimates of employment impacts to be biased in the same direction.

9.2.6.2 Energy Effects

The energy effects associated with the NESHAP include reduced energy consumption due to reduced output in affected

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[14] See Appendix B for descriptions of the data and methods used to estimate employment impacts.

industry segments plus the net change in energy consumption associated with the operation of emission controls.

The method we use to estimate reduced energy consumption due to output reductions is similar to the approach employed for estimating employment impacts.[15] Specifically, we assume that changes in energy use are proportional to estimated changes in domestic production. Estimates of the net change in energy consumption due to operating emission controls are unavailable.[16]

9.2.6.3 Foreign Trade Impacts

Other factors being the same, the implementation of the NESHAP will raise the production costs of domestic resin manufacturers relative to foreign producers, causing U.S. net exports of resin to decrease.

The extent to which imports to U.S. increase will depend on the supply elasticity of foreign-produced resin to the U.S. Unfortunately, we have not identified any estimates of resin import supply elasticities in the literature and the available data does not permit us to derive our own estimate. Accordingly, we assume that the import supply elasticity is the same as that for domestically produced resin.

We report estimates of the dollar value of the increase in imports associated with the implementation of the standard. There are two sources of this increase: (1) the increase in the quantity of goods imported; and (2) increases in prices of

[15] See Appendix B for a more detailed description of this procedure.

[16] We view these as short-run estimates of reduced energy consumption. In the long run, resources diverted from the production of DGEBPA and wet strength resin will likely be directed to producing other goods and services.

imported goods. The estimates we report reflect the contributions from both sources.

9.2.6.4 Regional Impacts

Substantial regional or community impacts may occur if a plant that employs a significant percent of the local population or contributes importantly to the local tax base is forced to close or to reduce output because of emission control costs.

Secondary employment impacts may be generated if a substantial number of plants close as a result of emission control costs. Secondary employment impacts include those suffered by employees of firms that provide inputs to the directly affected industry, employees of firms that purchase inputs from directly affected firms for end-use products, and employees of other local businesses.

9.2.7 Affected Plants

The NESHAP is expected to affect three DGEBPA and 17 wet strength resin plants. Because only three DGEBPA plants are affected, the analysis considers plant specific data for this industry. However, because of the large number of affected wet strength resin facilities, the analysis is based on three different model plants that have been developed to represent the 17 plants in the industry. Appendix A describes the characteristics of the affected DGEBPA and wet strength resin plants.

9.3 INDUSTRY PROFILE

This section describes market conditions for products that will be affected by the NESHAP. The affected products are diglycidyl ethers of bisphenol A (DGEBPA) which is a type of unmodified epoxy resin, and epichlorohydrin based non-nylon polyamide resin (wet strength resin).

We cover the following topics in this industry profile:

- Product descriptions and end uses.
- Market structure.
- Market trends and outlook.
- Foreign trade.
- Financial conditions.

9.3.1 Product Descriptions and End Uses

9.3.1.1 DEGBPA

Diglycidyl ether of bisphenol A (DGEBPA) is a type of unmodified epoxy resin. There are several types of unmodified epoxy resin, but the standard and most common commercial epoxy resin is DGEBPA. In fact, DGEBPA is often referred to as "conventional" epoxy resin. Epoxy resins are plastic materials which contain a specific molecular group that reacts with different curing agents or hardeners resulting in hard, infusible solids. These solids have useful properties including good adhesion to many substrates, low shrinkage, high electrical resistivity, and good corrosion and heat resistance. Commonly used curing agents for DGEBPA include phenolic, urea, melamine, furane, polyester, vinyl, polyurethane and silicone.

The primary application of epoxy resin is in protective coatings. Other applications include electrical laminates, adhesives, tooling, and flooring. Industrialized nations are by far the largest producers and consumers of epoxy resins. Table 9-4 reports patterns of consumption across end-use categories for the years 1989 and 1990.

Table 9-4

EPOXY END-USE CONSUMPTION
(millions of pounds)

End Use	1989	% of Total	1990	% of Total
Protective coatings	193	40.0	195	42.0
Reinforced uses				
Electrical laminates	57	11.8	55	11.9
Other	26	5.4	31	6.7
Export	86	17.8	68	14.7
Tooling, Casting, Molding	30	6.2	28	6.0
Bonding and Adhesive	25	5.2	28	6.0
Flooring, paving, aggregates	25	5.2	28	6.0
Other	41	8.5	33	7.1
Total	483		464	

Source: Plastics World, "Resin Report," January 1991.

9.3.1.1.1 Protective Coatings -

About 40 percent of domestic epoxy resin sales go to protective coatings markets. The primary uses of these coatings are automobile primers and finishes, maintenance and marine coatings, can coatings, and other product finishes. The popularity of epoxy resins in the coatings industry is due to the high chemical resistance, toughness, and adhesion properties.

Epoxy coatings are called high performance coatings. A high performance coating or lining is one that is superior to paint in adhesion, toughness, and resistance to continuing exposure to industrial chemicals, food products, water, sea water, weather and high humidity. These coatings are designed to protect from corrosive or otherwise detrimental exposure, and to slow the breakdown of industrial structures. The coatings need to be safe for use with materials in which they come into contact as well as be dense and have a minimum of absorption with contacting materials. Also, they should have a high resistance to the transfer of chemicals through the coating. Finally, they should maintain a generally good appearance even though subject to severe weather and chemical conditions.

Epoxy surface coatings are the third most common type of industrial finish behind alkyds and acrylics.[17] Epoxies tend to be more expensive, but have more attractive properties than other coatings including superior adhesion, flexibility and corrosion resistance when used on metallic substrates. However, due to their tendency to chalk or discolor upon exposure to sunlight they are not often used for architectural purposes. Solid DGEBPA low-molecular weight resins are the most common type of epoxy resin used in coatings.

There are several types of epoxy coatings.[18] Each has different properties, but all are resistant and cure by internal linkage only. This means they need not be exposed to the air to cure so that thick coatings can be achieved in a single application. The primary types of epoxy coatings are amine-cured epoxies, polyamide cured epoxies, phenolic epoxies, and coal tar epoxies. DGEBPA can also be reacted with oils or fatty acids to make epoxy esters and other polymers. The esters are used primarily in floor finishes, primers for appliances, and maintenance coatings. Epoxy esters accounted for approximately 5 percent of epoxy coating demand in 1991.

[17] Chemical Economics Handbook, Epoxy Surface Coatings.

[18] The material in this section was taken from Pulp and Paper (1979), Modern Plastics mid-October Encyclopedia issue.

Amine-cured epoxies are the most chemically resistant of the ambient temperature cure variety (they do not require heat or other processes to cure). However, they can be brittle and chalk quickly when exposed to the weather. They are mostly used in industry where an air-dry coating is required and the need for chemical resistance is high. Urea and Melamine are two of the curing agents used to make amine-cured epoxies.

Polyamide cured epoxies are somewhat less chemically resistant than amine-cured epoxy. However, they have much better weather resistant qualities. The coating is non brittle and fairly flexible. It has excellent resistance to alkali and to water. The uses of this type of resin are broad based and include maintenance coatings for most industries including the chemical, paper, marine, atomic power, and food industries.

Epoxy-phenolic systems offer chemical resistance along with excellent mechanical properties. When they are heat cured, they are the strongest and most resistant of the epoxy coatings. For this reason, they are used for chemically resistant coatings on process equipment, tank and drum linings, pipe linings, and for protection from direct exposure to various chemicals. They are also commonly used for exposure to solvents, vegetable and animal oils, fatty acids, foods, and alkalis.

Coal tar epoxy coatings have good chemical resistance, reasonable weather resistance, and outstanding resistance to fresh and salt water, brine, and hydrogen sulfide. More generally, they are resistant to both acidic and alkaline conditions. They are one of the most durable coatings for the protection of concrete and metal, either under water or above water, against corrosive elements. These resins are black and so have limited decorative use, and, of course, can be used only where black is acceptable. They are used throughout the chemical industry and in the marine industry, both on ships and on offshore structures.

The following is a list of some specific uses of epoxy coatings.

- Heavy duty industrial and marine maintenance coatings.
- Tank linings.
- Industrial floorings.
- Coatings for farm and construction equipment.
- Aircraft primers.
- Floor and gymnasium finishes.
- Maintenance coatings.
- Metal decorating finishes.
- Pipe coatings.
- Container coatings.
- Electrodeposition primers for automobiles.
- Solder masks.
- Beverage and food can coatings.
- Appliance primers.
- Hospital and laboratory furniture.
- Coating for jewelry and hardware.
- Impregnating varnishes.

9.3.1.1.2 Bonding and Adhesives -

Because of their excellent adhesion to many substrates, epoxy resins are widely used as high performance adhesives. For example, because of their extraordinary adhesion to metal they are used in the automobile, aircraft and construction industries. According to the September 1990 issue of Chemical Marketing Reporter, about 80 percent of epoxy adhesive sales go into the automobile and construction industries. According the Chemical Economics Handbook, production of epoxy adhesives and sealant grew at an average annual rate of 8 to 8.5 percent from 1983 through 1989.

9.3.1.1.3 Molding, Casting, and Tooling -

Uses in this category include encapsulation of electrical components by epoxy molding compounds. Also, epoxy casting resins are used as prototypes and master models in the manufacture of tools. Epoxies based on ultraviolet light stable structures are used in the casting of outdoor insulators switch gear components and instrument transformers.

9.3.1.1.4 Laminating and Composites -

Epoxy-based laminates are used in printed wiring boards, such as those used in computers and complex telecommunication equipment. Epoxy compounds are used in filament-wound glass reinforced pipe in oil field applications, in the manufacture of pressure vessels and tank and rocket motor casings, chemical plants, water distribution, and as electrical conduits. In the aerospace industry, graphite fiber-reinforced multifunctional epoxy resin composites are becoming standard.

9.3.1.1.5 Building and Construction -

Epoxies are used in flooring, to repair bridges, roads, and cracks in concrete, to coat reinforcing bars, and to perform as binders for patios, swimming pool decks and the soil around oil well drills.

9.3.1.2 Wet Strength Resins

Polyamide-epichlorohydrin or wet strength resins are a type of non-nylon polyamide resin sold almost exclusively in the paper additives market. Approximately 90 percent of these resins are used to improve the wet tensile strength of paper products. Other uses of these resins in the paper industry include flocculent, drainage and drying aids, dry creping aids, cationizing agent for unmodified (pearl) potato and tapioca starch (used for dry strength), and as a component of paper surface finishes.

Paper which has been treated with a wet strength resin shows greater resistance to rupture or disintegration when exposed to water. Note that wet strength is defined as tensile strength when the paper is completely absorbed with water, not water repellency. There are three primary types of wet strength resins: (1) Urea-formaldehyde resins, (2) melamine formaldehyde resins, (3) polyamide-polyamine epichlorohydrin and modifications. It is the third category that includes EPI-based non-nylon polyamide resins. Other wet strength additives include those made from polyacrylamide, dialdehyde starch, polyacrolein resin, and cellulosic resin. The wet strength of paper increases almost linearly with the addition of wet strength resin up to a point. Beyond this threshold the addition of wet strength resin has little affect on the wet strength of the paper.

There are a large number of uses for paper which retains tensile strength when wet. Examples include tea bags, paper towels, and paper groceries bags.

Demand for this type of paper is most likely inelastic because of its "necessary" nature and the small percentage of income which is typically spent on these types of products. Specifically wet strength resins are used for protection against:[19]

- Exposure to water of paper products used as drying or wiping media. Examples are paper towels, napkins, windshield wiping tissue, industrial wiping towels, lens paper, and facial tissue.
- Exposure to weather. Examples are packing cases, outdoor posters, building papers, paper bags, maps, and mulch paper.

[19] This list was drawn from Pulp and Paper (1979).

- Wrapping for wet materials. Examples are butcher wraps, fruit and vegetable wraps and boxes, frozen and prepared food packages, and foil wrapped wet wipes.

- Exposure to water by immersion in a processing operation. Examples are photographic paper, copy print paper, filter paper, saturating paper, and tea bag paper.

