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ECONOMIC IMPACT ASSESSMENT OF A CHLOROFLUOROCARBON PRODUCTION CAP

Support Document, Section 6
Proposed Rule,
Toxic Substances Control Act

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Disclaimer

This document is a contractor's study done with the supervision and review of the Office of Pesticides and Toxic Substances of the U.S. Environmental Protection Agency. The purpose of the study was to evaluate the economic implications of a chlorofluorocarbon (CFC) production cap at 1980 levels in the United States.

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The study is not an official EPA publication. The document cannot be cited, referenced or represented in any court proceedings as a statement of EPA's view regarding the chlorofluorocarbon industry or the impact of the regulations implementing the Toxic Substances Control Act.

PREFACE

This Note projects the economic costs of a regulatory "cap" that would restrict total U.S. annual chlorofluorocarbon (CFC) production to the 1980 level. Alternative cost estimates reflect alternative hypotheses about U.S. industries' responses to higher CFC prices. The U.S. Environmental Protection Agency plans to use this analysis for CFC rulemaking during 1981.

EPA Contract 68-01-6236 supported this research. The analysis extends a major study of CFC regulation that Rand performed under earlier EPA Contracts 68-01-3882 and 68-01-6111. The earlier study compared alternative regulatory methods, and found that they vary not only in their economic implications but also in their potential effectiveness in preventing cumulative CFC use and emissions during the 1980s. In contrast, the present study examines a single policy--the production cap--which would prevent nearly 25 percent of cumulative CFC use over the decade.

Quantitative outcomes--costs to the U.S. economy as a whole and to the CFC-using industries--receive emphasis in this document. Underlying data sources and methodology receive a more cursory treatment in the introduction and an appendix. For a more detailed explanation, the reader may wish to consult three publications from the earlier CFC research project:

- A. R. Palmer et al., Economic Implications of Regulating Chlorofluorocarbon Emissions from Nonaerosol Applications, R-2425-EPA, June 1980.

- W. E. Mooz and T. H. Quinn, Flexible Urethane Foams and Chlorofluorocarbon Emissions, N-1472-EPA, June 1980.
- K. A. Wolf, Regulating Chlorofluorocarbon Emissions: Effects on Chemical Production, N-1483-EPA, August 1980.

For a summary of findings from the earlier research, see:

- A. R. Palmer et al., Economic Implications of Regulating Nonaerosol Chlorofluorocarbon Emissions: An Executive Briefing," R-2575-EPA, July 1980.

SUMMARY

Regulation that would limit annual chlorofluorocarbon (CFC) production to the 1980 level could cost the U.S. economy as much as $342 million (in discounted 1976 dollars) between now and the end of 1990. Costs will reach this level if firms and consumers adapt rather slowly to the higher prices caused by restricted CFC supplies. In that case, only well-known CFC-saving technologies would be implemented early in the decade. Firms would begin to exploit less common technologies only by mid-decade, and consumers would begin to avoid CFC-made products only by the end of the decade.

It is more likely, however, that both firms and consumers will exploit CFC-saving opportunities earlier in the decade. If so, costs due to regulation would accumulate to only $275 million.

In addition to the costs imposed on the economy as a whole, a CFC production "cap" could transfer considerable wealth from CFC-using industries and their customers to other parts of the economy. The wealth transfers could run as high as twelve times the costs estimated above.

Most CFC-using firms in business today should be able to cope successfully with the higher costs imposed by regulation. The principal exception could be firms making CFC-blown thermoformed polystyrene foams for packaging. If their customers switch to cardboard and paper when foam prices rise, several foam making firms would go out of business, laying off perhaps as many as two thousand workers, nationwide.

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I. INTRODUCTION

How much would it cost the U.S. economy to preclude increased chlorofluorocarbon (CFC) production beyond the 1980 level? The answer depends on how firms and consumers respond to the higher prices caused by restricted CFC supplies:

- At a minimum, we expect firms to implement several well-known CFC-saving technologies, such as CFC recycling and substitution of alternative chemicals.[1] By 1985, CFC prices would be high enough to make all these technologies economically attractive, and the annual cost of using them would reach $59.5 million (in 1976 dollars). After 1985, staying below the CFC production cap would require additional CFC-saving technologies or an end to market growth for consumer products made with CFCs.
- Some lesser-known CFC-saving technologies also exist, but their costs or effectiveness are uncertain. If these technologies prove to be relatively inexpensive, the cost of meeting the CFC cap would be lower in each year. For example, the 1985 cost might be only $25.4 million (in 1976 dollars). Using an expanded set of existing technologies would enable industries both to satisfy growing consumer demand for final products and

[1] We do not include CFC-22 substitution in refrigeration devices among the "well-known technologies" referenced here. Though CFC-22 substitution could, in principle, help meet the production cap, it would happen only at extraordinarily high CFC prices. Long before such prices were reached, we would expect some use of less well-known (and less costly) technologies and some consumer responses to higher final product prices.

to comply with the production restriction through 1989.

- Costs would be lower still if consumers could find good substitutes for CFC-made products as the cost of making them rises. With only modest consumer response, the 1985 cost might be as low as $21.6 million. In combination with existing technologies, consumer response would help to hold CFC use below the cap through 1990.
- If industry develops new technologies for conserving CFCs, the yearly costs could be lower still.

Plausible scenarios are ones in which existing technology plus consumer response satisfy the CFC production constraint in all years through 1990. Our most costly plausible scenario predicts the decade's cumulative costs (discounted to 1980 and measured in 1976 dollars) should not exceed $341.6 million. A reasonable estimate places these costs closer to $270 million.

But the CFC production cap could cost CFC-using firms and their customers much more than it costs the economy as a whole. When a firm buys additional resources for controlling CFC use--recycling equipment, for example--the whole economy loses the opportunity to use those resources for other purposes. The preceding cost estimates measure only these real resource costs. However, when the firm pays higher prices for the CFCs it still uses, the added expenditure by the firm ends up in someone else's pocket. There is no loss to the economy as a whole, but there is a transfer of wealth away from CFC-using firms and their customers.[2]

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[2] Who receives the wealth transfer depends on how the regulation is implemented. See Palmer et al. (1980), Sec. V.

Unless CFC regulation provides mechanisms for ameliorating wealth transfers, they will be very high. Like resource costs, the magnitude of transfer payments depends on how user industries and their customers respond to higher CFC prices. If responsiveness is minimal, transfers would amount to twelve times the policy's real resource costs. If industry and consumers are more responsive, estimated transfer payments will be lower--but still substantially greater than resource costs.

This Note performs three functions: First, it assesses the economic implications of a CFC production cap to help the U.S. Environmental Protection Agency plan and prepare its rulemaking actions. Second, it identifies the sources of uncertainty about future behavior by industries and consumers. Third, it demonstrates how those uncertainties influence estimates of CFC regulations' economic implications--and in so doing, illustrates how actions in one CFC-using industry can influence outcomes in other economic sectors.

To perform these functions, the Note examines alternative scenarios describing industry and consumer response under a CFC production cap. Section II shows outcomes if only well-known technologies are implemented; this is the highest-cost and most pessimistic scenario. Section III identifies the lower costs potentially achievable from also implementing some less well-known technologies. Together, the scenarios of Secs. II and III show how specific changes in assumptions alter outcome estimates. But since neither of the first two scenarios explains how the CFC market would equilibrate at the end of the decade, neither scenario is complete. Section IV combines and extends results from the preceding sections to generate several plausible overall scenarios. Of these, we examine Scenario V in detail because it is the highest-cost plausible scenario, and Scenario VI because it portrays reasonable expectations for actual market outcomes. Finally, Section V discusses policy effects on consumer prices, energy use, plant closures and worker unemployment, and competitive standing of small businesses.

Regulatory outcomes are estimated using the data and methodology developed in Palmer et al. (1980). The appendix of this Note summarizes the method and describes some computational improvements developed for the analysis reported here.

THE POLICY

In all scenarios, the regulation puts a cap on aggregate CFC supply at the 1980 level. Market forces allocate the available CFC supply among competing firms and industries.

For all scenarios, the cap is set at 341.0 million "weighted" pounds. To compute the cap, we estimated 1980 domestic sales (in pounds) of CFC-11, CFC-12, CFC-113, and CFC-502,[3] multiplied each estimate by its respective weighting factor in Table 1.1,[4] and set the

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[3] The cap also applies to the CFC-12 contained in R-500, a refrigerant used in chillers. Amounts of CFC-114 and CFC-115 used in the applications considered here are too small to have noticeable effects on our estimates.

[4] These weights differ from the ones used in Palmer et al. (1980). The earlier weights gave larger measures of weighted pounds for the same level of CFC production--and thus gave lower dollar figures for price increases per weighted pound. Consequently, although resource cost and transfer payment estimates can be compared between the two studies, weighted-pound measures of CFC use or emissions and "permit prices" are not comparable. For further explanation, see the appendix.

Table 1.1

CFC WEIGHTING FACTORS

Type of CFC	Weighting Factor (Weighted Pounds Per Pound of CFC)
CFC-11	1.00
CFC-12	0.79
CFC-113	0.77
CFC-502[a]	0.19

SOURCE: Factors for CFC-11, CFC-12, CFC-113, and CFC-22 were reported in EPA (1980). Remaining factor computed by Rand.

[a] CFC-502 is 51.2 percent CFC-115 and 48.8 percent CFC-22, by weight. The EPA weighting factors are 0.20 for CFC-115 and 0.18 for for CFC-22. Although CFC-22 is otherwise ignored in this study, its contribution to ozone-depletion potential is reflected in the CFC-502 weighting factor. This allows regulation of CFC-22 to be treated as an extension of our analysis without revising the CFC-502 data.

restriction equal to the weighted sum. In 1981 and beyond, the weighted sum of CFC sales cannot exceed the cap, but different mixes of CFCs can be sold in different years. Because the weights reflect differences among CFCs in ozone-depletion potential, the weighted restriction holds constant the annual U.S. contribution to ozone depletion.[5]

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[5] The earth's atmospheric ozone layer shields plant and animal life from harmful ultraviolet radiation. Current atmospheric chemistry models suggest that CFC emissions deplete ozone. EPA hopes to protect the ozone layer by preventing U.S. CFC use that leads to emissions. However, the U.S. currently contributes only about one-third of worldwide annual emissions and other countries must also control emissions to assure protection of the worldwide ozone layer. For further explanation, see Palmer et al. (1980) and NAS (1979).

Insofar as possible, the restriction modeled here matches the "economic incentive approach" described by the Environmental Protection Agency in its October notice of proposed rulemaking [EPA (1980)]. The EPA notice proposes to cap weighted production of all CFCs at the 1979 level. Because our data refer to sales rather than production, our analysis effectively ignores amounts produced for the CFC manufacturers' internal consumption. Moreover, our restriction based on estimated 1980 sales might exceed somewhat a restriction based on actual 1979 data.

The principal difference between the regulation modeled here and EPA's proposal results from our omission of CFC-22. If that is also restricted, users of CFC-22 would compete with other users for restricted CFC supplies--but, of course, the cap would be greater by the weighted amount of current CFC-22 production. If CFC-22 demand response resembles that for other CFCs, our estimates of regulation's cost will be accurate for users of the CFCs we examine; if CFC-22 demand is less or more responsive, our cost estimates will be too low or too high, respectively.

CFC-USING INDUSTRIES

We estimate regulatory outcomes for several user categories and subcategories:[6]

- Flexible Foams: Makers of foams for cushioning using CFC-11 blowing agents, as in furniture, bedding, and carpet underlay.

[6] For more details, see Palmer et al. (1980).

- Solvents: Industrial users of CFC-113. The largest subcategory is use for cleaning and drying, principally in the electronics industry. "Other" uses include dry cleaning, refrigeration, and several other specialized applications.
- Rigid Foams: Makers of CFC-11 and CFC-12 insulation; makers of CFC-12 thermoformed polystyrene (TPS) packaging materials; and makers of other CFC-11 and CFC-12 noninsulating rigid foams.
- Mobile Air Conditioning (MAC): Makers and servicers of automobile air conditioning systems using CFC-12 refrigerant.
- Retail Food Refrigeration: Makers and servicers of food store refrigeration devices using CFC-12 and CFC-502 refrigerants.
- Chillers: Makers and servicers of industrial and commercial air conditioning systems using various CFC refrigerants, principally CFC-12.
- Home Refrigeration: Makers and servicers of refrigerators and freezers using CFC-12 refrigerant.
- Miscellaneous: Users of liquid fast freezing systems for food freezing; makers of sterilants for medical supplies; many other very small users of CFCs.

As background, Table 1.2 reports estimated CFC use, in CFC pounds and weighted pounds, by user category. The 1980 data entered the calculation of the regulatory restriction. The 1990 data provide a baseline against which to measure regulation's limitation on use.