- Disposables used in place of textiles. Examples are hospital bed sheets, hospital gowns and other sanitary single-use garments.

9.3.2 Market Structure

DGEBPA and wet strength resin are produced by a few large corporations, and many of these are conglomerates. Accordingly, market concentration is relatively high and vertical integration is common.

9.3.2.1 DGEBPA

The major producers of basic liquid epoxy resins (DGEBPA) are Dow Chemical Company, Ciba-Geigy Corporation, and Shell Chemical Company. They are also the largest producers of any type of unmodified epoxy resin - each having production rates on the order of 45.4 million kilograms per year. These three large companies have been producing epoxy resin for at least 12 years. Shell and Dow Chemical are also major producers of epichlorohydrin and bisphenol-A which are the primary feedstocks for epoxy. While Ciba-Geigy is not similarly backward integrated, it is a significant player in markets for further processed epoxy products, including formulated systems, electronic materials and composite materials.[20] These facts suggest that the market is fairly concentrated. Together, these three producers were

[20] CEH (1991) Epoxy Resins.

responsible for approximately 60 percent of unmodified epoxy resin production in 1990.[21]

DGEBPA and other types of unmodified epoxy resin are reasonably good substitutes. For this reason, entry and exit from the entire unmodified epoxy resin industry is worth examining. Table 9-5 lists companies who produced unmodified epoxy resin at some time over the period 1980 to 1991. An "X" in the column under a given year indicates that the company produced epoxy resin in that year. These lists of manufacturers comprise only those companies which responded to inquiries from the Society of the Plastics Industry. However, SPI's Committee on Resin Statistics estimates that these manufacturers account for about 95 percent of unmodified epoxy production.[22]

Table 9-5

COMPANIES PRODUCING UNMODIFIED EPOXY RESIN, 1980-1991

Company Name	80	81	82	83	84	85	86	87	88	89	90	91
Celanese Plastics	X	X	X	X	X	X						
Ciba-Geigy	X	X	X	X	X	X	X	X	X	X	X	X
Dow Chemical	X	X	X	X	X	X	X	X	X	X	X	X
Reichold Chemical	X	X	X	X	X	X	X	X	X	X	X	X
Shell	X	X	X	X	X	X	X	X	X	X	X	X
Union Carbide	X	X	X	X	X	X	X	X	X	X	X	X
Morton Industries	X	X	X									
Rhone Poulenc Inc.											X	X
Interez							X	X	X			
Hi-Tek Polymers*										X		

* Hi-Tek Polymers was owned by Rhone Poulenc in 1989.

Source: Society of the Plastics Industry 1.

[21] SPI I and MRI (1992).

[22] Source: SPI II.

Over the last 12 years the list of manufacturers has had no more than 7 companies on it, and, beginning in 1984, has had only six. Since 1980, only four companies have entered or exited. The average duration of manufacture over the 12 years from 1980 to 1991 was 8.3 years.

9.3.2.2 Wet Strength Resins

Firms which produced epichlorohydrin based non-nylon polyamide resins in either 1988 or 1990 are listed in Table 9-6. An "X" in the column under a given year means that the company produced the resin in that year, an "O" means that they did not. Over the two years of data, there were two entries into and one exit from this industry.

Table 9-6

COMPANIES PRODUCING EPI BASED NON-NYLON POLYAMIDE RESINS, 1988 AND 1990

	1988	1990
Borden	X	X
Callaway Chemical*	X	X
Georgia Pacific Corp.	X	X
Henkel of America, Inc.	X	X
Hercules Inc.	X	X
Trinova Corp.	X	O
Pioneer Plastics	O	X
Akzo	O	X

* A subsidiary of Exxon Corporation.

Source: Chemical Economics Handbook and MRI (1992).

In 1988, Hercules accounted for approximately 80 percent of the production of EPI-based polyamide. Henkel, Georgia-Pacific, Borden and Callaway each accounted for about 5 percent of the market. Trinova produced very little. It is unclear exactly what percentage of the market is controlled by Hercules in 1990. However, two Borden plants, five Hercules plants, and one Akzo plant together accounted for 80 percent of production in 1990.[23]

Raw materials for epichlorohydrin based polyamide resin include adipic acid, diethylenetriamine, and epichlorohydrin. No producer of epi-based polyamide resins also produced these feedstocks as of 1988.

As of 1991 Georgia Pacific owned or controlled over 6 million acres of timber and timberlands. They were also producing pulp and paper (8 percent of U.S. annual capacity), containerboard and packaging, uncoated free sheet paper, tissue, envelopes and other paper products. Hercules was producing various paper products in addition to wet strength resins in 1991.

9.3.3 Market Outlook

While domestic production of both DGEBPA and wet strength resin has fluctuated, the long-term trend has seen increased output of both products. DGEBPA prices have been relatively stable recently, but wet strength resin prices have fallen. The demand for both products is expected to increase moderately over the next few years.

9.3.3.1 DGEBPA

Domestic production of unmodified resins has fluctuated somewhat over the twenty year period 1971 to 1990. However, pro-

[23] MRI (1992).

duction has increased on average by about 7 percent annually over this time.[24] DGEBPA comprised about 60 percent of total unmodified epoxy resin production in 1990. Nominal prices peaked at \$2.89 (per kilogram) in 1984 and since then have fluctuated around \$2.40.[25]

Two recently published industry reports predict that U.S. epoxy resin production will experience healthy growth to the end of the 1990's. Network Consulting Inc. (1992) expects a 4 percent annual growth in domestic production to last through 1997. The Freedonia Group (1992) predicts North American production, which is dominated by U.S. firms, to grow at an annual rate of 4.4 percent to 1995.

The Freedonia Group attributes expected growth to an expanding export market which they predict will reach 300 million pounds by 1995. However, they expect the heavy growth in exports to be countered by a slower growth in North American consumption, which they expect to be just 3 percent per year.

Network Consulting, Inc. (1992) base their projections of growth on the recovery of the U.S. economy and the advent of environmental regulations which favor the use of epoxies in high solids and powder coatings. In recent years, environmental pressures have resulted in the rapid development of these epoxy products because they use substantially less organic solvent but retain the useful chemical and physical properties of epoxies.

The Freedonia Group expects epoxy adhesives to grow at 4.4 percent per year to 1995, reaching 37 million pounds. They expect epoxy coatings to grow four tenths of a percent faster

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[24] Computed from data in USITC I.

[25] USITC I.

than the overall coatings market at 2.8 percent per year to 1995. This means that by 1995, 235 million pounds of epoxy resin will be used in coatings.

Chemical Economics Handbook estimates that between 1983 and 1988 the use of epoxy resins in adhesives and sealants grew at an average rate of about 8.5 percent per year. An increase of about 7 percent occurred in 1989. Between 1989 and 1994, growth in the consumption of epoxy adhesives is expected to slow slightly to a 6 percent annual rate. They expect growth to be driven by the increasing use of resin based composites in aerospace, automotive and recreational markets. Also, there is a trend toward using epoxies instead of more expensive welds, especially in the automotive market. Technological advances may also contribute to the growth of epoxy adhesives. Improvements have been made in various properties including adhesion to plastics and toughness, and new systems have been introduced that allow faster bonding at lower initiation temperatures.

Chemical Economics Handbook estimates that epoxy surface coatings grew at an average annual rate of 3.5 to 4 percent between 1986 and 1990. They expect this growth to slow to 3 to 3.5 percent presently. Furthermore, they report that the consumption of epoxy esters will decline due to their adverse effects on the environment. On the other hand powder coatings are projected to grow at 5 to 10 percent annually because of the high quality of the coating and the lack of adverse environmental effects. Consumption of epoxy resins in surface coatings is projected by CEH to reach 215-220 million pounds by 1995.

9.3.3.2 Wet Strength Resins

The growth rate of production for non-nylon polyamide was more volatile than that of epoxy over the period 1971-1990. For example, production increased by 73 percent in 1974 and fell by

49 percent in 1975. However, the average growth rate of production was somewhat greater than that of epoxy, about 10 percent annually. The nominal price reached $2.54 per kilogram (dry weight basis) in 1985, but has since declined. Production and prices both fell sharply in 1990. Production fell by about 26 percent in 1990 and price declined substantially to $1.50 – a level it had not been below since 1972.[26]

In 1987, Chemical Economics Handbook reported that the growing trend to use neutral-cure wet-strength resins as replacements for formaldehyde based (melamine and urea) resins would continue through 1992, and that it would account for strong increases in the demand for wet strength resins. Urea formaldehyde and melamine formaldehyde resins are inferior as wet strength additives in unbleached paper production because of their acid curing characteristics. Specifically, they can cause embrittlement and deterioration of paper as well as reduce absorbency. Demand for epichlorohydrin based polyamide was predicted to continue to increase at a rate of 5 to 6 percent annually from 1987 through 1992. Production of non-nylon polyamide was somewhat erratic over the period 1987 through 1990, experiencing 10 percent decline in volume in 1990.

9.3.4 Foreign Trade

9.3.4.1 DGEBPA

Table 9-7 shows exports and imports of epoxy resin in millions of kilograms per year from 1981 through 1991 as reported by the U.S. Department of Commerce. The table also reports imports divided by exports.

[26] USITC I (various issues).

Table 9-7

U.S. TRADE IN EPOXY RESIN
(millions of kilograms)

Year	Exports	Imports/Exports
1981	42.3	.05
1982	45.7	.05
1983	41.5	.07
1984	44.5	.09
1985	40.5	.14
1986	44.0	.18
1987	55.7	.12
1988	69.0	.09
1989	85.1	.07
1990	94.4	.09
1991	97.9	.11

Source: U.S. Department of Commerce, Bureau of the Census.

According to the Bureau of the Census, exports in 1991 amounted to 97.9 million kilograms. In 1989 the principle destinations were: Far East countries other than Japan, which accounted for 27 percent; Canada which accounted for 23 percent; Western Europe, 21 percent; Japan, 11 percent; and Mexico, 7 percent.

Imports have been fairly stable and relatively small in volume through the eighties. In 1989, an estimated 50 percent of the imported epoxy resins were used in coatings, and the remainder went primarily into adhesives and electronic encapsulation.

9.3.4.2 Wet Strength Resins

Table 9-8 shows exports and imports of non-nylon polyamide resins in millions of kilograms per year from 1981 through 1991. The ratio of exports to domestic production, import to domestic production and imports to exports are also reported.

Table 9-8

U.S. TRADE IN NON-NYLON POLYAMIDE
(millions of kilograms)

Year	Exports	Imports	Imports/ Exports
1981	5.0	n.a.	n.a.
1982	3.6	n.a.	n.a.
1983	4.1	0.8	.19
1984	4.4	1.1	.24
1985	5.3	1.1	.21
1986	4.5	1.2	.26
1987	6.1	1.2	.19
1988	10.2	1.1	.11
1989	5.9	3.8	.64
1990	6.2	4.7	.76
1991	n.a.	6.1	n.a.

Sources: U.S. Department of Commerce (1992), USITC.

Exports fluctuated considerably during the 1980's, reaching a high of 10.2 million kilograms in 1988 and a low of 3.6 million kilograms in 1982. However, in most years exports ranged between 4 and 6 million kilograms. Imports were more stable over the period hovering around 1 million kilograms until 1988. However, in 1989 and 1990 imports of non-nylon polyamide increased.

9.3.5 FINANCIAL DATA

Baseline financial data for firms producing resins are displayed in Table 9-9. The ratio of net income to assets and the ratio of long term debt to long term debt plus equity are reported in the table. In order to compensate for cyclical fluctuations, net income over assets figures were averaged over the years 1988 through 1991. The long term debt ratio is reported for 1991.

Table 9-9

FINANCIAL DATA FOR RESIN PRODUCERS

	NI/A* (average 1988-1991)	LTD/(LTD+E) (1991)
Hercules	.02	.22
Shell	.03	.11
Dow	.09	.39
Ciba Geigy	.05	.20
Borden	.05	.41
Exxon	.06	.20
Georgia Pacific	.04	.58
Henkel	.05	.14

Source: Moody's Industrial Manual 1991; Annual Reports 1991.

* NI = net income A = assets
LTD = long term debt E = equity

Most of the resin producers are earning between a 4 and 6 percent return on their assets. Dow is earning by far the largest return at 9 percent. Hercules and Shell show the poorest returns at 2 and 3 percent, respectively.

Shell and Henkel have the smallest long term debt ratios at less than 0.15 each. Hercules, Ciba Geigy and Exxon are a little larger at around 0.2 each. Dow and Georgia Pacific have the highest ratios.

9.4 PRIMARY ECONOMIC IMPACTS AND CAPITAL AVAILABILITY ANALYSIS

9.4.1 Introduction

This section presents estimates of the primary economic impacts which would result from the implementation of the NESHAP and the results of the capital availability analysis. We also present results for Option I for the wet strength resin industry. Primary impacts include changes in market prices and output levels, changes in the value of shipments by domestic producers, and plant closures. The capital availability analysis assesses the ability of affected firms to raise capital and the impacts of control costs on plant profitability.

9.4.2 Estimates of Primary Impacts

As explained earlier in Section 9-2, we use partial equilibrium models of the affected industries to estimate primary impacts. The increase in production costs resulting from the purchase and operation of emission control equipment causes an upward, vertical shift in the domestic supply curves. The height of this shift is determined by the after tax cash flow required to offset the per unit increase in production costs. Because control costs vary across plants within each industry segment, the post-control supply curves are segmented. We assume a worst case scenario in which plants with the highest control costs (per unit of output) are marginal (highest cost) in the post-control market.

Foreign supply (net imports) is assumed to have the same elasticity as domestic supply in both markets.[27] Foreign and post-control domestic supply are added together to form total market post-control supply. The intersection of post-control market supply curve with market demand determine the new market equilibrium price and quantity. The post-control domestic

[27] The United States is a new exporter of both DGEBA and wet strength resin. Trade in DGEBA is substantial. Net exports accounted for approximately 15 percent of production in 1990. However, trade in wet strength resin is insignificant. The small volume of trade is due to the custom of shipping only the polyamide and letting the receiving company complete the epichlorohydrin reaction. In 1988 exports accounted for about 1 percent of domestic wet strength resin production, and imports were only a small fraction of exports.

output is given by post-control market output less post-control imports.

Table 9-10 presents the primary impacts predicted by the partial equilibrium analysis for the DGEBPA and wet strength resin industries. For example, we estimate that the NESHAP will result in a 0.12 cent per kilogram (0.05 percent) increase in the price of DGEBPA and an annual reduction in domestic production of about 106 metric tons (0.08 percent of baseline production). We also estimate that the NESHAP will cause the annual value of domestic shipments to fall by about $108,000 (0.03 percent). No plant closures are predicted.

Table 9-10 also shows the estimated impacts on the wet strength resin industry, both for the MACT Floor and Option I. Estimated price and output changes range from very small impacts associated with Option I to larger impacts under the MACT Floor. Under the MACT Floor, estimated increases in price and decreases in domestic production are approximately 4 percent, and about 1 plant closure is possible[28]. However, under Option I, price and output impacts are only 0.22 percent and 0.20 percent, respectively, and no plant closures are predicted.

We emphasize that the assumptions we adopt in our analysis are likely to cause us to overstate predicted plant closures. First, we assume that the plant with the highest per unit emission control costs also is the least efficient in that it has the highest baseline per unit production costs. Second, we assume a national market, but regional trade barriers might afford some protection for some plants. Finally, the production of wet strength resin is intermittent. When our analysis predicts a

[28] Table 4-1 reports fractions of plant closures. The 0.63 plant closure predicted for the wet strength resin industry means that we estimate that the marginal plant would lose 63 percent of its annual production.

Table 9-10

ESTIMATED PRIMARY IMPACTS ON DGEBPA
AND WET STRENGTH RESIN MARKETS

IMPACT	DGEBPA	WET STRENGTH MACT Floor	RESIN Option I
Price Change ¢/kilogram[a] Percent	 .12 .05	 .84 4.19	 .04 .22
Annual Change in Domestic Output Metric Tons[b] Percent	 -106 -.08	 -7347 -3.73	 -404 -.20
Annual Change in Value of Domestic Shipments $1,000[a] Percent	 -108 -.03	 -123 -.31	 7 .02
Plant Closures	.00	.63	.03

[a] 1992 dollars. b Wet weight basis.

plant closure, it means that the plant will cease production of wet strength resin, but not close operations altogether.

The estimated primary impacts reported above depend on a set of parameters used in the partial equilibrium model of the wet strength and DGEBPA resin industries. One of the parameters, the elasticity of demand, measures how sensitive buyers are to price changes. The estimated impacts reported above are based on a demand elasticity of -0.92 for the wet strength market and -1.5 for the DGEBPA market. In Appendix D, we report the results of analyses that show the sensitivity of the estimated impacts to changes in the demand elasticity. The "low" elasticity case adopts a demand elasticity of -0.5 for the wet strength resin industry and -0.62 for the DGEBPA industry. The results show slightly larger price increases, smaller reductions in market output and less adverse impacts on domestic producers than results reported above.[29] The "high" elasticity case uses a demand elasticity of -1.34 for the wet strength resin industry and -3.10 for the DGEBPA industry. In general, this case shows slightly smaller price increases but more adverse impacts on domestic producers. However, the sensitivity analysis generally shows that the estimated primary impacts are relatively insensitive to reasonable ranges of demand elasticity estimates.

Also, the estimated impacts reported in Table 9-10 is based on the assumption that plants with the highest emission control costs (per unit of output) are marginal (highest cost) producers in the post-control market. This assumption causes the adverse impacts associated with the regulatory alternatives to be overstated.

9.4.3 Capital Availability Analysis

The capital availability analysis involves examining pre- and post-control values of selected financial ratios. These ratios include net income divided by assets and long term debt divided by the sum of long term debt and equity. In order to reduce the effects of year-to-year fluctuations in net income, a four-year average (1988 through 1991) of net income over assets was used as the baseline. Changes in the long term debt ratio represent structural changes and so are not subject to the same cyclical fluctuations. Long term debt ratios from 1991 were used as the baseline.

[29] Also, the plant closure previously predicted for the wet strength resin industry under the MACT Floor is no longer predicted when a "low" elasticity of demand is assumed.

As explained in Section 9-2, these financial statistics lend insight into the ability of affected firms to raise the capital needed to acquire emission controls. They provide estimates of the changes in profitability which would arise from the implementation of the NESHAP.

To calculate the post-control ratio of net income to assets, annualized control costs were subtracted from pre-control net income, and capital control costs were added to pre-control assets. To calculate the post-control long term debt ratio, capital control costs were added to pre-control long term debt, both the numerator and denominator of this ratio. Note that both post-control ratios reflect a worst-case assumption that affected firms are required to absorb emission control costs without the benefit of higher market prices.

Financial data are available for all three DEGBPA producers and 5 of the 7 wet strength resin producers. The 5 wet strength producers own 15 of the 17 facilities.

All of the companies that produce DGEBPA and wet strength resins are large corporations. As a result, emission controls costs, which are relatively small, have no perceptible impacts on the firm's financial ratios after rounding. Accordingly, we conclude that affected companies will not find it difficult to raise the capital necessary to purchase and install the required emission controls.

9.4.4 Limitations of Estimated Primary Impacts

Several qualifications of the estimated primary impacts presented in this section need to be made. A single market for homogeneous output is assumed in the partial equilibrium analysis. However, there may be some regional trade barriers which would protect producers. Furthermore, the analysis assumes that plants with the highest per unit emission control costs are marginal post-control. This assumption will cause the impacts presented above to be overstated since market impacts are determined by the costs of marginal plants. Finally, some plants may find that the price increase resulting from regulations make it profitable to expand production. This would occur if a firm found its post-control incremental unit costs to be smaller than the post-control market price. Expansion by these firms would result in a smaller decrease in output and increase in price than otherwise would occur.

We have also noted that the estimated primary impacts depend on the parameters of the partial equilibrium model. The results of the sensitivity analyses presented in Appendix D, which are based on a larger (more elastic) estimate of demand elasticity, show slightly more adverse impacts on domestic producers.

The capital availability analysis also has limitations. First, future baseline performance may not resemble past levels. Second, the tools used to measure the impact of controls are limited in their scope. Finally, the financial analysis is based on a worst-case assumption that affected establishments will fully absorb emission control costs without the benefits of higher prices.

9.4.5 Summary of Primary Impacts

The estimated impacts of the NESHAP on the DGEBPA industry is relatively small. Predicted price increases, reductions in domestic output and the value of domestic shipments for the DGEBPA industry are 0.08 percent or less. The impacts estimated under the MACT Floor for the wet strength resin industry are somewhat more adverse. Predicted price increases, reductions in domestic output and the value of domestic shipments for the MACT Floor are about 4 percent, and one plant closure is possible.

Under the Option I Scenario, however, predicted price increases, reductions in domestic output and the value of domestic shipments are 0.22 percent or less, and no plant closures are expected. As noted earlier, these results are likely to overstate the true adverse impacts. Finally, because emission control costs are very small relative to the financial resources of affected producers, they should not find it difficult to raise the capital necessary to finance the purchase and installation of emission controls.

9.5 SECONDARY ECONOMIC IMPACTS

9.5.1 Introduction

This section presents estimates of the secondary economic impacts that would result from the implementation of the NESHAP. Secondary impacts include changes in employment, energy use, and foreign trade and regional impacts.

9.5.2 Labor Impacts

The estimated labor impacts associated with the NESHAP are based on the results of the partial equilibrium analyses of the two resin industries. These estimated impacts depend primarily on the estimates of reduction in domestic production reported earlier in Section 9-4.[30] Note that changes in employment due to the operation and maintenance of control equipment have been omitted from this analysis due to lack of data. Also, the estimated employment impacts reported below do not include potential employment gains in industries which produce substitute commodi-

[30] More specifically, we estimate employment impacts by assuming that labor use per unit of output will remain constant when the quantity of output changes. Production worker hours per dollar of output was calculated from 1989 Annual Survey of Manufactures and a producer price index for chemicals and allied products obtained from the Economic Report of the President 1991. See Appendix B for a more detailed discussion.

ties that might benefit from reduced DGEBPA and wet strength resin production. Thus, the changes in employment estimated in this section reflect only the direct employment losses due to reductions in domestic production of DGEBPA and wet strength resin.

Table 9-11 presents estimates of employment losses for each of the two industries. As Table 9-11 indicates, the estimated job losses are small (up to two production jobs). As expected, the estimated employment losses in the wet strength resin industry are smaller for Option I than for the MACT Floor. The generally small impacts occur primarily because only small reductions in output are expected to occur as a result of the implementation of the NESHAP. Also, the industry is characterized by a relatively high output/employment ratio or low labor intensity.

Table 9-11

ESTIMATED EMPLOYMENT LOSSES

IMPACT	DGEBPA	Wet Strength Resin, MACT Floor	Wet Strength Resin, Option I
Lost Jobs	0.34	1.84	0.10
Percent Loss	0.08	3.73	0.20

NOTE: Estimates do not include potential employment gains due to operating and maintaining emission controls.

9.5.3 Energy Use Impacts

The approach we employ to estimate reductions in energy use is similar to the approach employed to estimate labor impacts. Again, these impacts depend primarily on the estimated reductions in domestic output reported earlier in Section 9-4. Note that the changes reported below do not account for the potential increases in energy use due to operating and maintaining emission control equipment. This omission is due to lack of data.

Table 9-12 presents changes in the use of energy by each industry. As expected, the estimated changes in energy use are minor because only small reductions in output are expected as a result of the implementation of the NESHAP. The change in the use of energy by the wet strength resin industry differs substantially between the MACT Floor and Option I. Much smaller energy use reductions are expected under Option I.

Table 9-12

ESTIMATED ENERGY USE REDUCTIONS

INDUSTRY/IMPACT	
DGEBPA	
$1,000 1992	8.51
Percent Reduction	0.08
Wet Strength Resins (MACT Floor)	
$1,000 1992	45.55
Percent Reduction	3.73
Wet Strength Resins (Option I)	
$1,000 1992	2.50
Percent Reduction	.20

NOTE: Estimates do not include potential increases in energy use due to operating and maintaining emissions controls.