Table 1.2

PROJECTED PURCHASES OF CFC-11, CFC-12, CFC-113, AND CFC-502 IN THE ABSENCE OF REGULATION, BY USER CATEGORY: 1980 AND 1990

User Category	Purchases 1980 (millions of CFC pounds)	Purchases 1990 (millions of CFC pounds)	Purchases 1980 (millions of weighted pounds)	Purchases 1990 (millions of weighted pounds)
Flexible foams	46.8	71.5	46.8	71.5
Solvents[a]				
Cleaning and drying	54.1	94.5	41.7	72.8
Other	24.2	40.6	18.6	31.3
Rigid foams				
Insulation[b]	73.8	164.3	72.3	161.0
TPS packaging	14.5	22.6	11.5	17.9
Other noninsulation[c]	19.2	38.2	17.1	34.0
Mobile air conditioning				
Manufacturing	38.0	42.5	30.0	33.6
Servicing	60.3	82.3	47.6	65.0
Home refrigeration	7.1	9.4	5.6	7.4
Retail food refrigeration				
CFC-12	10.8	10.1	8.5	8.0
CFC-502	11.9	15.3	2.3	2.9
Chillers[d]	14.9	21.4	13.7	21.6
Miscellaneous[e]	31.6	69.6	25.3	55.7
TOTAL[f]	407.2	682.3	341.0	582.7

SOURCE: Palmer et al. (1980).

[a] Estimated 1990 solvents use differs from the source document. See appendix.

[b] Includes CFC-11 in rigid urethane and CFC-12 in extruded polystyrene board. On average, CFC-11 accounts for 88 percent of the weighted totals.

[c] CFC-11 is 54 percent of the weighted totals. The remainder is CFC-12.

[d] CFC-11 is 67 percent of the weighted totals. The remainder is CFC-12.

[e] CFC-12 is 94 percent of the weighted totals. The remainder is CFC-11.

[f] CFC use reported here exceeds the source document's data by inclusion of CFC-502.

MEASURING PRICES AND COSTS

In the absence of regulation, we expect most CFC prices to remain roughly constant in real terms.[7] Table 1.3 reports our estimated 1980 prices (in 1976 dollars). These form a baseline against which to compare CFC prices under regulation.

Although the production cap policy will raise different CFC prices by different amounts, the annual price increment per weighted pound will be the same for all the regulated CFCs. We call this price increment a "permit price." It is the price users would pay to buy a permit allowing them to purchase one weighted pound of any CFC, provided the CFC

Table 1.3

ESTIMATED BULK PRICES FOR VIRGIN CFCs, 1980

CFC	Bulk Rate per CFC Pound (in 1976 dollars)
CFC-11	$0.34
CFC-12	0.41
CFC-113	0.60
CFC-502	1.11

SOURCES: These estimates derive from the 1976 price estimates reported in Palmer et al. (1980), Table 3.5. The same source document explains the 1980 price estimate for CFC-113 and notes that this price is expected to vary with C-113 production levels. All other prices would be expected to remain constant in real terms through 1990 in the absence of regulation. See the appendix.

[7] That is, we would expect CFC prices to maintain approximately the same levels relative to one another, to substitute chemicals, and to chemical-using or recovery equipment. Though relative price changes might occur, they cannot be predicted reliably. An exception is CFC-113. Its price is expected to vary inversely with changes in CFC-113 production due to economies of scale. See the appendix.

manufacturers continue to charge the baseline prices. However, if permits are not issued, we would expect the CFC manufacturers' prices to rise by the permit price amount. In short, the permit price is a useful summary statistic for measuring CFC price adjustments under regulation.

The permit price as an economic concept receives attention in the appendix, but computations involving permit prices deserve a brief preliminary explanation. To convert the permit price to the price increment per CFC pound, multiply by the appropriate weighting factor in Table 1.1. To obtain the total price a user pays per CFC pound in any year, add the baseline price to the converted permit price.

Throughout this report, prices and costs are stated in 1976 dollars. This emphasizes the fact that the 1980 data shown herein come from prior projections rather than direct observation. Measuring costs in 1976 dollars also facilitates comparison between this document's results and those for other policy options analyzed in Palmer et al. (1980). Finally, using 1976 dollars avoids the ticklish problem of selecting an appropriate inflation factor. The proper factor would reflect price changes for chemical substitutes for CFCs, CFC-saving machinery and equipment, and other producer commodities purchased by CFC-using industries. According to the Survey of Current Business (1977, 1980), prices for all producer commodities rose about 45 percent from 1976 to mid-1980. Prices rose by somewhat more--about 50 percent--for all industrial chemicals and by somewhat less--about 40 percent--for all machinery and equipment. These figures provide a rough guide for updating the 1976 data reported below.

II. A HIGH-COST SCENARIO

> Scenario I: CFC-using industries respond to rising CFC prices only by exploiting more fully the CFC-saving technologies already in limited use. Firms recover and recycle CFCs, improve their production equipment, make revisions in product design, and turn to alternative chemicals where feasible. Higher production costs translate into higher final product prices, but final product sales nevertheless grow approximately at the rates anticipated before the CFC price increases. Consequently, firms now using CFCs remain in business and new firms enter final product markets.

The scenario is not farfetched--provided CFC prices do not rise too high or for too long. If CFC prices rise high enough, they or the costs of CFC-saving technologies will translate into substantially increased production costs and output prices. Customers then face strong incentives to select alternative final products. Meanwhile, CFC-using firms have reason to search for new low-cost technologies. If the search is unsuccessful and consumer demand weakens, fewer new firms will enter the final product markets and some existing CFC users might even go out of business. And even if CFC prices rise slowly--but for long enough--industry eventually might discover new ways to avoid heavy CFC use. Thus, if the scenario differs from reality, it most likely will do so at high CFC prices, in more distant years.

To describe behavior under a CFC production restriction, the scenario cannot be used beyond 1985. By that year, expanded rivalry for limited CFC supplies would raise the permit price to $1.70. Beyond 1985, the scenario is incomplete because it provides no mechanisms to clear the CFC market--to bring quantities demanded into line with restricted supplies--at any price. For this reason, the scenario is implausible beyond 1985.

For the years through 1985, the scenario's regulatory outcomes probably represent a "worst case" prediction. The scenario predicts robust growth in CFC-using applications. If, contrary to the scenario, consumers turn to alternative products or firms develop new technologies, less CFC would be purchased at each price. Consequently, CFC prices would not have to rise as high or as fast to keep purchases in line with the restricted supply. And, if the scenario overestimates the CFC price, it also overestimates resource costs and transfer payments.

Later sections of this report offer scenarios that do explain how the CFC market could clear throughout the next decade. Several market-clearing mechanisms surely exist, but which will prove most important is uncertain. Scenario I provides a useful backdrop for exploring various hypotheses about how the CFC market will clear. Thus, Scenario I represents a foundation upon which to build the market-clearing scenarios.

PRICE OUTCOMES

Assuming the foregoing scenario applies, Table 2.1 estimates equilibrium price outcomes (in real terms, 1976 dollars) for 1980 through 1985. The CFC prices are the totals users would pay per CFC pound, both to purchase CFCs and to buy permits if EPA issues them. If CFC manufacturers' prices (in real terms) remain at the levels in Table 1.3, users would pay the permit prices listed in Table 2.1. Since CFC production is not restricted in 1980, the CFC price is unaffected and the permit price is zero.

Price increases reflect the CFC weighting factors. With its relatively large weight, CFC-11 experiences the most dramatic price rises--43 percent per year, on average. In contrast, the least weighted CFC--CFC-502--shows relatively modest price increases, averaging only five percent per year. As intended, a policy that weights CFCs according to their ozone depletion potential penalizes use of some CFCs more than others.

Table 2.1

ANNUAL EQUILIBRIUM PERMIT PRICES UNDER
THE HIGH-COST SCENARIO
(In $ 1976)

	Total User Price Per CFC-Pound[a]				
Year	CFC-11	CFC-12	CFC-113	CFC-502	Permit Price[b]
1980	$0.34	$0.41	$0.60	$1.11	$0.00
1981	0.44	0.49	0.68	1.13	0.10
1982	0.65	0.65	0.86	1.17	0.31
1983	0.98	0.92	1.15	1.23	0.64
1984	1.49	1.32	1.57	1.33	1.15
1985	2.04	1.75	2.00	1.43	1.70

[a] Includes user payments for permits, if issued. Otherwise, the total user price is assumed paid to the CFC manufacturers.

[b] Assumes manufacturers' CFC prices are as indicated by Table 1.3 for all years. A permit entitles the holder to use one weighted pound of any CFC.

ADJUSTMENTS IN CFC USE

A production quota prevents emissions by preventing growth in aggregate annual CFC use. Absent regulation, weighted CFC use would accumulate to 2.3 billion pounds between 1980 and the end of 1985. Thus, between 1980 and the end of 1985, the policy would prevent about 13 percent of cumulative use that would otherwise have occurred.

The production quota holds annual use constant only in the aggregate. Some individual uses grow, while others decline commensurately. The annual mix of CFC use changes because final product demands grow at different rates and because options for conserving CFCs differ among users.

Table 2.2 shows patterns of expected use adjustments by year and user category. Annual use actually declines in flexible foams, solvents, rigid packaging foams (TPS), and CFC-12 retail food refrigeration. In mobile air conditioner servicing, CFC-12 annual use grows, but a little more slowly than it would in the absence of regulation. And CFC-502 use for retail food refrigeration grows noticeably as that CFC becomes a more heavily used substitute for CFC-12. Under this section's scenario, CFC purchases for the remaining categories--insulation and other nonpackaging rigid foams, mobile air conditioner manufacturing, chillers, home refrigeration, and miscellaneous uses--all grow at the same rates they would have in regulation's absence. The last two columns in Table 2.2 summarize policy's effects on use. Whereas the penultimate column shows cumulative use under the production cap, the final column shows what cumulative use would have been without regulation.

Table 2.2

PROJECTED CFC USE BY USER CATEGORY,
SCENARIO I: 1980-1985

(In millions of weighted pounds)

User Category/ CFC	Use Under Regulation 1980	1981	1982	1983	1984	1985	Cumulative	Unregulated Cumulative Use
Flexible foam	46.8	35.7	31.6	27.1	17.1	11.0	169.3	312.8
Solvents	60.3	61.0	56.2	49.7	47.5	45.4	320.1	416.5
Rigid foam								
TPS	11.5	11.5	10.8	8.9	7.3	0.8	50.8	77.2
Insulation	72.3	78.3	84.9	91.9	99.6	107.9	534.9	534.9
Other	17.1	18.3	19.6	21.1	22.5	24.1	122.7	122.7
Mobil air conditioning								
Manufacturing	30.0	30.3	30.7	31.0	31.4	31.7	185.1	185.1
Servicing	47.6	49.0	50.3	51.5	52.4	53.3	304.1	309.2
Retail food refrigeration								
CFC-12	8.5	6.5	2.9	2.5	2.1	1.8	24.3	50.1
CFC-502	2.3	2.8	3.4	3.5	3.6	3.7	19.3	14.7
Chillers	13.7	14.3	15.0	15.7	16.4	17.2	92.3	92.3
Home refrigeration	5.6	5.8	5.9	6.1	6.3	6.4	36.1	36.1
Miscellaneous	25.3	27.4	29.6	32.1	34.7	37.5	186.6	186.5
TOTAL[a]	341.0	341.0	341.0	341.0	341.0	341.0	2,046.0	2,338.6

[a] Detail might not sum to totals due to rounding.

RESOURCE COSTS

As CFC prices rise after 1980, resource costs rise also. The price increases encourage firms to adopt CFC-saving technologies. Firms' expenditures for this purpose measure the value of resources diverted from other uses. Under this section's scenario, annual resource costs would approach sixty million dollars by the end of 1985.[1]

As Table 2.3 shows, not all users pay resource costs. Some firms do not have readily available alternative technologies--at least under the assumptions of this scenario. Included in this group are makers of rigid foam insulation, mobile air conditioners, chillers, home refrigeration devices, and miscellaneous CFC-using products. In addition, some firms do not implement technological alternatives in the policy's early years. These firms wait until CFC prices rise substantially before making an adjustment. Thus, for example, initial years' resource costs are especially low for mobile air conditioner servicers.

In the aggregate, discounted resource costs under this section's scenario accumulate to 71 million dollars by the end of 1985. Most of the costs arise in the flexible foam, solvents, and TPS (packaging foam) categories.

TRANSFER PAYMENTS

Whereas resource costs arise from firms' efforts to avoid CFCs, transfer payments arise because firms pay more for CFCs they continue to use. Suppose, for example, a firm begins recycling CFC-11 when its price rises by one dollar, thus reducing CFC use from 100 to just 80

[1] For further explanation of resource costs, see the appendix.