9.5.4 Foreign Trade Impacts

Other factors being the same, the implementation of the NESHAP will raise the production costs of domestic resin manufacturers relative to foreign producers, causing U.S. imports of resin to increase and U.S. exports to decrease. The effects of the regulation on both the quantity and the value of net exports (exports-imports) are reported in Table 9-13.

The estimated trade impacts are small, both because of small predicted domestic price increases and because of the relatively small amount of trade that exists currently for the two products. For example, we estimate that the implementation of the standard will result in reduced DGEBPA net exports of about 20 metric tons annually (about .12 percent of baseline net exports) or about $38,000 per year. Note that we predict only a slight change in the dollar value of wet strength resin exports under both the

Table 9-13

ESTIMATED IMPACTS ON NET EXPORTS

INDUSTRY/IMPACT	
DGEBPA	
Volume (metric tons)	-20
Percent Change (volume)	-.12
Value ($1,000 1992)	-38
Wet Strength Resins (MACT Floor)	
Volume (metric tons)	-73
Percent Change (volume)	-3.73
Value ($1,000 1992)	1.23
Wet Strength Resins (MACT Floor)	
Volume (metric tons)	-4
Percent Change (volume)	-.21
Value ($1,000 1992)	.06

NOTES: Dollar estimates of trade impacts are adjusted for higher post-control prices. Changes in trade volumes are reported on a wet weight basis.

MACT Floor and Option I, even though we estimate that the volume of exports will fall by about 73 metric tons annually under the MACT Floor, and 4 metric tons annually under Option I. In either case, the higher post-control prices offset (approximately) the reduced physical volume of exports.

9.5.5 Regional Impacts

No significant regional impacts are expected from the implementation of the NESHAP because estimated employment impacts are small.

9.5.6 Limitations of Estimated Secondary Impacts

Our estimates of the secondary impacts associated with the NESHAP are based on changes in market equilibria predicted by the partial equilibrium models of the two affected markets. Accordingly, the caveats we discussed earlier in Section 9-4 for the primary impacts apply as well to our estimates of secondary impacts.

As noted earlier, the estimates of employment impacts do not include potential employment gains due to operating and maintaining emission control equipment or employment gains in the manufacturing of substitute products. Similarly, the estimates we report exclude potential indirect employment losses in industries that supply inputs to the resin industries. In short, the reported estimates of employment impacts include only direct production job losses in the DGEBPA and wet strength resin industries.

9.5.7 Summary of Secondary Impacts

The estimated secondary economic impacts of the alternative NESHAP are generally small. Estimated employment and energy impacts are small because only small reductions in industry output are expected. The estimated trade impacts are minor because only small domestic price increases are expected and because baseline trade volumes for the affected products are small. No significant impacts on regional economies are expected.

9.6 POTENTIAL SMALL BUSINESS IMPACTS

Firms in the DGEBPA and wet strength resin industries are classified as "small businesses" if they employ fewer than 750 employees.[31] No DGEBPA producer satisfies the criteria for a small business.[32] The three DGEBPA producers, Shell, Ciba-Geigy and Dow Chemical, employed over 30 thousand people in 1991. Ciba-Geigy employed over 90 thousand people in 1991. Employment data are available for 5 of the 7 wet strength facilities. Of the five, the company employing the fewest people was Hercules at approximately 15 thousand employees. No wet strength resin producer for which we have employment data comes close to qualifying as a small business. Table 9-14 shows the total employment of resin producing companies in 1991.

The Small Business Administration defines a small business as one which is not dominant in its field. There are three producers in the DGEBA industry. Each producer has a substantial market share.

The EPA Guidelines for Implementing the Regulatory Flexibility Act state that the definition of a small business is "any business which is independently owned and operated and not dominant in its field." The three corporations producing DGEBA each

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[31] EPA (1992). EPA Guidelines for Implementing the Regulatory Flexibility Act, Revised April 1992, Appendix C. Small Business Size Regulations, 13 CFR Part 121.

[32] EPA may adopt an alternative definition of a small business if an alternative size cutoff can be justified.

Table 9-14

EMPLOYMENT OF RESIN PRODUCERS

Company Name	Employment in 1991
Georgia Pacific	over 52,000
Henkel	41,000
Hercules	15,000
Dow	62,000
Borden	44,000
Exxon	101,000
Ciba-Geigy	91,000
Shell	30,000

Source: 1991 Annual Reports

have substantial market share. Similarly, the producers of wet strength resin are typically large conglomerates which employ well over 750 people.

9.7 ECONOMIC COSTS

Estimates of the economic costs associated with the implementation of the NESHAP for the DGEBPA and wet strength resin industries are presented below in this section of the report.

9.7.1 Economic Costs of Emission Controls: Conceptual Issues

Air quality regulations affect society's economic well-being by causing a reallocation of productive resources within the economy. Specifically, resources are allocated to the production of cleaner air and away from other goods and services that could otherwise be produced. Accordingly, the economic costs of emission controls can be measured as the value that society places on those goods and services not produced as a result of resources being diverted to the production of improved air quality. The conceptually correct valuation of these costs requires the identification of society's willingness to be compensated for these foregone consumption opportunities that would otherwise be available.[33]

In the discussion that follows, we distinguish between emission control costs and the economic costs associated with the regulatory alternatives. The former are measured simply as the annualized capital and annual operating and maintenance costs of controls under the assumption that all affected plants install controls. As noted above, economic costs reflect society's willingness to be compensated for foregone consumption opportunities.

Estimates of emission control costs will correspond to the conceptually correct measure of economic costs only if the following conditions hold:

- Marginal plants affected by an alternative standard must be able to pass forward all emission control costs to buyers through price mark-ups without reducing the quantity of goods and services demanded in the market.
- The prices of emission control resources (e.g., pollution control equipment and labor) used to estimate costs must correspond to the prices that would prevail if these factors were sold in competitive markets.
- The discount rate employed to compute the present value of future costs must correspond to the appropriate social discount rate.
- Emission controls do not affect the prices of goods imported to the domestic economy.

[33] Willingness to be compensated is the appropriate measure of economic costs, given the convention of measuring benefits as willingness to pay. Under this convention, the potential to compensate those members of society bearing the costs associated with a policy change is compared with the potential willingness of gainers to pay for benefits. See Mishan (1971).

9.7.1.1 Market Adjustments

A plant is marginal if it is among the least efficient producers in the market and, as a result, the level of its costs determine the post-control equilibrium price. A marginal plant can pass on to buyers the full burden of emission control costs only if demand is perfectly inelastic. Otherwise, consumers will reduce quantity demanded when faced with higher prices. If this occurs, estimated control costs will overstate the economic costs associated with a given air quality standard.

The emission control costs estimates do not reflect any market adjustments that are likely to occur as affected plants and their customers respond to higher post-control production costs. The estimates of economic costs presented later in this section do reflect estimates of such market adjustments.

9.7.1.2 Markets for Emission Control Resources

Other things being the same, estimated emission control costs will overstate the economic costs associated with an alternative air quality standard if the estimates are based on factor prices (e.g., emission control equipment prices and wage rates) which reflect monopoly profits earned in resource markets. Monopoly profits represent a transfer from buyers to sellers in emission control markets, but do not reflect true resource costs.

The extent to which sellers in emission control markets possess monopoly power has not been investigated. Consequently, we assume in this study that emission control resources are traded in competitive markets. The estimated economic costs reported in this section are overstated if this assumption does not hold.

9.7.1.3 The Social Discount Rate

The estimates of annualized emission control costs presented earlier in this report were computed by adding the annualized estimates of capital expenditures associated with the purchase and installation of emission control equipment to estimates of annual operating and maintenance costs. Capital expenditures were annualized using a 7 percent discount rate. The private cost of capital is appropriate for estimating how producers adjust supply prices in response to control costs.[34] In order to estimate the economic costs associated with the NESHAP, an appropriate measure of the social discount rate should be used in the amortization schedule.

There is considerable debate regarding the use of alternative discounting procedures and discount rates to assess the economic benefits and costs associated with public programs.[35] The approach adopted here is a two-stage procedure recommended by Kolb and Scheraga (1990).

First, annualized costs are computed by adding annualized capital expenditures (over the expected life of emission controls) and annual operating costs. Capital expenditures are annualized using a discount rate that reflects a risk-free marginal return on investment.[36] This discount rate, which is referred to below as the social cost of capital, is intended to reflect the opportunity cost of resources displaced by invest-

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[34] In other words, a discount rate reflecting the private cost of capital to affected firms should be used in analyses designed to predict market adjustments associated with emission control costs. The private cost of capital, assumed to be 10 percent in this analysis, is higher than the 7 percent social discount rate because it reflects the greater risk faced by individual procedures related to the risk faced by society at large.

[35] See Lind, <u>et al</u>. (1982) for a more detailed discussion of this debate.

[36] The risk-free rate is appropriate if the NESHAP, as a program, does not add to the variance of the return on society's investment portfolio.

ments in emissions controls. Kolb and Scheraga (1990) recommend a range of 5 to 10 percent for this rate. We adopt a midpoint value of 7.0 percent in this analysis.[37]

Second, the present value of the annualized stream of costs is computed using a consumption rate of interest which is taken as a proxy for the social rate of time preference. This discount rate, which is referred to below as the social rate of time preference, measures society's willingness to be compensated for postponing current consumption to some future date. Kolb and Scheraga (1990) argue that the consumption rate of interest probably lies between 1 and 5 percent. We do not, however, present estimates of the present value of the costs associated with the NESHAP in this report.

The resulting estimates of the present value of the economic costs associated with the NESHAP can be compared with estimates of the present value of corresponding benefits in the BCA. The social rate of time preference should be employed to discount the future stream of estimated benefits.

9.7.1.4 Costs of Imported Goods

The NESHAP is expected to cause an increase in prices paid for imports. From the perspective of the world economy, higher prices paid for imported goods represent a transfer from domestic consumers to foreign producers. However, from the perspective of the domestic economy alone, higher prices on imported goods represent an economic cost.

Since we do not consider the welfare of foreign producers in this analysis, we treat expenditures on DGEBPA and wet strength

[37] The 7 percent discount rate is also consistent with recent OMB recommendations.

resin due to higher prices as a cost. Note that there are two sources of this cost: (1) higher prices paid for baseline imports; and (2) higher prices paid for the additional imports induced by emission control costs faced by domestic producers.

9.7.2 Other Costs Associated with NESHAP

It should be recognized that the estimates of costs reported later in this section do not reflect all costs that might be associated with the NESHAP. Examples of these include administrative, monitoring, and enforcement costs (AME), and transition costs.

AME costs may be borne by directly affected firms and by different government agencies. These latter AME costs, which are likely to be incurred by state agencies and EPA regional offices, for example, are reflected neither in the estimates of emission control costs, nor in the estimates of economic costs.

Transition costs are also likely to be associated with the alternative standards. Analyses described in previous sections of this report, for example, predict that some plants will close because of emission control costs. This will cause some individuals to suffer transition costs associated with temporary unemployment and affected firms to incur shutdown costs. These transition costs are not reflected in the cost estimates reported later in this section.

9.7.3 Changes in Economic Surplus as a Measure of Costs

As was noted earlier, willingness to be compensated for foregone consumption opportunities is taken here as the appropriate measure of the costs associated with the NESHAP. In this case, compensating variation is an exact measure of willingness to be compensated. In practice, however, compensating variation is difficult to measure; consequently, the change in economic surplus associated with the air quality standard is used as an approximation to compensating variation.

The degree to which a change in economic surplus coincides with compensating variation as a measure of willingness to be compensated depends on whether the surplus change is measured in an input market or a final goods market. The surplus change is an exact measure of compensating variation when it is measured in an input market, but it is an approximation when measured in a final goods market.[38]

The direction of the bias in the approximation of compensating variation when the surplus change is measured in a final goods market depends on whether affected parties realize a welfare gain or suffer a welfare loss, but in either case, the bias is likely to be small.[39] Affected firms (and their customers) will suffer a welfare loss as the result of the implementation of emission controls. In this case, the change in economic surplus will exceed compensating variation, the exact measure of willingness to be compensated.[40]

9.7.4 Estimates of Economic Costs

Estimates of the annualized total economic costs associated with the NESHAP are reported in Table 9-15 (for a social cost of capital equal to 7.0 percent). The estimates of total annual costs of the NESHAP are $120 thousand for the DGEBPA industry, $465 thousand for the wet strength resin industry under the MACT Floor, and $51 thousand for the wet strength resin industry under Option I.

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[38] See Just, Heuth, and Schmitz (1982) for a more detailed discussion.

[39] See Willig (1974).

[40] See Appendix B for a detailed, technical description of the methods employed to compute changes in economic surplus.

Table 9-15

ESTIMATES OF ANNUALIZED ECONOMIC COSTS
(thousands of 1992 dollars)

Industry	Loss in Consumer Surplus	Loss in Producer Surplus	Loss in Residual Surplus	Loss in Surplus Total
DGEBPA	141	-3	-19	120
Wet Strength Resin MACT Floor	1,607	-841	-300	465
Option I	87	-22	-13	51

NOTE: Estimates are computed as the annualized reduction in economic surplus to the domestic economy.

We measure economic costs as net losses in economic surplus. Table 9-15 shows how losses in surplus are distributed among consumers, domestic producers and society at large. The latter is referred to as "residual" surplus in the table.

The loss in consumer surplus includes higher outlays for foreign and domestically produced DGEBPA and wet strength resin plus a dead weight loss due to foregone consumption. As Table 9-15 indicates, consumers in each market suffer a loss in surplus. These losses are due mostly to higher expenditures on DGEBPA and wet strength resin.

We compute the loss in producer surplus as annualized emission control costs incurred by plants remaining in operation plus the dead weight loss in surplus due to reduced output less increased revenue due to higher post-control prices. The estimated losses in producer surplus reported in Table 9-15 are negative, meaning that domestic producers would realize a net gain in economic surplus. This occurs because higher post-control market prices more than offset emission control costs.

Surplus losses to society at large are computed as "residual" adjustments to account for differences in private and social discount rates and transfer effects of taxes. The estimates of changes in producer surplus reflect a 10 percent real private rate on emission control capital costs. Recall that social costs are discounted at a 7.0 percent real rate.[41]

We note that the distribution of economic costs between consumers and domestic producers depends, in part, on the way we have constructed the post-control supply curve. As explained earlier, we have assumed that plants with the highest emission control costs (per unit of output) are marginal in the post-control market. This assumption is worst case in that it results in large increases in prices (relative to an alternative assumption that plants with high control costs are not marginal), thus shifting the cost burden to consumers and away from plants that continue to operate in the post-control market. Any alternative construction of the post-control supply curve would result in smaller price increases and shift a larger share of economic costs away from consumers to domestic producers. In other words, smaller price increases would reduce the economic rent realized by domestic producers in the post-control market.

Earlier, we explained that economic costs differ from emission control costs. Recall that the latter are computed simply as annualized capital costs plus annual operating and maintenance costs, assuming that all plants install controls. Table 9-16 reports estimates of annualized emission control costs. These estimates are $145 thousand for the DGEBPA industry and range from

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[41] Since the loss in producer surplus measures the burden of the alternative borne by producers, we calculate it using the private cost of capital.

$52 thousand under the MACT Floor to $519 under Option I for the Wet Strength resin industry. The emission control costs reported in Table 9-16 exceed the economic costs reported in Table 9-15 under the MACT Floor scenario. This occurs because the estimated economic costs reflect market adjustments away from marginally expensive production.

Table 9-16

ESTIMATES OF THE ANNUALIZED EMISSION CONTROL COSTS
(thousands of 1992 dollars)

DGEBPA	Wet Strength Resin MACT Floor	Wet Strength Resin Option I	Total
145	519	N.A.	664
145	N.A.	52	197

NOTE: Estimates are computed as annualized capital costs plus annual operating and maintenance costs, assuming all plants continue to operate after controls are installed. Capital costs are annualized at a 7 percent discount rate.

APPENDIX A

AFFECTED PLANTS AND EMISSION CONTROL COSTS

This appendix describes the affected DBGEPA and wet strength resin plants and the estimates of emissions and emission control costs used in this study.

AFFECTED PLANTS

There are three major DBGEPA producers. Consequently, we are able to use plant specific data for baseline emissions, emissions reductions, and control costs. Data on production rates at DBGEPA plants, however, is considered confidential and is not available to the public. We use an average annual production rate of 45,000 metric tons (wet weight) as baseline output for each of the three DGEBPA facilities.[42]

There are 17 wet strength resin facilities nationwide. However, only five of these plants are expected to incur emission control costs under the MACT Floor and nine under Option I. We assume that each of these plants produce 11,600 metric tons annually.[43]

EMISSION CONTROL COSTS

Table A-1 reports emission control capital costs and annualized costs for the three DGEBPA facilities. Table A-2 shows the same information for the five affected wet strength resin plants. Annualized costs include amortized capital costs plus the annual operating and maintenance costs associated with emission controls.

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[42] Draft BID, Section 6, Appendix A (wet weight).

[43] Draft BID, Section 6, Appendix A (wet weight).

Table A-3 shows capital and annualized costs for the nine wet strength resin plants expected to be affected by Option I (estimated costs are the same for all nine plants).

Table A-1

CONTROL COSTS AT DGEBPA PLANTS

PLANT	CAPITAL COSTS (1992$)	ANNUALIZED COSTS (1992$)[a]
DOW	254,873	31,207
Ciba-Geigy	104,778	75,461
Shell	67,618	38,266

[a] Capital costs annualized at a 7 percent discount rate.

Table A-2

MACT FLOOR CONTROL COSTS AT AFFECTED WET STRENGTH RESIN PLANTS

PLANT ID #	CAPITAL COSTS (1992$)	ANNUALIZED COSTS (1992$)[a]
1	24,500	86,000
2	37,400	112,000
3	360,000	91,000
12	48,000	111,000
14	39,500	119,000

[a] Capital costs annualized at a 7 percent discount rate.

Table A-3

OPTION I CONTROL COSTS
AT AFFECTED WET STRENGTH RESIN PLANTS

NUMBER OF PLANTS	CAPITAL COSTS (1992$)	ANNUALIZED COSTS (1992$)[a]
9	15,348	5,782

[a] Capital costs annualized at a 7 percent discount rate.

APPENDIX B

TECHNICAL DESCRIPTION OF ANALYTICAL METHODS

This technical appendix provides detailed descriptions of the analytical methods employed to conduct the following analyses:

- Partial equilibrium analysis (i.e., computing post-control price, output and trade impacts).
- Estimating changes in economic surplus.
- Labor and energy impacts.
- Capital availability.

We also present the baseline values used in the partial equilibrium analysis.

PARTIAL EQUILIBRIUM ANALYSIS

The partial equilibrium analysis requires the completion of four tasks. These tasks are:

- Specify market demand and supply.
- Estimate the post-control shift in market supply.
- Compute the impact on market quantity.
- Compute the impact on market price.
- Predict plant closures.

Market Demand and Supply

Baseline or pre-control equilibrium in a market is given by:

$$Q_d = \alpha P^{\epsilon} \qquad \text{(B.1)}$$

$$Q_s^d = \beta P^{\gamma} \qquad \text{(B.2)}$$

$$Q_s^f = \rho P^\gamma \tag{B.3}$$

$$Q_d = Q_s^d + Q_s^f = Q \tag{B.4}$$

where, Q = output;

P = price;

ϵ = demand elasticity;

γ = supply elasticity;

α, β and ρ are constants;

Subscripts d and s reference demand and supply, respectively; and,

Superscripts d and f reference domestic and foreign supply, respectively.

The constants α, β and ρ are computed such that the baseline equilibrium price is normalized to one. Note that the market specification above assumes that domestic and foreign supply elasticities are the same.

Market Supply Shifts

Supply price for a model plant will increase by an amount just sufficient to equate the net present value of the investment and operation of the control equipment to zero. Specifically,

$$\frac{[(C \cdot Q) - (V+D)](1-t)+D}{S} = k \tag{B.5}$$

where C is the change in the supply price;

Q is output;

V is a measure of annual operating and maintenance control costs.

t is the marginal corporate income tax rate;

S is the capital recovery factor;

D is annual depreciation (we assume straight-line depreciation);

k is the investment cost of emissions controls.

Solving for C yields the following expression:

$$C = \frac{kS-D}{Q(1-t)} + \frac{V+D}{Q} \quad (B.6)$$

Estimates of k and V were obtained from EPA (1991). The variables, D, I, and S are computed as follows:

$$D = k/T \quad (B.7)$$

and

$$S = r(1+r)^T/((1+r)^T-1) \quad (B.8)$$

where r is the discount rate or cost of capital faced by producers;

T is the life of emission control equipment.

Solving for P in Equation (B.2) yields the following expression for the baseline inverse market supply function for domestic producers.

$$P = (Q_s^d/\beta)^{1/\gamma} \quad (B.9)$$

Emission control costs will raise the supply price of the i^{th} model plant by C_i (as computed in Equation (B.6)). The aggregate domestic market supply curve, however, does not identify the supply price for individual plants. Accordingly, we adopt the worst-case assumption that model plants with the highest after-tax per unit control costs are marginal in the post-control market. Specifically, we write the post-control supply function as

$$P = (Q_s^d/\beta)^{1/\gamma} + C(C_i, q_i) \tag{B.10}$$

where q_i is the total output of all model plants of type i.

The function $C(C_i, q_i)$ shifts segments of the pre-control domestic supply curve vertically by C_i. The width or horizontal distance of each segment is q_i. The resulting segmented post-control domestic supply curve is illustrated in Figure B-1 as S_2, compared with pre-control supply S_1.[44]

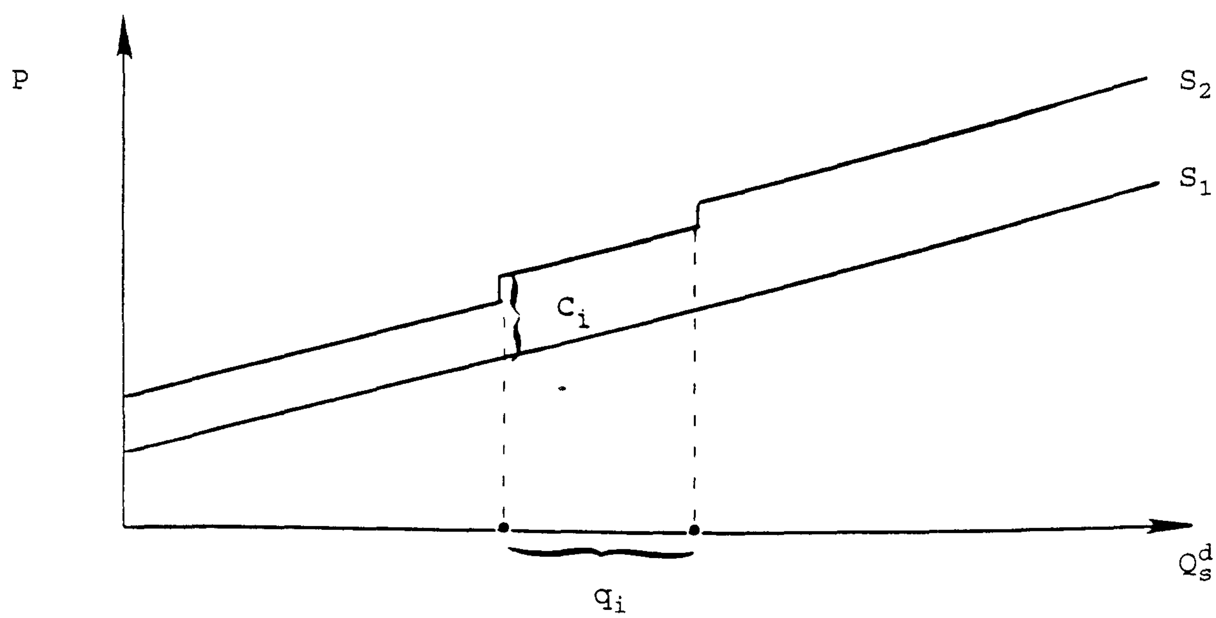

Figure B-1.