Table 2.3

PROJECTED RESOURCE COSTS BY USER CATEGORY,
SCENARIO I: 1980-1985

(In $ million 1976)

	Resource Costs					
User Category	1981	1982	1983	1984	1985	Cumulative[a]
Flexible foam	0.7	2.1	4.7	15.2	23.8	29.9
Solvents	0.1	2.0	6.4	11.4	19.0	25.2
Rigid foam						
TPS	0.0[b]	0.3	1.5	3.2	13.9	11.7
Insulation	---	---	---	---	---	---
Other	---	---	---	---	---	---
Mobile air conditioning						
Manufacturing	---	---	---	---	---	---
Servicing	0.0[b]	0.1	0.3	0.9	2.0	2.0
Retail food refrigeration	0.1	0.7	0.8	0.8	0.9	2.4
Chillers	---	---	---	---	---	---
Home refrigeration	---	---	---	---	---	---
Miscellaneous	---	---	---	---	---	---
Total	0.9	5.1	13.5	31.4	59.5	71.0

[a]Sum of annual resource costs, discounted to 1980 at 11 percent.

[b]Positive, but less than 0.1 after rounding.

pounds. The recycling expense shows up as a resource cost in Table 2.3. The additional 80 dollars paid for CFCs still in use represents a transfer payment. If the government sells permits at one dollar apiece, the 80 dollars ends up in the U.S. Treasury. If, instead, the CFC producers raise their CFC-11 price by one dollar, the 80 dollars is added to producer revenue. But either way, user industries pay the added expense.[2]

Estimated transfer payments are especially high under the assumptions of Scenario I. According to the scenario, only CFC-conserving technologies with well-known costs and effectiveness are ever employed by CFC-using firms. Many firms continue to use CFCs in large quantities despite the production quota. Consequently, CFC prices must rise substantially to clear the market, and many firms make large transfer payments.

Most user categories would face rapidly increasing transfer payments throughout the period, as Table 2.4 indicates. The exceptions are flexible foams, where methylene chloride substitution and CFC recovery and recycle would be pervasive by 1985, and rigid packaging foams, where pentane substitution also becomes pervasive.

In all categories, cumulative transfer payments exceed cumulative resource costs. For some users--those who make TPS rigid packaging foams--transfer payments are just 22 percent larger than resource costs. But for other categories--those with zero resource costs--transfers are

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[2] For further explanation of transfer payments, see the appendix. Ways to mitigate transfer payments under a production quota are the subject of a research task currently underway at the Rand Corporation under EPA contract No. 68-01-6236.

Table 2.4

PROJECTED TRANSFER PAYMENTS BY USER CATEGORY, SCENARIO I: 1980-1985

(In $ million 1976)

User Category	TRANSFER PAYMENTS 1981	1982	1983	1984	1985	Cumulative[a]
Flexible foam	3.7	9.8	17.3	19.7	18.7	48.1
Solvents	6.3	17.6	31.9	54.5	77.2	125.0
Rigid foam						
TPS	1.2	3.4	5.7	8.4	1.4	14.3
Insulation	8.1	26.5	58.9	114.3	183.1	255.8
Other	1.9	6.1	19.6	25.8	40.9	57.8
Mobile air conditioning						
Manufacturing	3.1	9.6	19.9	36.0	53.9	80.8
Servicing	5.1	15.7	33.0	60.2	90.5	134.7
Retail food refrigeration	1.0	2.0	3.8	6.5	9.3	15.1
Chillers	1.5	4.7	10.1	18.9	29.2	42.2
Home refrigeration	0.6	1.9	3.9	7.2	10.9	16.1
Miscellaneous	2.8	9.3	20.5	39.8	63.7	89.1
TOTAL[b]	35.1	106.5	218.4	391.3	578.8	879.1

NOTE: Transfer payment estimates are calculated prior to rounding the permit price data to the nearest cent.

[a] Sum of annual expenses, discounted to 1980 at 11 percent.

[b] Detail might not sum to totals due to rounding.

the only expense imposed by regulation. In the aggregate, cumulative transfer payments are twelve times as high as cumulative resource costs. For each dollar spent to avoid CFC use, user industries together would spend twelve dollars to buy CFC permits or otherwise pay higher CFC prices due to regulation.

III. AN EXPANDED RESPONSE SCENARIO

> Scenario II: In response to rising CFC prices, CFC-using industries not only exploit technologies already in limited use, but also search out and implement existing technologies having uncertain costs or effectiveness. On average, the added technologies prove to be as effective--and no more costly--than the better known ones. The technologies make products more costly, but final product sales nevertheless grow at about the rates expected prior to regulation. CFC-using firms remain in business and new ones enter the growing final product markets.

In contrast with Scenario I, Scenario II recognizes that several CFC-saving technologies of uncertain cost or effectiveness could be drawn into use by rising CFC prices.[1] Foods currently frozen by the liquid fast freezing process could be frozen using non-CFC refrigerants. Hospital supplies might be sterilized with recycled CFC-12--or without the CFC. Mobile air condition systems might be redesigned to require smaller initial refrigerant charges. Rigid foams for such products as marine flotation devices might be "blown" with other chemicals. And some solvent applications other than cleaning and drying might prove amenable to recycling or chemical substitution. Many of these options are known to be technologically feasible; indeed, some have been used historically. Unlike Scenario I, Scenario II assumes these options would come into play as readily and effectively under CFC regulation as the options we know more about.

More precisely, Scenario II analyzes behavior by three user groups. By reference to the categories and subcategories identified in Table 1.2, the three groups are:

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[1] For a detailed description of such technologies, see Palmer et al. (1980).

Group A: Flexible foams; solvent cleaning and drying; TPS rigid foams; mobile air conditioner servicing; retail food refrigeration.

Group B: Rigid foam insulation; chillers; home refrigeration.

Group C: "Other" solvents; "other noninsulation" rigid foams; mobile air conditioner manufacturing; miscellaneous.

Group A's user categories have predictable technical responses to rising CFC prices. For this group, CFC use should exhibit a marked degree of price response. For example, in both Scenarios I and II, we expect Group A's use to decline by about 55 percent if the permit price reaches $2.81.[2]

In contrast, Group B is technologically unresponsive to higher CFC prices in both Scenarios I and II. CFC-conserving technical options for Group B do not now exist or are so costly and time-consuming to implement they would not become important before the end of the decade. Unless consumers refuse to pay higher prices for Group B's products--a possibility excluded by Scenario II--CFC use will be unaffected by regulation.

Finally, all other user categories belong to Group C. For this group, technical options exist but are too rarely used for us to know precisely how costly or effective they are. Scenario I assumes Group C firms are like those in Group B--unresponsive. Scenario II assumes

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[2] The most costly of the well-known technological options we examined in Scenario I would be induced at an estimated permit price of $2.81.

Group C firms are proportionately just as responsive to permit prices as Group A.[3]

How plausible is Scenario II? What we know about CFC-saving technologies in Group C tells us a 55 percent use reduction is credible if CFC prices rise by as much as $2.81 per weighted pound. But because we know little about the costs of Group C's technologies, we cannot be sure how extensively they will be used at lower CFC prices. Scenario II could be overly optimistic about Group C's response to small price increases, and thus might underestimate resource costs in the policy's early years.

While Scenario II might prove optimistic about the early years of regulation, the scenario is surely too pessimistic about later years. Even including Group C's technologies does not allow technology alone to achieve the 1990 use restriction. Like Scenario I, Scenario II ignores consumer responses and new technologies that would help achieve the 1990 policy target.

Despite its possible shortcomings, Scenario II demonstrates a notable characteristic of production quota policy: The availability of low-cost technologies in a few user categories makes the policy less costly to everyone. CFC-saving technologies remove some of the demand pressure on prices. Consequently, prices rise more slowly in Scenario II than in Scenario I. High-cost technologies do not have to be

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[3] Greater Group C responsiveness would lower costs below Scenario II's outcomes. Suppose, for example, Group C stops using CFCs as soon as the permit price reaches $0.01. Under this purely exploratory assumption, total cumulative resource costs reach only $19.2 million, and total cumulative transfer payments reach just $236.4 million. The permit price would rise slowly to $0.84 in 1990.

introduced as soon. And in each year, both resource costs and annual transfer payments are lower.

CFC PRICE OUTCOMES

Comparing Tables 2.1 and 3.1 reveals the price implications of Scenario II's expanded response assumption. Prices rise much more slowly in the early part of the decade. By 1985, Scenario II's permit price reaches only 67 cents, compared with $1.70 for Scenario I. Extremely high permit prices arise in Scenario II, but only near the end of the decade--beyond the limit of Scenario I.

Table 3.1

ANNUAL EQUILIBRIUM PERMIT PRICES UNDER THE EXPANDED RESPONSE SCENARIO II

(In $ 1976)

	Total User Price Per CFC Pound[a]				
Year	CFC-11	CFC-12	CFC-113	CFC-502	Permit Price[b]
1980	$0.34	$0.41	$0.60	$1.11	$0.00
1981	0.40	0.46	0.64	1.12	0.06
1982	0.51	0.54	0.73	1.14	0.17
1983	0.64	0.65	0.85	1.17	0.30
1984	0.79	0.77	0.99	1.20	0.45
1985	1.01	0.94	1.19	1.24	0.67
1986	1.30	1.17	1.43	1.29	0.96
1987	1.51	1.33	1.60	1.33	1.17
1988	1.91	1.65	1.94	1.41	1.57
1989	2.69	2.27	2.59	1.56	2.35

[a] Includes user payments for permits, if issued. Otherwise, the total user price is assumed paid to the CFC manufacturers.

[b] Assumes CFC sales prices are as indicated in Table 1.3. A permit entitles the holder to use one weighted pound of any regulated CFC.

ADJUSTMENTS IN CFC USE

Because Scenario II extends further into the future than Scenario I, Table 3.2 shows a larger cumulative effect on aggregate CFC use than does Table 2.2. Relative to unregulated outcomes, the policy prevents 23 percent of cumulative use by the end of 1989. Of course, between 1981 and 1985, Scenarios I and II show the same cumulative prevention. But in Scenario II, we can observe annual prevention for later years as well, reaching 40 percent in 1989. The regulatory policy is the same for either scenario, but Scenario II's outcomes are observable for a longer period.

For years when both scenarios yield estimates, Scenario II differs from Scenario I in user category outcomes. Compare 1985 use in Table 3.2 with the end-year of Table 2.2. Flexible foams, cleaning and drying solvents, rigid foam packaging (TPS), and mobile air conditioner servicing all use more CFCs under Scenario II. The reason: Under Scenario II's expanded response assumption, "other" solvents, "other" rigid foam, mobile air conditioner manufacturing, and miscellaneous user categories all use less CFCs. Implementation of CFC-saving technologies across more user categories spreads the burden of meeting the overall use restriction.

Between 1981 and 1989, five of Table 3.2's user categories show marked growth. Three are members of Group B--user categories that will grow despite higher CFC prices. In addition, mobile air conditioner servicing--a price-responsive member of Group A--grows because increased CFC recycling does not offset growth in final product demand. Finally, CFC-502 use in retail food refrigeration grows because it is a less

Table 3.2

PROJECTED CFC USE BY USER CATEGORY, SCENARIO II: 1980-1989
(In millions of weighted pounds)

	Use Under Regulation											
											Cumulative	
User Category	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Regulated	Unregulated
Flexible foam	46.8	40.4	36.3	34.1	30.6	29.1	23.8	16.0	12.6	13.1	282.8	570.4
Solvents	60.3	60.6	59.6	56.3	52.7	47.6	45.1	44.0	40.5	35.5	502.2	780.5
Rigid foam												
TPS	11.5	11.7	11.6	11.4	10.8	9.4	8.6	8.2	5.6	0.0	88.8	141.4
Insulation	72.3	78.3	84.9	91.9	99.6	107.9	116.9	126.6	137.2	148.6	1064.2	1064.2
Other	17.1	17.1	17.0	16.8	16.7	16.3	15.9	15.3	14.7	13.9	160.8	237.4
Mobile air conditioning												
Manufacturing	30.0	28.3	26.5	24.9	23.2	21.5	19.7	18.0	16.3	14.6	223.0	315.7
Servicing	47.6	49.0	50.5	51.9	53.3	54.7	56.0	57.4	58.5	59.5	538.4	549.9
Retail food refrigeration												
CFC-12	8.5	7.3	4.9	2.5	2.1	1.8	1.5	1.3	1.1	0.9	31.9	82.5
CFC-502	2.3	2.6	3.3	3.5	3.7	3.8	3.9	4.0	4.1	4.2	35.4	25.6
Chillers	13.7	14.3	15.0	15.7	16.4	17.2	18.0	18.8	19.7	20.6	169.4	169.4
Home refrigeration	5.6	5.8	5.9	6.1	6.3	6.4	6.6	6.8	7.0	7.2	63.7	63.7
Miscellaneous	25.3	25.5	25.6	25.7	25.7	25.4	25.0	24.4	23.6	22.7	248.9	370.3
TOTAL[a]	341.0	341.0	341.0	341.0	341.0	341.0	341.0	341.0	341.0	341.0	3,410.0	4,371.6

[a]Detail may not sum to totals due to rounding.

heavily weighted CFC that can economically be substituted for CFC-12 when CFC prices rise.[4]

Two user categories virtually eliminate CFC use by the end of 1989 in this scenario. Makers of thermoformed polystyrene sheet (TPS rigid foam) switch to pentane at high CFC prices. Similarly, much of the CFC-12 use in retail food refrigeration is replaced by CFC-502. In both cases, Scenario II assumes products are made by the same firms before and after regulation, but regulation induces chemical substitution.