Domestic Market Supply Shift Due to Emission Control Costs

[44] The supply curves in Figure B-1 are drawn as linear functions for ease of exposition. Because the supply curves are specified as Cobb-Douglas, they are log-linear.

Impact on Market Price and Quantity

The impacts of the alternative standards on market output are estimated by solving for post-control market equilibrium and then comparing that output level, Q_2, to the pre-control output level, Q_1. Because post-control domestic supply is segmented, a special iterative algorithm was developed to solve for post-control market equilibrium. The algorithm first searches for the segment in the post-control supply function at which equilibrium occurs and then solves for the post-control market price that clears the market.

Since the market clearing price occurs where demand equals post-control domestic supply plus foreign supply, the algorithm simultaneously solves for the following post-control variables.

- Equilibrium market price.
- Equilibrium market quantity.
- The quantity supplied by domestic producers.
- The net quantity supplied by foreign producers.

We assess the market impacts of control costs by comparing baseline values to post-control values for each of the variables listed above.

Trade Impacts

We report trade impacts as the change in both the volume and dollar value of net exports. We assume that exports comprise an equivalent percentage of domestic production in the pre- and post-control markets. We also assume that foreign and domestic supply elasticities are the same. As the volume of imports rises and the volume of exports falls, the volume of net exports will decline. However, if demand is inelastic, it is uncertain whether the dollar value of net exports will rise or fall. The dollar value of imports will increase due to increases in both volume and price. Exports will decrease in volume, but price will increase. If demand is inelastic then the dollar value of exports will increase. If the increase in the dollar value of exports is greater than that of imports then the alternative will result in an increase in the dollar value of net exports.

We use the following algorithms to compute trade impacts:

Change in volume of imports =

$$Q^f_{s_2} - Q^f_{s_1} \quad \text{(B.11.a)}$$

Change in dollar value of imports =

$$P_2(Q^f_{s_2} - Q^f_{s_1}) + (P_2 - P_1) \cdot Q^f_{s_1} \quad \text{(B.11.b)}$$

Change in volume of exports =

$$\frac{Q_e}{Q^d_{s_1}}(Q^d_{s_2} - Q^d_{s_1}) \quad \text{(B.11.c)}$$

Change in dollar value of exports =

$$\frac{Q_e}{Q^d_{s_1}}(P_1 Q^d_{s_1} - P_2 Q^d_{s_2}) \quad \text{(B.11.d)}$$

where the subscript e references exports by domestic producers.

We report the change in the volume of net exports as (B.11.c) minus (B.11.a). We report the change in the dollar value of net exports as the difference between (B.11.d) and (B.11.b).

We also report the change in the dollar value of shipments by domestic producers. This value, ΔVS, is given by

$$\Delta VS = P_2 \cdot Q^d_{s_2} - P_1 Q^d_{s_1} \qquad (B.12)$$

Plant Closures

We predict that any plant will close if its post-control supply price is higher than the post-control equilibrium price. Post-control supply prices are computed by Equation (B.10). We round fractions of plant closures to the nearest integer.

CHANGES IN ECONOMIC SURPLUS

The shift in market equilibrium will have impacts on the economic welfare of three groups:

- Consumers.
- Producers.
- Society at large.

The procedure for estimating the welfare change for each group is presented below. The total change in economic surplus, which is taken as an approximation to economic costs, is computed as the sum of the surplus changes for the three groups.

Change in Consumer Surplus

Consumers will bear a dead weight loss associated with the reduction in output. This loss represents the amount over the pre-control price that consumers would have been willing to pay for the eliminated output. This surplus change is given by:

$$\int_{Q_2}^{Q_1} (Q/\alpha)^{1/\epsilon}\, dQ - P_1 \cdot (Q_1 - Q_2) \qquad \text{(B.13)}$$

In addition, consumers will have to pay a higher price for post-control output. This surplus change is given by:

$$(P_2 - P_1) \cdot Q_2 \qquad \text{(B.14)}$$

The total impact on consumer surplus, ΔCS, is given by (B.13) plus (B.14). Specifically,

$$\Delta CS = \int_{Q_2}^{Q_1} (Q/\alpha)^{1/\epsilon}\, dQ - P_1 Q_1 + P_2 Q_2 \qquad \text{(B.15)}$$

This change, ΔCS, includes losses of surplus incurred by foreign consumers. In this report we are only concerned with domestic surplus changes. We have no method for identifying the marginal consumer as foreign or domestic.

To estimate the change in domestic consumer surplus we assume that total consumer surplus is split between foreign and domestic consumers in the same proportion that sales are split between foreign and domestic consumers in the pre-control market. That is, the change in domestic consumer surplus, ΔCS_d, is:

$$\Delta CS_d = \left[1 - \left(\frac{Q_e}{Q_{s_1}^d} + Q_{s_1}^f \right) \right] \Delta CS \qquad \text{(B.16)}$$

While ΔCS is a measure of the consumer surplus change from the perspective of the world economy, ΔCS_d represents the consumer surplus change from the perspective of the domestic economy.

Change in Producer Surplus

To examine the effect on producers, output can be divided into two components:

- Output eliminated as a result of controls.
- Remaining output of controlled plants.

The total change in producer surplus is given by the sum of the two components.

Note that post-tax measures of surplus changes are required to estimate the impacts of controls on producers' welfare. The post-tax surplus change is computed by multiplying the pre-tax surplus change by a factor of (1-t) where t is the marginal tax rate. As a result, every one dollar of post-tax loss in producer surplus will be associated with a complimentary loss of t/(1-t) dollars in tax revenues.

Output eliminated as a result of control costs causes producers to suffer a dead-weight loss in surplus analogous to the dead-weight loss in consumer surplus. The post-tax dead-weight loss is given by:

$$\left[P_1 (Q^d_{s_1} - Q^d_{s_2}) - \int_{Q^d_{s_2}}^{Q^d_{s_1}} (Q/\beta)^{1/\gamma}\, dQ \right] (1-t) \qquad (B.17)$$

Plants remaining in operation after controls realize a welfare gain of $P_2 - P_1$ on each unit of output, but incur a per unit welfare loss of C_i. Thus, the post-tax loss in producer surplus for m model plant types remaining in the market is

$$\left[(P_1 - P_2)\, Q_{s_2}^{d} + \sum_{i=1}^{m} C_i q_i \right] (1-t) \qquad \text{(B.18)}$$

The total post-tax change in producer surplus, ΔPS, is given by the sum of (B.17) and (B.18). Specifically,

$$\Delta PS = \left[P_1 Q_{s_1}^{d} - P_2 Q_{s_2}^{d} - \int_{Q_{s_2}^{d}}^{Q_{s_1}^{d}} (Q/\beta)^{1/\gamma}\, dQ + \sum_{i=1}^{m} C_i q_i \right] (1-t) \qquad \text{(B.19)}$$

Recall that we are interested only in domestic surplus changes. For this reason we do not include the welfare gain experienced by foreign producers due to higher prices. This procedure treats higher prices paid for imports as a dead-weight loss in consumer surplus. Higher prices paid to foreign producers represent a transfer from the perspective of the world economy, but a welfare loss from the perspective of the domestic economy.

Residual Effect on Society

The changes in economic surplus, as measured above, must be adjusted to account for two effects which cannot be attributed specifically to consumers and producers. These two effects are caused by tax impacts and differences between private and social discounts rates.

Two adjustments for tax impacts are required. First, per unit control costs C_i, which are required to predict post-control market equilibrium, reflect after-tax control costs. The true resource costs of emissions controls, however, must be measured on a pre-tax basis. For example, if after-tax control costs exceed pre-tax control costs, C_i overstates the true resource costs of controlling emissions.

A second tax-related adjustment is required because changes in producer surplus have been reduced by a factor of (1-t) to reflect the after-tax welfare impacts of emissions control costs on affected plants. As was noted earlier, a one dollar loss in pre-tax producer surplus imposes an after-tax burden on the affected plant of (1-t) dollars. In turn, a one dollar loss in after-tax producer surplus causes a complimentary loss of t/(1-t) dollars in tax revenues.

A second adjustment is required because of the difference between private and social discount rates. The rate used to shift the supply curve reflects the private discount rate (or the marginal cost of capital to affected firms). This rate must be used to predict the market impacts associated with emission controls. The economic costs of the NESHAP, however, must be computed at a rate reflecting the social cost of capital. This rate is intended to reflect the social opportunity cost of resources displaced by investments in emission controls.[45]

The adjustment for the two tax effects and the social cost of capital, which we refer to as the residual change in surplus, ΔRS, is given by:

$$\Delta RS = -\sum_{i=1}^{m} (C_i - pc_i)q_i + \Delta PS \cdot [t/(1-t)] \qquad (B.20)$$

where pc_i = per unit cost of controls for model plant type i, computed as in (B.5) with t=0 and r=social cost of capital.

[45] See Section 7 for a more detailed discussion of this issue.

The first term on the right-hand-side of (B.20) adjusts for the difference between pre- and post-tax differences in emission control costs and for the difference between private and social discount rates. Note that these adjustments are required only on post-control output. The second term on the right-hand-side of (B.19) is the complimentary transfer of the sum of all post-tax producer surplus.

Total Economic Costs

The total economic costs, EC, is given by the sum of changes in consumer and producer surplus plus the change in residual surplus. Specifically,

$$EC = \Delta CS_d + \Delta PS + \Delta RS \tag{B.21}$$

LABOR AND ENERGY IMPACTS

Our estimates of the labor and energy impacts associated with the alternative standards are based on input-output ratios and estimated changes in domestic production.

Labor Impacts

Labor impacts, measured as the number of jobs lost due to domestic output reductions, are computed as

$$\Delta L = \frac{P_1 (Q^d_{s_1} - Q^d_{s_2}) L_1}{2000} \tag{B.22}$$

where ΔL is the change in employment, L_1 is the production worker hours per dollar of output, and all else is as previously defined. The number 2000 is used to translate production worker hours into jobs (i.e., we assume a 2000 hour work year).

Energy Impacts

We measure the energy impacts associated with the alternative standards as the reduction in expenditures on energy inputs due to output reductions. The method we employ is similar to the procedure described above for computing labor impacts. Specifically,

$$\Delta E = E_1 P_1 \left(Q^d_{s_1} - Q^d_{s_2}\right) \qquad (B.23)$$

where ΔE is the change in expenditures on energy inputs, E_1 is the baseline expenditure on energy input per dollar output and all else is as previously defined.

BASELINE INPUTS

The partial equilibrium model described above requires, as inputs, data on the characteristics of affected plants and baseline values for variables and parameters that characterize each market. The characteristics of affected plants have been described earlier in Appendix A. These include the number of plants by model type and a measure of output for each model plant. Appendix A also reports estimates of capital and annual emission control costs.

Table B-1 reports the baseline values of variables and parameters for each market. The baseline price of DGEBPA is taken from the Chemical Economic Handbook (p. 580.601G); the baseline price

Table B-1

BASELINE INPUTS

Variable/Parameter	MARKET	
	DGEBPA	Wet Strength Resin
Price (P_1)[a]	$2.59	$.20
Domestic Output ($Q^d_{s_1}$)[b]	135.0	197.2
Import Ratio[c]	0.028	0
Export Ratio[d]	0.178	0.010
Supply Elasticity (ϵ)	3.76	3.76
Demand Elasticity (γ)	-1.50	-0.924
Tax Rate (t)	0.25	0.25
Private Discount Rate (r)	0.1	0.1
Social Discount Rate	0.07	0.07
Equipment Life (T)[e]	10	10
Labor (L_1)[f]	0.0025	0.0025
Energy (E_1)[g]	0.031	0.031

Notes: [a] Dollars (1992) per kilogram (wet weight).
[b] Thousands of metric tons (wet weight).
[c] Imports divided by domestic production.
[d] Exports divided by domestic production.
[e] Years.
[f] Production worker hours per dollar of output.
[g] Energy expenditure per dollar of output.

of wet strength resin is from Synthetic Organic Chemicals.[46] [47] Baseline domestic output in each market is computed as the sum of

[46] Prices were converted to 1992 dollars using the producer price index for chemicals and allied products (Economic Report of the President).

[47] Wet strength resin prices were converted from a dry weight to wet weight basis using a wet-to-dry weight conversion factor of 7.7 (computed from data in the Chemical Economics Handbook, p. 580.1000X).

production at all domestic plants (see Appendix A from production rates at DGEBPA and wet strength resin plants).

The import and export ratios reported in Table B-1 were computed from production and trade data for DGEBPA (unmodified epoxy resins) and wet strength resin (epi-based non-nylon polyamide) reported in Chemical Economics Handbook (pp. 580.601M, 580.601K and 580.1000Y). Imports of wet strength resin were reported to have been "insignificant."

We describe the data and procedures employed to estimate supply and demand elasticities (γ and ϵ, respectively) in Appendix C. Note that we use the estimates of the demand elasticities reported in Table B-1 for the "base case" results presented in Sections 4, 5, and 7 of this report. We assess the sensitivity of the estimated impacts to demand elasticity by reporting in Appendix D results based on "low" and "high" estimates.

We use a marginal tax rate of 25 percent to assess the impacts of emission controls. We adopt a 10 percent private discount rate (real marginal cost of capital) and a 7.0 percent social discount rate. The expected life of emission control equipment is 10 years.

Finally, the values for labor hours per unit of output (L_1) and energy use per unit of output (E_1) were obtained from the Annual Survey of Manufactures. Data from the ASM used to derive these estimates include 1989 annual values for total production worker hours used, total expenditures on energy; and the value of shipments. Recall that these data are available at the 4-digit SIC code level. DGEBPA, wet strength resins and other resin products are included in SIC code 2821. For this reason, L_1 and E_1 are the same in both resin markets.

CAPITAL AVAILABILITY ANALYSIS

Pre- and post-control values of the following financial measures are compared in the capital availability analyses:

- Net income/assets.
- Long-term debt/long-term debt plus equity.

Pre-Control Financial Measures

Pre-control measures of net income and net income/assets are computed by averaging data for the period 1988 through 1991 where these data are available. The long-term debt ratio is computed from 1991 data, or the most recent year available.

All figures are adjusted to 1991 dollars by the producer price index for chemicals and allied products. Then, pre-control values are estimated by:

i) $$n = \sum_{i=1988}^{1991} n_i/4 \qquad \text{(B.24)}$$

ii) $$r = \sum_{i=1988}^{1991} (n_i/a_i)/4 \qquad \text{(B.25)}$$

iii) $$l = l_{1991}/(l_{1991} + e_{1991}) \qquad \text{(B.26)}$$

where n = average net income

n_i = net income in year i

r = average return on assets

a_i = assets in year i

l = long-term debt ratio

l_{1987} = long-term debt in 1991

e_{1987} = equity in 1991

Post-Control Values

To determine the impact of controls, an estimate of the cost of controls is made. In order to get an idea of the steady-state cost, an annualized cost is used. The annualized cost, AC, for a plant is:

$$AC = V + kS \qquad (B.27)$$

where the variables are as defined previously.

Annualized costs and capital costs are estimated for each model plant type. For each establishment, post-control measures are given by:

$$pn = \sum_{i=1988}^{1991} \frac{n_i - AC}{4} \qquad (B.28)$$

$$pr = \sum_{i=1988}^{1991} \frac{(n_i - AC)/(a_i + k)}{4} \qquad (B.29)$$

$$pl = \frac{l_{1991} + k}{l_{1991} + e_{1991} + k} \qquad (B.30)$$

where pn = post-control average net income
AC = annualized cost for the company
pr = post-control return on assets
k = capital cost for the company
pl = post-control long-term debt ratio

APPENDIX C

ESTIMATION OF INDUSTRY SUPPLY AND DEMAND

INTRODUCTION

This appendix describes the analytical approach and the data we employed to estimate the supply and demand elasticities used in this EIA. We also report and evaluate the statistical properties of the estimates.

APPROACH

The approaches we adopt to estimate supply and demand elasticities are consistent with economic theory and, at the same time, exploit the available data. Briefly, we derive an industry-wide estimate of supply elasticity from an estimated production function. Because the data required to estimate the production function are available only at a four-digit SIC level (SIC 2821 which includes both the epoxy and wet strength resin industries), we obtain a single estimate of supply elasticity. We adopt this single estimate for both the DGEBPA and wet strength resin industries, implicitly assuming that the two industries face similar production functions.

Because both DGEBPA and wet strength resin are used as intermediate inputs to produce other goods, the demand for these inputs is derived from the goods they are used to produce. The data required to estimate the derived demand functions are available separately for both DGEBPA and wet strength resin. As a result, we obtain estimates of demand elasticities for each of the two industry segments.

Supply Elasticity

As noted above, we derive an estimate of the market supply elasticity from an industry-wide estimate of the production function. Given the production function, we solve for the dual cost function. Then, exploiting the result that market price is established at marginal production cost, we derive the inverse supply curve as the derivative of the cost function with respect to output. The important result is that the parameters of the supply function can be stated in terms of the parameters of the estimated production function.

We assume that the industry is economically efficient in that production costs are minimized subject to a production constraint. In equation form, this can be written as:

$$\underset{x_i}{\text{minimize}} \quad \Sigma\, r_i x_i \tag{C.1}$$

$$\text{subject to:} \quad Q = f(x_i)$$

where x_i = factor inputs (used to produce resins)

r_i = factor prices

Q = output (of resins)

The solution to this problem is a set of input demand functions:

$$x_i^* = g(r_i, Q) \tag{C.2}$$

If the input demand functions are substituted back into the objective function, one obtains a cost function in terms of input prices and output.

$$C = h(r_i; Q) \tag{C.3}$$

Equilibrium in the market is established at the point where price equals marginal cost. That is:

$$P \quad = \quad \partial C/\partial Q \quad = \quad h'(r_i;Q) \qquad (C.4)$$

where P is output price. Equation (C.4) is a relationship between output and output price and thus represents the industry supply curve.

An explicit functional expression for the right-hand side of (C.4) can be determined if one makes a specific assumption on the form of the production function. For this analysis, we assume a multiplicative form for the production function with two variable inputs and a capital factor. Because we use time series data to estimate the production function, we also include a time factor to account for changes in technology. Specifically,

$$Q_t = AK_t^{\alpha_K}\, t^{\lambda}\, L_t^{\alpha_L}\, M_t^{\alpha_M} \qquad (C.5)$$

where
- Q_t is industry output in year t
- K_t is real capital stock in year t
- L_t is production man-hours in year t
- M_t is an index of materials input in year t
- t is time in years
- A, α_L, α_M, λ are parameters to be estimated.

Equation (C.5) can be written in linear form by taking the natural logarithms of both sides. Thus, linear regression techniques can be applied.

Given a particular form for the production function, the steps described by Equations (C.2) to (C.4) can be used to derive the implied supply function. For this analysis, we assume that capital stock is fixed.[48] The derived supply function can be written as:

$$\ln Q = B_0 + \gamma \ln P + B_2 \ln K + B_3 \ln P_L + B_4 \ln P_M + B_5 \ln t \qquad (C.6)$$

where P_L = factor price of labor input
P_M = factor price of material input
K = fixed real capital stock

The B_i and γ coefficients are functions of the α_i, the coefficients of the production function. For example, γ, the supply price elasticity, can be shown to be equal to

$$\gamma = \frac{\alpha_L + \alpha_M}{1 - \alpha_L - \alpha_M} \qquad (C.7)$$

It is clear from (C.7) that it may be necessary to place restrictions on the estimated coefficients of the production function in order to have well-defined supply function coefficients. For example, the sum of the coefficients for labor and materials should be less than one. Otherwise, γ is undefined or, if both coefficients are positive, γ would be negative. For this reason, the production function is estimated with the restriction that the sum of coefficients for the inputs should equal one. This is equivalent to assuming long-run constant costs in the

[48] This specification, which treats in place capital as sunk, is consistent with our objective of modeling how supply adjusts to price changes in the post-control market. This response will depend on the behavior of avoidable production costs and emission control costs.

industry, an assumption that seems reasonable on <u>a priori</u> grounds and appears to be consistent with the data.[49]

<u>Demand Functions</u>

Wet strength resin is used primarily in the production of pulp and paper products (SIC 2851). DGEBPA is used to produce a variety of products; about 50 percent of industry output is used to sealants and adhesives (SIC 2621) and coatings and paints (SIC 2891). As intermediate inputs, the demand for both wet strength resin and DGEBPA are derived from the demand for the products they are used to produce.

We assume that firms using wet strength resin and DGEBPA as inputs attempt to maximize profits subject to a production constraint. The profit function can be written

$$\max_{Q,W} \pi = P_e \cdot g(Q,W) - P \cdot Q - r_w \cdot w \tag{C.8}$$

where π = profit;

P_e = the price of the final good (e.g., pulp and paper products);

Q = input use of wet strength resin or DGEBPA;

W = a vector of other inputs

P = the price of wet strength resin or DGEBPA; and,

r_w = a vector of prices of other inputs.

Note that the function $g(Q,W)$ defines the production function for the end product, say Q_e.

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[49] The unrestricted estimates of the production function coefficients summed nearly to unity. Thus, the restriction on the coefficients is only marginally binding.

The solution to C.8 yields a system of input demand equations of the form

$$Q = h(P, P_e, r_w) \tag{C.9}$$

In words, C.9 states that the derived demand for wet strength resin or DGEBPA depends on its own price, the price of the final good, and the prices of other inputs.

We adopt a multiplicative function form for equation C.9. Specifically, we write the derived demand function as

$$Q_e = BP^{\beta}.P_e^{\beta_e} \tag{C.10}$$

where Q = the quantity demanded of wet strength resin or DGEBPA;

P = the price of wet strength resin or DGEBPA;

P_e = the price of the end product; and,

B, β, β_e are parameters to be estimated.

The parameter β, of course, is the demand elasticity for the input – either wet strength resin or DGEBPA.

Note that equation C.10 excludes variables for the prices of other inputs (r_w of equation C.9). Unfortunately, data on these prices are unavailable. This requires us to adopt the implicit assumption that the use of wet strength resin and DGEBPA in end products is fixed by technology.

Because the markets for wet strength resin and DGEBPA are simultaneous in P and Q, it is necessary to apply a systems estimator in order to obtain consistent estimates of the coefficients for the demand equations. We employ a two-stage least squares estimator (2SLS) to estimate the demand equations. In order to estimate consistent demand equation coefficients, one uses as instruments the exogenous variables included in the system of demand and supply equations. The supply-side instruments used to estimate the demand functions include capital stock (K), a cost index (P_v) measuring the weighted-average cost of variable inputs (labor and materials), and time.

DATA

Table C-1 identifies the variable names, units of measure, and variable descriptions for the data available for the analysis. Those variables directly related to a specific SIC were obtained from the Annual Survey of Manufactures (ASM).[50] These data are defined for 4-digit SICs and represent annual values which cover the years 1958-1989. Recall that both DGEBPA and wet strength resins belong to SIC 2821 code. Industry segment price and output data, obtained from the ITC and SPI, were used to estimate demand elasticities. These data are available for the years 1971-1990.

Items 1 through 9 of Table C-1 were used to estimate the production function (see Equation C.5) for SIC 2821. We formed the industry output variable, Q, as VSHIP/PISHIP; this ratio yields the real value of shipments in SIC 2821. The capital stock variable, K, is measured as CAP, the real value of capital stock in millions of 1972 dollars. Labor input, L, is measured as PRODH, millions of production worker hours. The time trend, t, is measured by the variable YEAR. Finally, we measure materials use, M, as the ratio of COSTMAT/PIMAT;

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[50] We thank Eric Bartlesman of the Federal Reserve Board for providing the data set to us.