RESOURCE COSTS AND TRANSFER PAYMENTS

According to Table 3.3, Scenario II substantially modifies Scenario I's estimated resource costs. When both scenarios yield annual estimates, total annual resource costs are lower in Scenario II. In 1985, for example, Scenario II's total is less than half as high as Scenario I's total. Scenario II also distributes resource costs among more user categories. Flexible foams, solvents, TPS rigid foams, and MAC servicing all generate much lower annual resource costs under Scenario II; Group C categories generate higher annual resource costs than in Scenario I.

Scenario II also shows rising annual resource costs beyond 1985. Because a longer time period is observable under Scenario II, all the cumulative resource cost data in Table 3.3 exceed their counterparts from Table 2.3.

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[4] Price-induced CFC-502 substitution for CFC-12 in retail food refrigeration results because the policy's CFC weighting creates incentives to substitute less ozone-depleting CFCs for others.

Table 3.3

PROJECTED RESOURCE COSTS BY USER CATEGORY, SCENARIO II: 1980-1989
(In $ million 1976)

	Resource Costs									
User Category	1981	1982	1983	1984	1985	1986	1987	1988	1989	Cumulative[a]
Flexible foam	$0.3	$0.8	$1.8	$3.6	$5.4	$11.1	$21.3	$27.0	$28.2	$46.7
Solvents	0.1	0.6	2.2	4.8	9.6	14.6	19.6	29.1	44.8	58.5
Rigid foam										
TPS	0.0[b]	0.1	0.3	0.7	1.8	2.9	3.7	8.2	18.2	15.8
Insulation	-	-	-	-	-	-	-	-	-	-
Other	0.0[b]	0.2	0.5	1.0	2.0	3.4	5.4	8.0	11.8	14.9
Mobile air conditioning										
Manufacturing	0.1	0.3	0.8	1.4	2.6	4.2	6.4	8.9	12.3	17.3
Servicing	0.0[b]	0.0[b]	0.1	0.1	0.3	0.7	1.1	2.0	3.5	3.4
Retail food refrigeration	0.0[b]	0.3	0.8	0.8	0.9	0.9	0.9	0.9	0.9	3.6
Chillers	-	-	-	-	-	-	-	-	-	-
Home refrigeration	-	-	-	-	-	-	-	-	-	-
Miscellaneous	0.1	0.3	0.8	1.6	3.1	5.4	8.6	12.9	19.1	23.8
TOTAL	0.6	2.5	7.1	14.0	25.4	43.0	66.9	97.1	138.7	184.0

[a]Sum of annual resource costs, discounted to 1980 at 11 percent.

[b]Resource costs positive, but less than 0.1 after rounding.

Table 3.4

PROJECTED TRANSFER PAYMENTS BY USER CATEGORY, SCENARIO II: 1980-1989
(In $ million 1976)

User Category	Transfer Payments 1981	1982	1983	1984	1985	1986	1987	1988	1989	Cumulative[a]
Flexible foam	2.6	6.3	10.2	13.7	19.5	23.0	18.7	19.8	30.9	77.4
Solvents	3.9	10.3	16.8	23.5	31.9	43.4	51.4	63.8	83.5	166.9
Rigid foam										
TPS	0.7	2.0	3.4	4.8	6.3	8.3	9.6	8.8	0.0	24.6
Insulation	5.0	14.7	27.4	44.5	72.3	112.5	148.0	215.9	349.7	470.6
Other	1.1	3.0	5.0	7.4	10.9	15.3	18.0	23.2	32.9	58.2
Mobile air conditioning										
Manufacturing	1.8	4.6	7.4	10.4	14.4	19.0	21.1	25.7	34.4	71.1
Servicing	3.1	8.8	15.5	23.8	36.7	53.9	67.1	92.1	140.0	214.5
Retail food refrigeration	0.6	1.4	1.8	2.6	3.7	5.2	6.2	8.2	12.2	21.0
Chillers	0.9	2.6	4.7	7.3	11.5	17.3	22.0	31.0	48.6	70.4
Home refrigeration	0.4	1.0	1.8	2.8	4.3	6.4	8.0	11.0	16.9	25.5
Miscellaneous	1.6	4.4	7.7	11.5	17.0	24.0	28.5	37.2	53.3	91.9
TOTAL[b]	21.8	59.2	101.8	152.3	228.5	328.2	398.6	536.7	802.3	1,292.0

NOTE: Transfer payments are estimated prior to rounding permit price data to the nearest cent.

[a] Sum of annual transfer payments, discounted to 1980 at 11 percent.

[b] Detail may not sum as totals due to rounding.

Table 3.4 shows that Scenario II's transfer payment estimates also differ from those of Scenario I. Total annual transfer payments are lower in Scenario II because CFC prices are lower in each year. In addition, Group C users have lower annual transfer payments because their use of CFC-saving technologies in Scenario II allows them to avoid some CFC expenditures.

Scenario II's cumulative transfer payments are higher than in Scenario I. This merely reflects the longer period observable under Scenario II.

IV. MARKET-CLEARING SCENARIOS

Neither of the preceding sections' scenarios is complete. Scenario I seems sensible for the first few years, but cannot be extended beyond 1985. Scenario II reasonably predicts expanded user response in the mid-decade, but cannot be extended beyond 1989. Neither scenario provides sufficient mechanisms to clear the CFC market in all years of the policy.

To be plausible, a scenario should allow the CFC market to clear every year. Historically, economic markets have adjusted even to dwindling supplies of precious nonrenewable resources. The CFC regulation studied here does not eliminate CFCs--it merely eliminates their growth. Therefore, it is implausible to suppose the CFC market will not clear--that demand will not equilibrate with supply at any price.

LIKELY SOURCES OF ADDED RESPONSE

Scenario II almost clears the 1990 market. At a permit price of $2.81--where the most costly analyzed technology would come into use--Scenario II predicts 1990 aggregate CFC demand for 356.7 million weighted pounds. This figure exceeds the production cap by merely 15.7 million--less than five percent. A modest degree of consumer response or a few added technological responses would extend Scenario II through 1990.

Consumer response to higher final product prices will surely help reduce CFC demand. Contrary to the assumptions in Scenarios I and II, consumers purchase fewer products at high prices than at low ones.

Because regulation makes CFC-made products more expensive, fewer will be sold than Scenarios I and II assume. And lower final product sales implies less CFC use.

Consumer response will affect some user industries more than others. Home refrigerator and freezer sales, for example, should hardly be affected. CFCs contribute so little to total production costs that even high CFC prices will not cause much change in refrigerator or freezer prices; and consumers cannot easily store perishables without refrigeration. Also, industries that substitute other chemicals for CFCs (or otherwise avoid much CFC use) become less subject to consumer response. For example, once a type of flexible foam is blown with methylene chloride it becomes immune to further CFC price increases--and its purchasers will not face any further foam price increases due to CFC regulation. But there are some CFC-using industries susceptible to consumer responses. They will be greatest for products that: (a) require a fixed amount of CFC per unit; (b) use enough CFC per unit for CFC price changes to affect production costs noticeably; and (c) have good substitute products available to consumers.

According to this reasoning, the flexible foams still made with CFCs at the 1990 permit price of $2.81 should experience some consumer response. Under Scenario II, these foams use 13.7 million weighted pounds of CFC-11 in 1990, mostly in molded and slabstock applications that do not appear amenable to methylene chloride conversion. Because CFC-11 currently accounts for at least five percent of total production costs, a $2.81 permit price could substantially raise current production costs and foam prices--at least 41 percent. To avoid these high foam prices, customers could instead buy innerspring mattresses and rubber or felt carpet underlay; furniture and auto seat makers could instead use nonfoam cushioning materials. Because Scenario II (as well as Scenario I) ignores these consumer incentives and opportunities, it surely overstates flexible foam CFC use.

Similarly, there should be some consumer response in the residential market for foam insulation. Given current technology, this insulation cannot be made without CFCs.[1] CFCs' current share of total production costs is about seven percent. Thus, a permit price of $2.81 would raise production costs substantially--by at least 58 percent for rigid urethane insulation and at least 38 percent for extruded polystyrene board. In residential structures, fiberboard sheathing makes a reasonably good substitute for the rigid foams; in housing, rigid urethane foam saves only about 15 percent on heating costs--and polystyrene board saves even less--relative to fiberboard.[2] Because home builders would face incentives as well as opportunities to avoid foam insulation at a 1990 permit price of $2.81, Scenario II's estimate of 37.3 million weighted pounds in residential use of rigid foam insulation is surely too high.

A modest degree of consumer response in just the preceding two foam applications would be sufficient to help clear the 1990 CFC market at the $2.81 permit price. Suppose, for example, a one percent increase in

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[1] CFC recycling might be technologically feasible, but would be prohibitively expensive even at a permit price near $3.00.

[2] Foam is a supplementary insulation material in residential structures, and thus contributes less to energy savings than in other insulation applications. See Palmer et al. (1980), Table 3.C.10, p. 114.

final product prices reduces flexible foams sales by one percent and residential insulation sales by just one-half percent.[3] Then the 1990 flexible foams use would reach only 8 million weighted pounds, and the 1990 residential insulation use would reach only 27.4 million weighted pounds.[4] Together, these revised use figures would eliminate the 15.7 million pounds by which Scenario II exceeds the production cap in 1990 at $2.81.

Although anticipated consumer response in the foams categories alone is sufficient to meet the 1990 constraint, other product areas will probably also experience consumer response at high CFC prices. For example, customers could buy nonfoam packaging materials, cork buoys, and inflatable flotation devices instead of using rigid foams. Then Scenario II's estimate of 13.9 million weighted pounds of "other" rigid foam CFC use at the 1990 $2.81 permit price would be too high.

High CFC prices might also encourage technological responses not anticipated by Scenario II. In the miscellaneous products category, Scenario II assumes technological responses would occur primarily in the two largest subcategories--liquid fast freezing and sterilants. The remaining miscellaneous products--warning devices, heat detectors, and

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[3] Our literature review uncovered no previous studies estimating elasticities of demand for either cushioning materials or insulation. An elasticity of about minus one is not uncommon for consumer durables having close substitutes, as is the case for cushioning foams. The demand for insulation should be at least as elastic as we assume here. Energy studies suggest the long-run energy demand elasticity lies between -0.5 and -1.5. [See, for example, Nordhaus (1979) and Taylor (1977).] Because insulation and energy are substitutes in producing home "comfort," and because insulation is currently a small share of the total cost of producing comfort, a simple production model suggests insulation demand should be at least as elastic as energy demand.

[4] Estimates assume fixed proportions in production and constant arc elasticities throughout the consumer demand schedule.

blowers and drain cleaners--use CFCs as propellants. Such applications expanded rapidly at a time when CFCs were receiving a clean toxicologic bill of health relative to alternative chemicals. Alternative ways to make these products might be stimulated by high CFC prices. If so, even the 22.7 million weighted pounds of miscellaneous use estimated for Scenario II would be too high.

In summary, there are 87.6 million weighted pounds of CFC use postulated by Scenario II (at the $2.81 permit price in 1990) that might show additional CFC demand adjustments. Very modest consumer response in the flexible foams and rigid insulating foams categories would reduce use enough to meet the 1990 production constraint. But additional demand adjustment might also be observed for certain "other" rigid foams and for the miscellaneous products. Overall, an 18 percent use reduction (from 87.6 to 71.9 million weighted pounds) in the four categories where some added adjustment could be expected would be just sufficient to meet the 1990 production cap. If the permit price reaches $2.81--raising the CFC-11 price over 800 percent and the CFC-12 price over 500 percent--an 18 percent use reduction among the four categories is likely.

CONSUMER RESPONSE EFFECTS ON RESOURCE COSTS AND TRANSFER PAYMENTS

Other things equal[5], consumer response reduces aggregate resource

[5] Throughout this discussion and the remainder of this document, we assume the production cap policy does not include any provision to ameliorate transfer payments. When we relax the previous section's assumption of zero consumer response, it becomes possible for transfer payment compensation policies to affect market outcomes (permit prices and final product prices in particular). By assuming from here on that there is no compensation policy, we are holding "other things equal."

costs and aggregate transfer payments. When consumers buy fewer CFC-made products, less CFC is demanded by industry, and permit prices are lower than otherwise. Lower permit prices mean firms do not employ as many high-cost technologies and so resource costs are lower. Lower permit prices also translate directly into lower transfer payments.

In meeting the regulatory limitation on CFC use, lower-cost actions by consumers substitute for higher-cost actions by firms. The actions by consumers do impose some costs on them. For example, the consumer who chooses fiberboard sheathing instead of CFC foam insulation must pay higher fuel costs. We include these costs to consumers in our resource cost measures.[6] Nevertheless, consumer response lowers our measures of aggregate resource costs because consumer actions are less costly than the actions firms would otherwise have to undertake to meet the production cap.

The consumers who respond to higher final product prices do so in order to improve their own welfare. The consumer who chooses fiberboard sheathing (and pays higher heating costs), for example, does so in order to avoid high prices for foam insulation. Though final product substitution imposes some costs on consumers, they make the choice voluntarily because it is less costly than the alternative--higher costs for the CFC-made products.

[6] Our methodology automatically includes the net resource costs due to consumer response. See the appendix.

Table 4.1

EQUILIBRIUM PERMIT PRICES UNDER ALTERNATIVE SCENARIOS

(1976 dollars per weighted pound)

Year	Scenario III	Scenario IV	Scenario V	Scenario VI
1980	$0.00	$0.00	$0.00	$0.00
1981	0.06	0.06	0.10	0.09
1982	0.17	0.13	0.31	0.28
1983	0.30	0.27	0.64	0.45
1984	0.45	0.35	1.15	0.68
1985	0.67	0.55	1.70	0.94
1986	0.96	0.81	2.81	1.16
1987	1.17	1.06	2.81	1.35
1988	1.57	1.18	2.81	1.62
1989	2.35	1.64	2.81	1.93
1990	2.81	2.81	2.81	2.80[a]

[a] Differs from $2.81 due to computations based on a piecewise-linear approximation to the 1990 CFC demand curve.

SOME ALTERNATIVE MARKET-CLEARING SCENARIOS

Figure 4.1 compares four market-clearing scenarios with Scenarios I and II. (For convenience, Table 4.1 numerically reports the figure's annual permit prices for the four new scenarios.) Each market-clearing scenario makes different assumptions about how and when available market-clearing responses come into play:

Scenario III: Uses Scenario II's expanded technological responses, but adds some consumer response only in 1990 to help clear that year's market.

Scenario IV: Uses Scenario II's technological responses, but adds some consumer response in all years, 1981 through 1990.

Scenario V: Uses Scenario I through 1985, adding just enough technological and consumer response to clear the

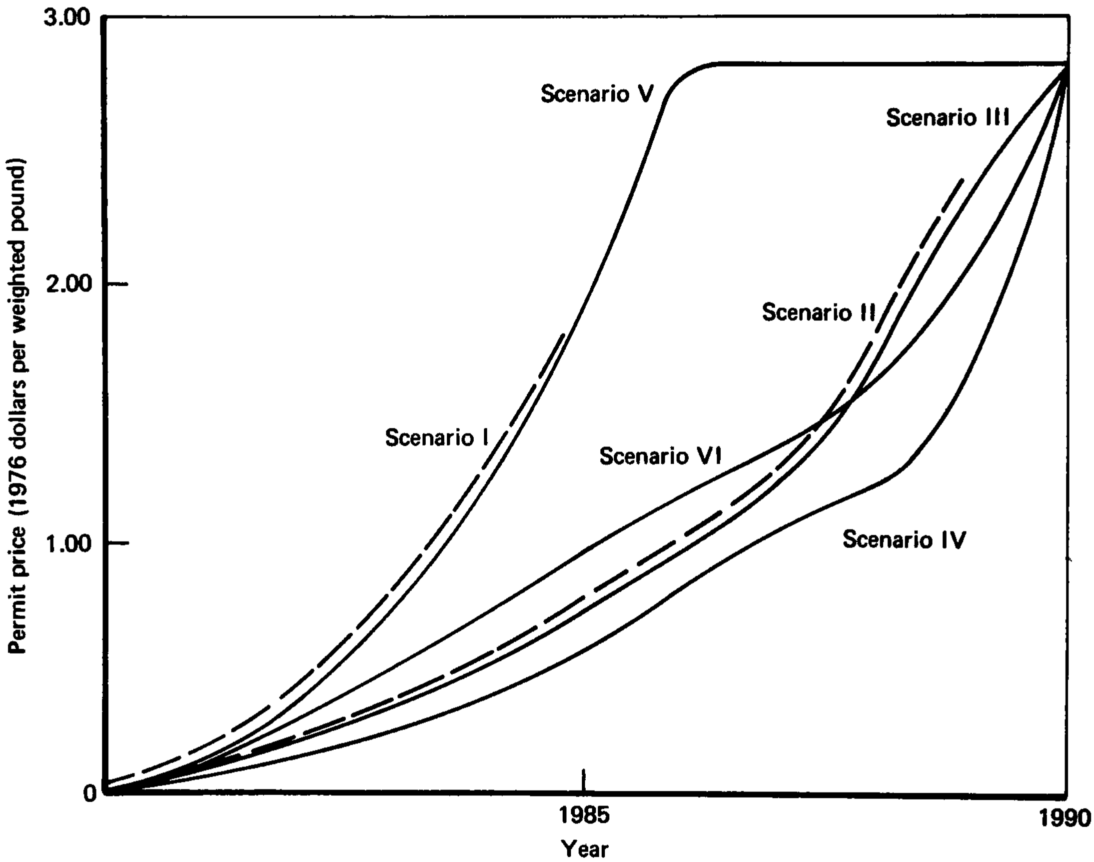

Fig. 4.1—Equilibrium permit prices under alternative scenarios

market each year after 1985 at the highest estimated permit price.

Scenario VI: Assumes a gradual transition from Scenario I's relatively unresponsive 1980 CFC demand patterns to the 1990 demand patterns of Scenarios III through V.

The more extensive are responses in a given year, the lower is a scenario's permit price for that year in Figure 4.1 (and Table 4.1).

A scenario with higher permit prices also has higher total cumulative resource costs and transfer payments. All the market-clearing scenarios prevent 24 percent of unregulated cumulative CFC use and emissions. But Table 4.2 shows high total cumulative costs for Scenario V and much lower costs for Scenario IV, with Scenarios III and VI in the middle of the cost range.

Scenario III: A Pessimistic View of Consumer Response

Scenario III illustrates how a modest degree of consumer response can extend Scenario II through 1990. The annual outcomes for Scenarios II and III are identical through 1989. Through added consumer response, Scenario III goes on to clear the 1990 market, generating $170 million in 1990 resource costs and nearly $1 billion in 1990 transfer payments. Because Scenario III outcomes can be estimated for an additional year, the cumulatives are higher than for Scenario II.

Although Scenario III reasonably assumes consumers will respond to higher final product prices in 1990, the scenario arbitrarily assumes consumers will respond only in 1990--not in earlier years. The scenario is optimistic about Group C industries' technological responses early in the decade, but exceedingly pessimistic about consumer demand response until the end of the decade.

Table 4.2

AGGREGATE RESOURCE COSTS AND TRANSFER PAYMENTS, SCENARIOS III, IV, V, VI: 1981 TO 1990

(In $ million 1976)

	Scenario			
Year	III	IV	V	VI
	Resource Costs			
1981	0.6	0.5	0.9	0.8
1982	2.5	2.1	5.1	4.1
1983	7.1	6.0	13.5	10.2
1984	14.0	12.1	31.4	20.2
1985	25.4	21.6	59.5	34.7
1986	43.0	36.1	85.4	53.7
1987	66.9	57.2	104.1	76.4
1988	97.1	84.2	124.3	104.6
1989	138.7	119.6	146.3	138.0
1990	170.1	170.1	180.8	182.7
Cumulative[a]	243.5	217.4	341.6	274.7
	Transfer Payments			
1981	21.8	19.5	35.1	32.3
1982	59.2	45.8	106.5	97.1
1983	101.8	93.2	218.4	152.0
1984	152.3	120.2	391.2	231.4
1985	228.5	186.9	578.8	321.3
1986	328.3	275.2	958.2	395.9
1987	398.6	360.5	958.2	460.4
1988	536.7	401.8	958.2	552.4
1989	802.3	557.8	958.2	659.6
1990	958.2	958.2	958.2	956.4
Cumulative[a]	1629.4	1363.5	2979.3	1829.8

NOTE: Transfer payments are estimated prior to rounding permit prices to the nearest cent.

[a]Sum of annual resource costs and transfer payments, discounted to 1980 at 11 percent.

Scenario IV: An Optimistic View of Consumer Response

Scenario IV is optimistic about both technological and consumer responses. Scenario IV makes the same technological-response assumptions as Scenario II, and the same 1990 consumer-response assumptions as Scenario III. But Scenario IV also assumes consumers will be just as responsive to high final product prices in all prior years as they are in 1990. In short, Scenario IV optimistically assumes both firms and consumers can adjust quickly to the changing market conditions caused by CFC regulation.

Scenarios V and VI: Two Transition Scenarios

In contrast with Scenario IV, Scenario V is very pessimistic about both technological and consumer response. Through 1985, Scenario V uses Scenario I's "high cost" CFC demand assumptions. After 1985, Scenario V assumes that technological responsiveness increases just enough to clear each year's market at the highest estimated permit price through 1989 and that no consumer responsiveness occurs until 1990. Thus, Scenario V allows for a transition from the very cautious 1980 demand patterns of Scenario I to the more responsive 1990 demand patterns of Scenarios III and IV. But Scenario V assumes the transition is slow to develop and minimal in every year.

Scenario VI also assumes a transition from the 1980 Scenario I demand patterns to the 1990 ones of Scenarios III through V. But relative to Scenario V, Scenario VI's transition starts earlier, and proceeds at a more uniform rate. Scenario VI recognizes that firms and consumers take time to adjust fully to the new market environment presented by CFC regulation. But the scenario presumes the adjustment process starts right away, as soon as CFC prices begin to rise.

Of the four market-clearing scenarios, the last two appear especially pertinent to decisionmaking. Scenario V generates the highest plausible estimate of regulation's costs, given the available data. If CFC regulation is justified even at Scenario V's high costs, the regulation would be justified under the lower costs of any of the other scenarios. However, Scenario V is exceedingly pessimistic. It should be interpreted as a "worst case" unlikely to be faced in reality. Even without assuming that totally new technologies will be developed or that consumers and firms will rapidly respond to higher prices, Scenario VI demonstrates that regulation's resource costs could be 20 percent lower--and transfer payments could be 39 percent lower--than Scenario V predicts. For planning purposes, Scenario VI poses reasonable expectations for the future, while Scenario V places an upper bound on how costly regulation might be.

DETAILED OUTCOMES UNDER SCENARIO V

As Table 4.3 shows, CFC prices tend to stabilize after 1985 in Scenario V.[7] Prior to 1985, Scenario V matches Scenario I; both scenarios include only Group A's technological responses until they are exhausted. After 1985, Scenario V combines two price assumptions, a

[7] Slight adjustments in the CFC-113 price after 1985 reflect our assumption of economies of scale in this CFC's production. See the appendix.

Table 4.3

ANNUAL EQUILIBRIUM CFC AND PERMIT PRICES,
SCENARIO V: 1980 TO 1990

(In $ 1976)

	Total User Price per CFC Pound[a]				
Year	CFC-11	CFC-12	CFC-113	CFC-502	Permit Price[b]
1980	$0.34	$0.41	$0.60	$1.11	$0.00
1981	0.44	0.49	0.67	1.13	0.10
1982	0.65	0.65	0.86	1.17	0.31
1983	0.98	0.92	1.15	1.23	0.64
1984	1.49	1.32	1.56	1.33	1.15
1985	2.04	1.75	2.00	1.43	1.70
1986	3.15	2.63	2.90	1.64	2.81
1987	3.15	2.63	2.92	1.64	2.81
1988	3.15	2.63	2.94	1.64	2.81
1989	3.15	2.63	2.97	1.64	2.81
1990	3.15	2.63	2.96	1.64	2.81

[a]Includes user payments for permits, if issued. Otherwise, the total user price is assumed paid to the CFC manufacturers.

[b]Assumes manufacturers' CFC prices are as indicated by Table 1.3 for all years. A permit entitles the user to use one weighted pound of any CFC.

reasonable one and a pessimistic one. The reasonable one is that the market will clear at the $2.81 permit price in 1990. The pessimistic assumption is that the market will not clear at lower permit prices between 1985 and 1990.

The detailed outcomes of Tables 4.4 through 4.6 result from Scenario V's specific assumptions about how responses are distributed among user categories. Though Scenario V is more pessimistic about technological response than Scenario II, both scenarios distribute responses the same way. For 1980 through 1985, Scenario V assumes no Group C response. For 1985 through 1989, Scenario V shows less Group C response than Scenario II, but both scenarios distribute the response among Group C users in proportion to their baseline (unregulated) use. By 1990, Scenarios V and II share the same assumptions about Group C response.

Scenario V assumes consumer responses occur only in 1990 and only in flexible foams and residential foam insulation. All of the resource costs attributable to product-substitution by consumers shows up in the estimates for the product areas where consumer response occurs.

As expected, total annual resource costs are higher under Scenario V than under any other scenario, as illustrated by Table 4.5. From 1986 to 1990, resource costs gradually increase for the Group C users as they become more responsive to higher CFC prices. Consistent with the assumptions about consumer responses, Table 4.5 shows large increases in resource costs in 1990 for flexible foams and insulation.

Because of Scenario V's high equilibrium permit prices, Table 4.6 shows higher transfer payments than under Scenario II for virtually

Table 4.4

PROJECTED CFC USE BY USER CATEGORY,
SCENARIO V: 1980 TO 1990
(In millions of weighted pounds)

	Use Under Regulation											Cumulative	
User Category	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Regulated	Unregulated
Flexible foam	46.8	35.7	31.6	27.1	17.1	11.0	11.5	12.0	12.6	13.1	8.0	226.5	641.9
Solvents	60.3	61.0	56.2	49.7	47.5	45.4	39.9	38.0	35.8	33.5	34.2	501.5	884.6
Rigid foam													
TPS	11.5	11.5	10.8	8.9	7.3	0.8	0.0	0.0	0.0	0.0	0.0	50.8	159.3
Insulation	72.3	78.3	84.9	91.9	99.6	107.9	116.9	126.6	137.2	148.6	151.1	1215.3	1225.2
Other	17.1	18.3	19.6	21.1	22.5	24.1	22.7	19.9	16.8	13.6	14.4	210.1	271.4
Mobile air conditioning													
Manufacturing	30.0	30.3	30.7	31.0	31.4	31.7	28.7	24.1	19.6	15.2	14.3	287.0	349.3
Servicing	47.6	49.0	50.3	51.5	52.4	53.3	54.5	56.1	57.8	59.5	61.3	593.3	614.9
Retail food refrigeration													
CFC-12	8.5	6.5	2.9	2.5	2.1	1.8	1.5	1.3	1.1	0.9	0.8	29.9	90.5
CFC-502	2.3	2.8	3.4	3.5	3.6	3.7	3.8	4.0	4.1	4.2	4.4	39.8	28.5
Chillers	13.7	14.3	15.0	15.7	16.4	17.2	18.0	18.8	19.7	20.6	21.6	191.0	191.0
Home refrigeration	5.6	5.8	5.9	6.1	6.3	6.4	6.6	6.8	7.0	7.2	7.4	71.1	71.1
Miscellaneous	25.3	27.4	29.6	32.1	34.7	37.5	36.3	32.7	28.4	23.5	23.7	331.2	426.0
TOTAL[a]	341.0	341.0	341.0	341.0	341.0	341.0	341.0	341.0	341.0	341.0	341.0	3751.0	4954.3

[a]Detail may not sum to totals due to rounding.

Table 4.5

PROJECTED RESOURCE COSTS BY USER CATEGORY,
SCENARIO V: 1981 TO 1990
(In $ million 1976)

	Resource Costs										
User Category	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Cumulative[a]
Flexible foam	0.7	2.1	4.7	15.2	23.8	24.9	25.9	27.0	28.2	37.4	91.5
Solvents	0.1	2.0	6.4	11.4	19.0	33.8	39.2	45.1	51.5	56.1	121.6
Rigid foam											
TPS	0.0[b]	0.3	1.5	3.2	13.9	16.0	16.7	17.4	18.2	19.0	49.6
Insulation	-	-	-	-	-	-	-	-	-	13.9	4.9
Other	-	-	-	-	-	1.8	4.8	8.2	12.0	13.7	16.4
Mobile air conditioning											
Manufacturing	-	-	-	-	-	2.3	5.7	9.1	12.6	13.6	17.6
Servicing	0.0[b]	0.1	0.3	0.9	2.0	2.9	3.1	3.3	3.5	3.7	9.2
Retail food refrigeration	0.1	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	4.3
Chillers	-	-	-	-	-	-	-	-	-	-	-
Home refrigeration	-	-	-	-	-	-	-	-	-	-	-
Miscellaneous	-	-	-	-	-	2.9	7.7	13.2	19.5	22.5	26.5
TOTAL[c]	0.9	5.1	13.5	31.4	59.5	85.4	104.1	124.3	146.3	180.8	341.6

[a]Sum of annual resource costs, discounted to 1980 at 11 percent.

[b]Resource costs positive, but less than 0.1 after rounding.

[c]Detail may not sum to totals due to rounding.

Table 4.6

PROJECTED TRANSFER PAYMENTS BY USER CATEGORY,
SCENARIO V: 1981 TO 1990
(In $ million 1976)

	Transfer Payments										
User Category	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Cumulative[a]
Flexible foam	3.7	9.9	17.3	19.7	18.7	32.4	33.8	35.3	36.9	22.5	119.3
Solvents	6.3	17.6	31.9	54.5	77.1	112.2	106.7	100.6	94.1	96.1	350.6
Rigid foam											
TPS	1.2	3.4	5.7	8.4	1.4	0.0	0.0	0.0	0.0	0.0	14.3
Insulation	8.1	26.5	58.9	114.3	183.1	328.1	355.6	385.2	417.4	424.6	1082.3
Other	1.9	6.1	13.5	25.8	40.9	64.8	57.7	49.7	40.8	40.5	172.0
Mobile air conditioning											
Manufacturing	3.1	9.6	19.9	36.0	53.9	80.6	67.8	55.1	42.7	40.2	211.3
Servicing	5.0	15.7	33.0	60.2	90.5	152.9	157.5	162.3	167.2	172.2	488.7
Retail food refrigeration	1.0	2.0	3.8	6.5	9.3	15.0	14.8	14.6	14.6	14.6	47.4
Chillers	1.5	4.7	10.1	18.9	29.2	50.5	52.9	55.4	58.0	60.7	162.8
Home refrigeration	0.6	1.8	3.9	7.2	10.9	18.6	19.1	19.7	20.2	20.8	59.0
Miscellaneous	2.8	9.3	20.5	39.8	63.7	102.0	91.7	79.8	66.1	66.6	271.7
TOTAL	35.1	106.5	218.4	391.2	578.8	958.2	958.2	958.2	958.2	958.2	2979.3

NOTE: Transfer payments are estimated prior to rounding permit price data to the nearest cent.

[a]Sum of annual transfer payments, discounted to 1980 at 11 percent.

[b]Detail may not sum to totals due to rounding.

every user category--even those which use considerably fewer CFCs. The sole exception is thermoformed polystyrene sheet products. Beginning in 1985, TPS foam makers avoid high transfer payments by using pentane instead of CFC-12. But for all other user categories, even low use levels generate high transfer payments at Scenario V's high permit prices.

DETAILED OUTCOMES UNDER SCENARIO VI

Because Scenario VI is more optimistic about the economy's ability to adjust to rising CFC prices, the estimated economic impacts of the production cap are less than under Scenario V. Estimated Scenario VI outcomes appear in Tables 4.7 through 4.10.

While CFC prices under Scenario VI reach the same 1990 levels as under Scenario V, they do so more gradually. By 1985, for example, Scenario VI's prices of CFC-11, CFC-12, and CFC-113 are all at least 25 percent lower than in Scenario V.

Relative to Scenario V, the lower permit prices of Scenario VI result from earlier technological responses by Group C firms and earlier consumer responsiveness for flexible foams and residential foam insulation. Scenarios V and VI share the same assumptions for 1980 and 1990, but Scenario VI assumes the transition to 1990's greater technological and consumer responses occurs gradually over the entire decade.

Table 4.9 verifies that lower permit prices translate into lower overall resource costs. For example, Scenario VI's total resource costs in 1985 are 37 percent below those for Scenario V. But by 1990, both scenarios show about the same total resource costs.

Table 4.7

ANNUAL EQUILIBRIUM CFC AND PERMIT PRICES,
SCENARIO VI: 1980 TO 1990

	Total User Price Per CFC Pound[a] (In $ 1976)				
Year	CFC-11	CFC-12	CFC-113	CFC-502	Permit[b] Price
1980	$0.34	$0.41	$0.60	$1.11	$0.00
1981	0.43	0.48	0.67	1.13	0.09
1982	0.62	0.63	0.83	1.16	0.28
1983	0.79	0.77	0.99	1.20	0.45
1984	1.02	0.95	1.19	1.24	0.68
1985	1.28	1.15	1.40	1.29	0.94
1986	1.50	1.33	1.58	1.33	1.16
1987	1.69	1.48	1.74	1.37	1.35
1988	1.96	1.69	1.97	1.42	1.62
1989	2.27	1.93	2.23	1.48	1.93
1990	3.14	2.62	2.95	1.64	2.80

[a]Includes user payments for permits, if issued. Otherwise, the total user price is assumed paid to the CFC manufacturers.

[b]Assumes CFC sales prices are as indicated in Table 1.3. A permit entitles the holder to use one weighted pound of any CFC.

Table 4.8

PROJECTED CFC USE BY USER CATEGORY,
SCENARIO VI: 1980 TO 1990)

(In millions of weighted pounds)

User Category	Use Under Regulation											Cumulative	
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990[a]	Regulated	Unregulated
Flexible foam	46.8	36.4	33.8	29.1	27.3	22.6	16.8	10.3	10.1	9.7	8.1	251.0	641.9
Solvents	60.3	61.1	57.1	53.1	48.8	46.8	45.7	44.6	41.9	39.2	34.1	532.7	884.6
Rigid foam													
TPS	11.5	11.5	11.0	10.3	9.0	8.3	7.9	7.4	3.9	0.0	0.0	80.8	159.3
Insulation	72.3	78.3	84.7	91.7	99.0	106.8	115.1	124.0	133.2	142.9	151.1	1199.1	1225.2
Other	17.1	18.1	18.9	19.3	19.2	18.9	18.3	17.7	16.5	15.4	14.4	193.8	271.4
Mobile air conditioning													
Manufacturing	30.0	30.0	29.5	28.5	26.8	24.8	22.7	20.8	18.4	16.1	14.2	261.8	349.3
Servicing	47.6	49.0	50.3	51.7	53.0	54.3	55.7	57.1	58.4	59.6	61.3	598.0	614.9
Retail food refrigeration													
CFC-12	8.5	6.7	3.0	2.5	2.1	1.8	1.5	1.3	1.1	0.9	0.8	30.2	90.5
CFC-502	2.3	2.8	3.4	3.5	3.6	3.7	3.8	4.0	4.1	4.2	4.4	39.8	28.5
Chillers	13.7	14.3	15.0	15.7	16.4	17.2	18.0	18.8	19.7	20.6	21.6	191.0	191.0
Home refrigeration	5.6	5.8	5.9	6.1	6.3	6.4	6.6	6.8	7.0	7.2	7.4	71.1	71.1
Miscellaneous	25.3	27.0	28.4	29.5	29.6	29.4	28.7	28.2	26.6	25.0	23.6	301.3	426.0
TOTAL[b]	341.0	341.0	341.0	341.0	341.0	341.0	341.0	341.0	341.0	341.0	341.0	3751.0	4954.3

[a]Outcomes for 1990 differ slightly from Scenario V due to piecewise linear approximation of Group C demand schedules.

[b]Detail may not sum to totals due to rounding.

Table 4.9

PROJECTED RESOURCE COSTS BY USER CATEGORY,
SCENARIO VI: 1981 TO 1990

(In $ million 1976)

User Category	Resource Costs 1981	1982	1983	1984	1985	1986	1987	1988	1989	1990[a]	Cumulative[b]
Flexible foam	0.6	1.4	3.5	5.4	10.4	17.9	27.1	29.1	31.5	37.3	74.7
Solvents	0.1	1.6	4.1	8.3	12.3	16.6	21.6	29.6	39.0	56.7	84.4
Rigid foam											
TPS	0.0[c]	0.2	0.7	1.7	2.7	3.5	4.8	10.9	18.2	19.0	26.2
Insulation	0.0	0.0[c]	0.1	0.2	0.5	1.0	1.8	3.2	5.5	13.9	10.4
Other	0.0[c]	0.1	0.3	0.9	1.9	3.4	5.0	7.8	10.9	14.1	18.8
Mobile air conditioning											
Manufacturing	0.0[c]	0.1	0.4	1.3	2.6	4.2	5.9	8.6	11.3	14.1	21.0
Servicing	0.0[c]	0.1	0.1	0.3	0.6	1.0	1.4	2.1	3.3	3.7	5.4
Retail food refrigeration	0.1	0.7	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	4.3
Chillers	-	-	-	-	-	-	-	-	-	-	-
Home refrigeration	-	-	-	-	-	-	-	-	-	-	-
Miscellaneous	0.0[b]	0.1	0.4	1.4	3.0	5.4	8.0	12.5	17.6	23.1	30.3
TOTAL[d]	0.8	4.1	10.2	20.2	34.7	53.7	76.4	104.6	138.0	182.7	274.7

[a] Outcomes for 1990 differ slightly from Scenario V due to piecewise linear approximation of Group C demand schedules.

[b] Sum of annual resource costs, discounted to 1980 at 11 percent.

[c] Resource costs positive, but less than 0.1 after rounding.

[d] Detail may not sur to totals due to rounding.

Table 4.10

PROJECTED TRANSFER PAYMENTS BY USER CATEGORY,
SCENARIO VI: 1981 TO 1990

(In $ million 1976)

	Transfer Payments										
User Category	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990[a]	Cumulative[b]
Flexible foam	3.4	9.6	13.0	18.6	21.3	19.5	13.9	16.4	18.8	22.7	84.9
Solvents	5.8	16.2	23.6	33.1	44.1	53.0	60.1	67.8	75.9	95.7	233.8
Rigid foam											
TPS	1.0	3.1	4.6	6.1	7.8	9.2	10.0	6.3	0.0	0.0	28.0
Insulation	7.4	24.1	40.8	67.2	100.6	133.6	167.4	215.9	276.4	423.6	663.0
Other	1.7	5.4	8.6	13.0	17.8	21.3	24.0	26.8	29.7	40.4	91.7
Mobile air conditioning											
Manufacturing	2.8	8.4	12.7	18.2	23.4	26.4	28.1	29.8	31.2	39.8	111.3
Servicing	4.6	14.3	23.0	36.0	51.2	64.7	77.1	94.6	115.4	171.9	305.2
Retail food refrigeration	0.9	1.8	2.7	3.9	5.2	6.2	7.1	8.4	10.0	14.6	29.4
Chillers	1.4	4.3	7.0	11.2	16.2	20.9	25.4	32.0	39.9	60.6	101.0
Home refrigeration	0.5	1.7	2.7	4.2	6.1	7.7	9.2	11.3	13.9	20.8	36.4
Miscellaneous	2.6	8.1	13.1	20.1	27.7	33.4	38.0	43.1	48.3	66.2	145.1
TOTAL[c]	32.3	97.1	152.0	231.4	321.3	395.9	460.4	552.4	659.6	956.4	1829.8

NOTE: Transfer payments are estimated prior to rounding permit prices to the nearest cent.

[a]Transfer payments for 1990 differ slightly from Scenario V, due to slightly lower equilibrium permit price.

[b]Sum of annual transfer payments, discounted to 1980 at 11 percent.

[c]Detail may not sum to totals due to rounding.

The distribution of resource costs differs between Scenario V and Scenario VI. For Group A firms, Scenario VI uniformly predicts lower resource costs from 1981 through 1989. These lower costs are partly offset by higher resource costs among Group C firms and in flexible and insulating foams. Relative to Scenario V, Scenario VI assumes Group C firms and purchasers of flexible and insulating foams can partly avoid high transfer payments by incurring some added resource costs.

Table 4.10 shows that Scenario VI's transfer payments are dramatically less than in Scenario V in nearly all user categories. For 1985 through 1987, Scenario VI's lower permit prices make it advantageous for TPS foamers to continue some CFC use despite high transfer payments. Total cumulative transfer payments are nearly 40 percent less in Scenario VI than in Scenario V.

V. OTHER MEASURES OF POLICY EFFECTS

This section translates the cost estimates of previous sections into other measures of policy effects: consumer prices, competitiveness of small businesses, plant closures and worker unemployment, and energy implications. As indicated below, the effects examined here correspond to the cost outcomes of Scenarios V or VI. Effects for the other plausible scenarios--III and IV--lie within the range of outcomes for Scenarios V and VI.

CONSUMER PRICE EFFECTS

For most products consumers buy, the price effects of a CFC production cap will be very small, even under Scenario V's high-cost assumptions and even for the last years of the decade.

The largest percentage increases in product prices can be expected for certain of the CFC-blown plastic foams. Section IV explained that a permit price of $2.81 could increase some foam prices substantially--as much as 41 percent for some flexible urethane foams and perhaps 38 to 58 percent for some foam insulation. However, such large increases will not be the norm. For many foam products, producers can avoid much of regulation's impact by reducing CFC use. For example, small and medium-sized flexible urethane foam plants would convert most of their output to methylene chloride long before the permit price reaches $2.81. Price increases will be far less for these foam products--perhaps 10 to 20 percent by the late 1980's.

In many cases the effects of foam price increases on the prices of goods consumers buy will be quite small. Many foams are intermediate products used in automotive seats or to insulate the walls of a home refrigerator or freezer. Because the foam accounts for only a small fraction of the total costs of such consumer products, the consumer price increases due to higher foam prices will typically be two percent or less. Even in such products as furniture, where foam cushions comprise 10 to 15 percent of production costs, consumer product prices will generally increase less than 5 percent.

For TPS foam products, price increases should be less--perhaps much less--than 25 percent. According to some industry estimates of the cost of converting to pentane blowing agents, the prices of TPS meat trays, egg cartons, and fast food containers could rise 20 to 25 percent. But, as noted in Palmer et al. (1980), pentane conversion could be less costly than our scenarios assume--and so TPS foam product prices might only rise 10 to 12 percent. Because pentane conversion occurs by mid-decade in our scenarios, these price increases would be observed by then.

Below, in our discussion of plant closures and worker layoffs, we explain that TPS foams compete with nonfoam packaging materials, such as paper and cardboard. It is possible that foam purchasers will select alternative packaging materials long before TPS foam prices rise as much as our scenarios predict. If so, final product consumers will not experience the full price increases estimated above.

In all the refrigeration products--chillers, mobile air conditioners, home appliances, and retail food refrigeration systems--higher CFC prices would cause only small percentage increases in consumer product prices. Refrigerant costs are currently under five percent of final product costs. Even a $2.81 permit price would raise refrigerant costs to less than 6.5 times today's levels. Consequently, higher refrigerant prices would raise final product costs less--typically much less--than 3 percent.

Price effects for products made with CFC solvents would also be very small. Solvents currently account for less than one percent of the production costs for electronics components. A five-fold increase in solvents costs (caused by a $2.81 permit price) would raise electronics product prices less than five percent even if firms could not use alternative solvents. Solvent substitution possibilities make the likely final product price effect even smaller.

Information about the miscellaneous products category is too scant for us to compute price effects for those products. For a general discussion of the markets for these products and their likely responses to higher CFC prices, see Palmer et al. (1980).

EFFECTS ON SMALL BUSINESSES

The production cap policy is not inherently biased against small--or large--firms. Under a production cap policy, businesses of all sizes pay the same permit prices. Historically, firms that made large CFC purchases have sometimes received volume discounts. Discounting might well continue under regulation. Nevertheless, the change in CFC user prices because of regulation should be approximately the same for large and small purchasers.

With few exceptions, the ability to cope with higher prices is not dependent on the size of a firm. Especially successful firms will be those that make timely management decisions and have good working relationships with employees, suppliers, and buyers. These characteristics appear in small as well as large firms. Even very small firms typically belong to trade associations and distribution networks that convey information for decisionmaking.[1] And research shows that small firms are at least as quick as larger ones to find and implement new cost-saving technologies.[2] Firms of different sizes typically have the same opportunities to deal successfully with higher CFC prices.

One notable exception we have identified arises in the flexible foam industry. One way to respond to higher CFC prices is recovery and recycling, which requires investment in capital equipment. At present, there seems to be little variation in the equipment available to plants of different sizes. Therefore, the cost of using recovery equipment per unit of output (or per unit of CFC use avoided[3]) varies substantially among plants. A large foam plant can economically begin recovery and recycle at a lower CFC price than its smaller competitor, and can charge lower foam prices to its customers.

Recycling economics could prove important to the size structure of the flexible foams industry--though there are reasons to be sceptical. A large firm typically has multiple plants, some of which can have quite low output levels; a large firm faces the same economics in its small

[1] Two examples of organizations serving small (as well as large) CFC-using firms are the Society of the Plastics Industry and the Air Conditioning and Refrigeration Institute.

[2] For example, see Utterback (1974).

[3] See Palmer et al. (1980), Table 3.A.7, p. 61.

plants as a small firm with a single small plant.[4] The coexistence of large and small firms in the industry today suggests many reasons for differences in size; firms may offer different foam products or serve different communities. To the extent small and large firms are not direct competitors, differences in their recycling costs will not seriously affect firms' ability to survive higher CFC prices. Finally, a growing market for CFC recovery equipment should encourage development of different systems with different capacities and costs. Unless and until that happens, there may be cases where high CFC prices disadvantage the small foam producer, but only if he directly competes with a firm having a larger production facility.[5]

A similar capital bias might also arise for the TPS rigid foams. Recovery and recycle is also an option for that user category. Another option, pentane substitution, also appears to require substantial capital investment for fireproofing plants--an investment that does not vary proportionately to the plant's output level or CFC use. Because both of the major CFC-saving technologies in TPS foams involve some capital bias against small plants, higher CFC prices could affect the size structure of that industry.

There are also good reasons to be sceptical of a large capital bias effect on the TPS foam industry. As for the flexible foams, it is incorrect to equate small plants with small firms. The TPS foam industry is already highly concentrated, with over 80 percent of total output

[4] Although Palmer et al. (1980) provides data on the distribution of plant sizes, we have almost no data on ownership distributions.

[5] As an alternative to a production cap policy, mandatory requirements for recovery and recycling are at least as biased against small firms. See Palmer et al. (1980), Sec. III.A.

produced by a few large companies.[6] These large companies have some plants producing relatively small quantities of foam. Moreover, the industry is so concentrated that there is little scope for change in industry structure even if small firms were greatly disadvantaged by regulation.

For reasons given below, the TPS foam industry could decline due to CFC regulation. The survival of large as well as small TPS foam producers might be endangered. The capital bias might mean small plants will be among the first to close. But they may not be the only ones--and closures are likely among plants owned by large as well as small firms.

PLANT CLOSURES AND WORKER LAYOFFS

All of the scenarios we have investigated reasonably assume some expansion in all final product markets between 1980 and 1990--despite higher CFC prices. Some markets, home refrigeration for example, will grow rather slowly--but they would grow slowly even in regulation's absence. Regulation might reduce the growth rate for some user industries. Scenario VI, for example, assumes that consumer response to higher final product prices would reduce growth in the flexible foam and residential insulation markets. But all of the scenarios assume user industries will make more final products in 1990 than today.[7]

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[6] See Palmer et al. (1980), p. 106.

[7] There are some declining segments of user industries. Within the retail food industry, for example, the number of "Mom and Pop" food stores has been declining for several years and will continue to do so. Higher CFC prices--or any other unfavorable change in market conditions--might speed the decline of these borderline firms. However, even if plant closures are observed under these conditions, it would be impossible to say whether regulation or natural processes were responsible.

In most user industries, firms in business today should be able to remain in business despite regulation--provided they respond efficiently to higher CFC prices. The foreseeable technological responses can take place within existing plants, through replacement, modification or addition of some equipment, or through conversion to alternative chemicals. By making such changes at the appropriate time, existing firms can continue to operate at their current levels, perhaps even participating in market growth over time.

The one case we have identified where CFC regulation could seriously injure existing firms (and their workers) is the TPS packaging foam industry. Many of the products made by this industry--egg cartons and fast-food packages, for example--compete with cardboard and paper products. The overall market for packaging materials will grow over the next decade, but TPS packaging could decline substantially as its price rises relative to nonfoam packaging. And the workers and equipment for TPS manufacturing cannot convert readily to producing nonfoam packaging.[8]

Available data provide only a crude indication of how many firms and workers might be affected by a decline in the TPS foam industry. Fewer than ten firms supply most of today's market. These include Mobil Chemical Corporation, W.R. Grace Foampak Division, Western Foam Pak,

[8] All of our scenarios assume TPS firms will convert to pentane at high CFC prices, thereby remaining in business while reducing CFC use to zero. If, instead, many of these firms go out of business early in the decade, our estimates of resource costs for this industry will be too high throughout the decade, and our estimates of market-wide permit prices will be too high for the early years. In short, cardboard or paper substitution for TPS foams is a mixed blessing. It would cause plant closures in existing TPS firms, but reduce the economic costs of regulation.

Dolco Packaging Corporation, and Huntsman Container Corporation. Some of these firms' plants already use pentane and would not be affected by CFC regulation. Though the remaining plants belonging to these firms might be susceptible to closures, we do not know how many; and there could be closures among other plants owned by other firms not identified by our study. Available data indicate there are two to three thousand workers in TPS foam plants, with perhaps 1800 workers employed in the small plants most susceptible to the capital bias discussed previously.

Information about the miscellaneous CFC-using products is too scant for us to predict the likelihood or extent of plant closures. The industries in question include firms with multiple product lines. However, some plants produce only a single CFC-based product and are located in small communities where they could be a major source of employment. Though we expect many of these firms to adapt to higher CFC prices by using alternative technologies, isolated cases of plant closures and worker layoffs cannot be ruled out.

ENERGY IMPLICATIONS

The production cap policy we have analyzed will not substantially increase U.S. energy consumption. Some industry sources anticipate that severe CFC cutbacks in such products as home refrigeration, chillers, and foam insulation would extract a heavy energy penalty. But a production cap would not severely cut CFC use in these user categories. None of our scenarios predicts any policy effect on CFC use in home refrigeration, chillers, or foam insulation outside the residential construction market. The predicted reductions in residential insulation (under

Scenarios V and VI) are quite small. And such energy effects as might arise in any other product areas are even smaller.

To the extent that the production cap does increase energy use, the financial cost already appears in our resource cost estimates. Energy costs enter our calculations as part of the cost of CFC-saving technologies. In residential insulation, the amount of foam consumers will buy at each price depends on the energy penalty associated with using fiberboard sheathing instead; thus, energy cost also enters our calculations as part of the consumer response analysis. Wherever regulation predictably increases energy use, the costs are included in the tables on resource costs.

The largest energy use effects would be in the residential construction market for foam insulation--and these effects would be very small under any scenario. For a "typical" residential structure, replacing foam with nonfoam insulation increases annual energy consumption by about 70 gallons of fuel oil (or by the energy-equivalent in some other fuel).[9] Of course, not all homes are the same: some would face a greater energy penalty, and some less. On average, the homeowners (or builders) who would switch to fiberboard in Scenarios V or VI would face lower energy penalties than owners of "typical" homes. But even if we were to assume all the consumers who switch to fiberboard have "typical" homes--as we do for Scenario VI in Table 5.1--the aggregate effect on energy consumption would be quite modest. The table's ten-year total energy consumption effect is only 83 million gallons (or

[9] See Palmer et al. (1980), pp. 113-116.

Table 5.1

MAXIMUM INCREASE IN ENERGY USE IN THE RESIDENTIAL INSULATION MARKET

SCENARIO VI: 1981 THROUGH 1990

	Annual Energy Penalty in Millions of Equivalent Gallons of Fuel Oil[a]		
Year	Rigid Urethane Market	Polystyrene Board Market	Total
1981	--	--	--
1982	0.2	0.0[b]	0.3
1983	0.5	0.1	0.6
1984	1.2	0.2	1.4
1985	2.4	0.5	2.8
1986	4.3	0.9	5.1
1987	6.9	1.4	8.4
1988	10.9	2.3	13.2
1989	16.4	3.5	19.9
1990	25.6	5.5	31.1
Cumulative[c]	68.5	14.4	82.8

[a] Each year's penalty includes increased energy use for all structures built without foam insulation due to CFC regulation in prior years. Estimates assume the penalty per million pounds of foam not used is 134,927.3 equivalent gallons of fuel oil for rigid urethane foam and 94,702.0 equivalent gallons for extruded polystyrene board.

[b] Energy penalty positive, but less than 0.1 after rounding.

[c] Sum of annual energy penalties. Detail may not sum to totals due to rounding.

less than two million barrels) of fuel oil.[10] The U.S. currently imports three times that much crude oil in a single day.

Adjustments to a production cap by other user categories will also have some energy implications. For example, in the solvents category, slight increases in energy use are expected. Under all scenarios, some solvent users switch to non-CFC solvents that have higher boiling points than CFC-113. As a result, the energy requirements for cleaning and drying operations increase. However, the amount of increased energy use in the solvents category is surely smaller than even the slight impact for insulation. And the energy costs in solvents and other product areas are already reflected in our estimates of the policy's resource costs.

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[10] For Scenarios III, IV, and V, energy impacts would be even smaller. These scenarios show no effect until 1990, when energy use would increase by the equivalent of 11.3 million gallons of fuel oil.

APPENDIX: METHODOLOGY

This appendix details the methodology used to simulate market outcomes under a CFC production cap policy. Because the policy under consideration allows market forces to allocate CFC use, economic outcomes will depend upon how the private sector responds to higher CFC prices. Consequently, the critical methodological issue is the estimation of the CFC demand schedule, which describes how CFC use varies as its price is increased by regulation.

CAUTIOUS CFC DEMAND SCHEDULES

This report's underlying demand schedules are based on two types of information supplied by industry sources. First, many CFC-using and producing firms provided data used to project "baseline" CFC use for each user category in the absence of regulation. Second, industry sources supplied information on a wide variety of technical options for reducing CFC use under regulation in various user categories; this information is discussed in detail in Sec. III of Palmer et al. (1980).

The baseline forecast of CFC use is reported in Table 1.2 for 1980 and 1990, and in Table A.1 for the interim years. Although these estimates use a different CFC weighting scheme (discussed below), except for solvents, the underlying forecasts of growth in the CFC markets are identical with those of our earlier report.

The baseline forecast for CFC-113 is estimated from a simulation model that relates solvent demand to the CFC supply price.[1] Based on

[1] The supply price is the price at which producers will be willing to sell incremental units of output. Unlike the other CFCs, the

Table A.1

PROJECTED CFC USE BY USER CATEGORY; BASELINE FORECAST, 1980 TO 1990
(In millions of weighted pounds)

User Category	Unregulated CFC Use[a] 1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Cumu-lative
Flexible foam	46.8	48.8	50.9	53.1	55.4	57.8	60.4	63.0	65.7	68.5	71.5	641.9
Solvents	60.3	63.7	67.3	71.0	75.0	79.2	83.7	88.4	93.3	98.6	104.1	884.6
Rigid foam												
TPS	11.5	12.0	12.6	13.1	13.7	14.3	15.0	15.7	16.4	17.1	17.9	159.3
Insulation	72.3	78.3	84.9	91.9	99.6	107.9	116.9	126.6	137.2	148.6	161.0	1225.2
Other	17.1	18.3	19.6	21.1	22.5	24.1	25.8	27.6	29.6	31.7	34.0	271.4
Mobile air conditioning												
Manufacturing	30.0	30.3	30.7	31.0	31.4	31.7	32.1	32.5	32.8	33.2	33.6	349.3
Servicing	47.6	49.1	50.7	52.3	53.9	55.6	57.4	59.2	61.1	63.0	65.0	614.9
Retail food refrigeration												
CFC-12	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	8.0	90.5
CFC-502	2.3	2.4	2.4	2.5	2.5	2.6	2.6	2.7	2.8	2.8	2.9	28.5
Chillers	13.7	14.3	15.0	15.7	16.4	17.2	18.0	18.8	19.7	20.6	21.6	191.0
Home refrigeration	5.6	5.8	5.9	6.1	6.3	6.4	6.6	6.8	7.0	7.2	7.4	71.1
Miscellaneous	25.3	27.4	29.6	32.1	34.7	37.5	40.6	44.0	47.6	51.5	55.7	426.0
Total[b]	341.0	358.9	377.9	398.2	419.8	442.8	467.3	493.4	521.3	551.0	582.7	4954.3

[a]Based on CFC weighting factors in Table 1.1. See appendix text for discussion.

[b]Detail may not sum to totals because of rounding.

industry-supplied information, the supply price of CFC-113, P_s, is given by

$$P_s = \left(\frac{V_0}{V}\right)^{0.5} P_0, \qquad (1)$$

where V is the current volume of production and V_0 and P_0 are the volume of production and price per pound of CFC-113 in a base year. This report revised the CFC-113 supply price assumption in Palmer et al. (1980) and bases the supply price equation on 1980 data. From Tables 1.2 and 1.3, the 1980 base-year values in Expression (1) are V_0 = 78.3 million pounds of CFC and
P_0 = $0.60.[2] While this revision has little effect on projected baseline CFC use early in the decade, revised 1990 CFC-113 use is 135.1 million pounds of CFC (or 104.1 million weighted pounds), about 8 percent lower than in Palmer et al. (1980).

The baseline CFC use-levels in Table A.1 assume that CFC supply prices (except for solvents) remain constant at the levels indicated in Table 1.3. At higher CFC prices, some technical options for reducing CFC use will become attractive to regulated firms. These options generally involve the acquisition of capital equipment (e.g., a CFC recovery unit) or conversion to an alternative chemical. These

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supply price of CFC-113 solvent is not independent of the size of the market. The production of this CFC is subject to economies of scale over a wide range of output. As a result, when the demand for CFC-113 grows, producers tend to compete by lowering the CFC price. This results in a higher quantity of CFC demanded than if the supply price remained constant.

[2] In Palmer et al. (1980), the assumed value for V_0 was 68.0 million pounds, which implies CFC supply prices about 7 percent less than those computed here.

responses by firms account for the majority of CFC use-reductions under all our scenarios.

Our analysis translates industry-supplied data on technical options into two variables: the cost per pound of CFC use-reduction, including amortized fixed expenses and any change in variable costs, and the amount that CFC use is reduced by the implementation of the activity. The first variable defines a "critical price increment" for the activity: i.e., how much the CFC price must be raised above the baseline level to induce the activity's voluntary implementation. The second variable determines the effectiveness of the activity.

As an illustration, consider CFC recovery and recycle for smaller plants producing molded flexible urethane foam. According to Palmer et al. (1980, pp. 53-61), the cost of installing and operating a carbon absorption unit for these plants is $0.70 per pound of recovered CFC-11. If the price of CFC-11 rises by this amount, we expect the option will voluntarily be undertaken, reducing CFC use in these plants by 50 percent below baseline levels. This amounts to a reduction of 3.7 million pounds of CFC-11 use in 1980 and 5.7 million pounds in 1990, if the price increase is applicable to both years.

Within each user category, there may be a number of CFC-saving activities. The critical price increment and effectiveness of an option generally depends upon the characteristics of the CFC-using plant. For example, recovery and recycle costs more per pound of CFC recovered in small plants than in large plants. Thus, we can describe the technical responses of firms to higher prices by Expression (2):

$$[(\Delta P_{1j}, \Delta C_{1j}), \ldots, (\Delta P_{nj}, \Delta C_{nj})] , \tag{2}$$

where ΔP_{ij} = the critical price increment for the i^{th} activity ($i \varepsilon n$) of the j^{th} user category, ΔC_{ij} = emissions reduction of activity i,j, and the activities are ordered from the least costly (i.e., lowest critical price increment) to the most costly (i.e., highest critical price increment). We estimated this information for each user category for 1980 and 1990.

In Palmer et al. (1980), the analysis of technical options was based on cautious assumptions in two respects. First, when alternative data for the cost of an option were available, we generally based estimates of critical price increments on the higher cost data. Second, where available information was inadequate to estimate the critical price increment or effectiveness of a technical option, we assumed the option would not be implemented, regardless of the increase in CFC prices. The latter assumption affects estimates of CFC use under regulation in the Group C user categories, for which CFC-saving activities are available, but have unreliable data. These cautious assumptions are carried over here in the analysis of Scenario I. However, the other scenarios relax the stringent (and unrealistic) assumption that Group C user categories are unresponsive to higher prices.

When combined with the baseline forecast of CFC use by user category, the information summarized by Expression (2) identifies points on the CFC demand schedule of the user categories, based on our cautious assumptions. Specifically, given a permanent increase in the price of a CFC, all CFC-saving activities with critical price increments less than or equal to the increment in the CFC price are assumed to be implemented. If regulation increases the CFC price by an amount equal to

ΔP_{kj}, then the quantity of CFC demanded by the j^{th} user category is:

$$C_{kj} = C_{Bj} - \sum_{i=1}^{k} \Delta C_{ij}, \tag{3}$$

where C_{Bj} is baseline CFC use for the user category. Thus, the demand schedule for user category j is defined by the set of price-quantity pairs:[3]

$$[(0, C_{Bj}), (\Delta P_{1j}, C_{1j}), \ldots, (\Delta P_{nj}, C_{nj})] . \tag{4}$$

In this demand schedule, the pair $(0, C_{Bj})$ corresponds to the absence of regulation. In addition, each price, ΔP_{ij}, is expressed as an increase over the CFC supply price (in 1976 dollars). That is, the prices in Expression (4) are the full prices paid for the CFC less the CFC supply price. These price increments could be in the form of a permit price, a CFC tax, or an increase in the CFC manufacturers' price, depending upon how the policy is implemented.

Expression (4) specifies the user category demand schedules estimated in Palmer et al. (1980). These demand schedules are step functions: All CFC users who implement a particular activity do so at the same permit price (or at the same cost per pound). Each critical price increment for a user category defines a new step in the demand schedule. The height of each step determines the resource cost per pound of the activity. This represents the value of resources used by the economy to reduce CFC use. Because estimates of critical price

[3] Consistent with the assumptions in Palmer et al. (1980) and Scenario I of this report, this demand schedule also assumes that consumers take no actions to reduce their use of CFC-made products. This assumption is relaxed in Scenarios III to VI, as discussed below.

increments are generally based on cautious (i.e., high cost) assumptions, the implied resource costs per pound correspond to the cost characteristics of firms in the least advantageous position to reduce CFC use. It is likely that some firms could implement an activity at a lower cost than others. By assuming that no firms react to the regulation until the CFC price is raised by the full critical price increment, our previous estimates of resource costs are probably too high.

To correct for this bias, the demand schedules described by Expression (4) are transformed from step functions into piecewise linear functions. Methodologically, this is accomplished by using linear interpolation to determine the quantity of CFC demanded when the price increment is between the levels implied by adjacent price-quantity pairs in Expression (4). Thus, if the CFC price increase, ΔP, is such that $\Delta P_{kj} \leq \Delta P < \Delta P_{k+1,j}$, the quantity of CFC demanded in user category j as a function of the price increment is:

$$C_j(\Delta P) = C_{k+1,j} + \left(\frac{\Delta P_{k+1,j} - \Delta P}{\Delta P_{k+1,j} \quad \Delta P_