Table C-1

VARIABLES AND DEFINITIONS OF PRIMARY DATA

	Variable[a]	Unit	Description
1.	YEAR	—	Observation identifier, 1958-1989
2.	SIC	4-digit	Industry identifier
3.	PISHIP	index	Producer price index for Value of Shipments (SICs 2821, 2891 and 2851)
	VSHIP	millions $	Value of industry shipments
5.	CAP	millions 1972 $	Real capital stock (SIC 2821)
6.	COSTMAT	millions $	Cost of materials inputs (SIC 2821)
7.	PIMAT	index	Price index for materials inputs (SIC 2821)
8.	PRODW	millions $	Production worker wages (SIC 2821)
9.	PRODH	millions hours	Production worker hours (SIC 2821)
10.	PRICE	dollars per kilogram	Price per kilogram (Type A Liquid Resin, DGEBPA Resin and Non-Nylon Polyamide Resin)
11.	SALES	millions of kilograms	Quantity sold by domestic producers annually (DGEBPA use in protective coatings, DGEBPA use in bonding and adhesives and Non-Nylon Polyamide Resin)
12.	IPD	index	Implicit Price Deflator (1.0 in 1972)

a Items 1-9 obtained from the ASM. Items 10 and 11 obtained from the ITC and the SPI. Item 12 obtained from 1991 Economic Report of the President.

this ratio yields the real cost of material inputs for SIC 2821 in millions of 1972 dollars.

Items 3, 10, 11 and 12 were used to estimate the derived demand equations. The dependent variable for the wet strength resin equation, quantity demanded, is measured as sales of non-nylon polyamides in millions of kilograms per year. The "real" price variable for this equation is measured as the nominal price of non-nylon polyamides (item 10) divided by IPD (item 12). The "real" price of the end-product good is measured as PISHIP for SIC 2821 (pulp and paper) divided by IPD.

We estimate two derived demand functions for DGEBPA – one for DGEBPA use in coatings and paints and another for DGEBPA use in sealants and adhesives. The dependent variables for each equation are measured as sales for the respective use in millions of kilograms annually. The real price variable for DGEBPA use in coatings and paints is measured as the nominal price of Type A liquid resin divided by IPD; the real price for DGEBPA use in coatings and adhesives is measured as the nominal price of DGEBPA resin divided by IPD. Both price variables are expressed as dollars per kilogram. Finally, the real prices of end-products are formed by the ratios of PISHIP/IPD for SICs 2891 (coatings and paints) and 2621 (sealants and adhesives).

The 2SLS estimates of the derived demand equations require data for three instrumental variables – time, capital stock and a cost index for variable inputs. Time and capital stock are measured as the variables YEAR and CAP (for SIC 2821). We form the cost index for variable inputs as a weighted index of PIMAT and PRODH (for SIC 2821), expressed in constant 1972 dollars.

STATISTICAL RESULTS

__Production Function/Supply Equation__

A restricted least squares estimator was used to estimate the coefficients of the production function shown in Equation (C.5). A log-linear specification was estimated with the sum of the α_i restricted to unity. The results are shown in Table C-2. The equation explains about 96 percent of the variation in the output variable. While the coefficients on labor and time are significant at the 99 percent confidence level, the coefficients

Table C-2

ESTIMATED PRODUCTION FUNCTION COEFFICIENTS
(t-ratios in parentheses)

Industry	Time	Capital	Labor	Materials	Adjusted R^2
SIC 2821	.323 (7.118)	.211 (.632)	.485 (3.036)	.304 (1.552)	.96

on capital and materials are not statistically significant at conventional confidence levels.

Using the estimated coefficients reported in Table C-2 and the result shown in Equation C.7, we derive a supply elasticity estimate of 3.76. Note that the calculation of statistical significance for the elasticity is not straightforward since it is a non-linear function of the production function coefficients. No attempt has been made to assess the statistical significance of the estimated elasticity.

Demand Equations

Table C-3 reports estimates of the derived demand equations for wet strength resin and DGEBPA. The reported coefficients are 2SLS estimates of the parameters of Equation C.10. We have also corrected the estimates of all three equations for first-order serial correlation using the Prais-Winston algorithm[51] and the two DGEBPA equations for heteroschedasticity.

[51] The Prais-Winston algorithm is similar to the more familiar Cochrane-Orcutt estimator. However, unlike the Cochrane-Orcutt method, the Prais-Winston algorithm does not skip the first observation and uses the full generalized least squares (GLS) transformation.

Table C-3

2SLS ESTIMATED DERIVED DEMAND COEFFICIENTS
(t-ratios in parentheses)

Industry	Own Price (β)	End-Product Price (β_e)
Wet strength resin	-.924 (4.363)	1.136 (1.023)
DGEBPA (in coatings and paints)	-1.474 (1.780)	.097 (.115)
DGEBPA (in sealants and adhesives)	-1.481 (2.620)	2.040 (2.445)

We have estimated the derived demand function for wet strength resin consistently with the approach described earlier in this appendix. The estimated own-price coefficient is correctly signed and highly significant. The estimated coefficient on the end-product price (SIC 2621) is correctly signed but not statistically significant.[52]

The estimated own-price coefficients for DGEBPA are sensitive to the instruments used in the two-stage procedure and to corrections for autocorrelated errors. As a result, it was necessary to modify the general approach described earlier in this appendix. Specifically, the estimated equation for DGEBPA used in coatings and paints includes only the cost index for variable inputs and includes a time trend variable as an explana-

[52] Note that we do not report adjusted R^2 for the derived demand equations. First, Basemann (1962) warns that low multiple correlation coefficients for simultaneous equation estimators are not evidence of poor fit or lack of joint significance of the set of explanatory variables. Second, the correction for autoregressive errors renders R^2 meaningless.

tory variable.[53] The estimated equation for DGEBPA used in sealants and includes both time and the variable cost index as instruments, but not the capital stock variable.

The estimated own-price coefficients are -1.474 and -1.481, respectively, for DGEBPA used in coatings and paints, and in sealants and adhesives. Accordingly, we adopt a mid-point demand elasticity of -1.5 for DGEBPA. We caution, however, that this estimate is not robust. As noted above, the estimates for DGEBPA are sensitive to the specification of instrumental variables and to corrections for autocorrelated errors.

We acknowledge the uncertainty in our estimate of demand elasticities for wet strength resins and especially for DGEBPA. Accordingly, we assess the sensitivity of our estimated economic impacts by reporting in Appendix D results corresponding to "low" and "high" demand elasticity cases. The low demand elasticities are -.50 and -.62, respectively, for wet strength resin and DGEBPA; the corresponding high demand elasticities are -1.34 and -3.10. The low and high demand elasticities are, respectively, minus and plus two standard deviations of the mid-point estimates.[54]

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[53] The estimated coefficient for the time trend variable is .468 and the associated t-ratio is 5.104.

[54] We use the standard error of the estimate for DGEBPA used in coatings and paints for the high demand elasticity case and the standard error for DGEBPA use in sealants and adhesives for the low demand elasticity case. This procedure causes us to use relatively higher demand elasticities for both cases, thus representing "worst" case scenarios.

APPENDIX D

SENSITIVITY ANALYSES

INTRODUCTION

This appendix presents the results of a sensitivity analysis that explores the degree to which the results presented earlier in this report are sensitive to estimates of demand elasticity.

SENSITIVITY ANALYSIS: DEMAND ELASTICITY

The "base case" results presented earlier in this report are based on demand elasticities of -1.50 for DGEBPA and -.92 for wet strength resin. Below, we report results for "low" and "high" demand elasticity cases. These alternative cases use the following values for demand elasticities:

- Low demand elasticity: -.62 for DGEBPA and -0.50 for wet strength resins.
- High demand elasticity: -3.10 for DGEBPA and -1.34 for wet strength resins.

The greater the elasticity of demand (in absolute value), the more consumers will reduce the quantity they purchase in response to a given change in price. Therefore, we expect that when we use a higher demand elasticity in the partial equilibrium analysis, the reduction in market output will be greater and the price change will be smaller than in the base case. Similarly, when we use a lower elasticity, we expect the change in price to be greater, and the change in market quantity to be smaller, relative to the base case.

Tables D-1 through D-4 present estimates of the primary economic impacts associated with the NESHAP for each of the two industry segments in the case of low and high demand elasticities. Tables D-1 and D-2 report results based on low demand elasticities and Tables D-3 and D-4 report results based on high demand elasticities.

In general, the results of the sensitivity analysis are consistent with the base case results presented earlier in this report. For the DGEBPA industry, no plant closures are predicted, and even in the high demand elasticity case, the estimated reduction in market output is just 0.12 percent. However, for the sensitivity analysis of the wet strength resin market, when a low elasticity of demand is employed, the plant closure predicted in the previous analysis is less probable. Also, when a "low" elasticity of demand is assumed, the impacts on domestic production, the value of domestic production, net exports, employment and energy are reduced. The estimated impacts of Option I on the wet strength resin industry are very small, even when a high elasticity of demand is assumed.

Table D-1

SENSITIVITY ANALYSIS: ESTIMATED PRIMARY IMPACTS ON THE DGEBPA MARKET WITH LOW ELASTICITY OF DEMAND

		Change in Value of Domestic Shipments		
Price Change (%)	Market Output Change (%)	($1,000 1992)	(%)	Plant Closures
.06	-.04	51	.01	.00

Note: Results are based on a demand elasticity of -.62.

Table D-2

SENSITIVITY ANALYSIS: ESTIMATED PRIMARY IMPACTS ON THE WET STRENGTH RESIN MARKET WITH LOW ELASTICITY OF DEMAND

			Change in Value of Domestic Shipments		
Regulatory Option	Price Change (%)	Market Output Change (%)	($1,000 1992)	(%)	Plant Closures
MACT Floor	4.60	-2.23	897	2.28	.02
Option I	0.24	-.12	48	.12	.38

Note: Results are based on a demand elasticity of -0.50

Table D-3

SENSITIVITY ANALYSIS: ESTIMATED PRIMARY IMPACTS ON THE DGEBPA MARKET WITH HIGH ELASTICITY OF DEMAND

		Change in Value of Domestic Shipments		
Price Change (%)	Market Output Change (%)	($1,000 1992)	(%)	Plant Closures
.04	-.12	-293	-.08	.00

Note: Results are based on a demand elasticity of -3.10

Table D-4

SENSITIVITY ANALYSIS: ESTIMATED PRIMARY IMPACTS ON THE WET STRENGTH RESIN MARKET WITH HIGH ELASTICITY OF DEMAND

Regulatory Option	Price Change (%)	Market Output Change (%)	Change in Value of Domestic Shipments ($1,000 1992)	(%)	Plant Closures
MACT Floor	3.86	-4.95	-505	-1.28	.84
Option I	.20	-.27	-27	-.07	.05

Note: Results are based on a demand elasticity of -1.34.

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TECHNICAL REPORT DATA

(Please read Instructions on reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-453/D-94-034		

4. TITLE AND SUBTITLE	5. REPORT DATE
Economic Impact Analysis of the Polymers and Resins II NESHAP	July 1994
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Emission Standards Division Research Triangle Park, NC 27711	10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. 68D10144
12. SPONSORING AGENCY NAME AND ADDRESS Director Office of Air Quality Planning and Standards Office of Air and Radiation U.S. Environmental Protection Agency Research Triangle Park, NC 27711	13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE EPA/200/04

15 SUPPLEMENTARY NOTES

16. ABSTRACT

An economic analysis of the industries affected by the Polymers and Resins II National Emissions Standard for Hazardous Air Pollutants (NESHAP) was completed in support of this proposed standard. The industries for which economic impacts were computed were the epoxy resins and wet strength resins industries.

The faciities in these industries must control epichlorohydrin emissions by the level of control required in the standard. Several types of economic impacts, among them product price changes, output changes, job impacts, and effects on foreign trade, were computed for the selected regulatory alternatives.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Control Costs Industry Profile Economic Impacts	Air Pollution control	

18 DISTRIBUTION STATEMENT	19. SECURITY CLASS *(Report)*	21. NO. OF PAGES
Release Unlimited	Unclassified	101
	20. SECURITY CLASS *(Page)* Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE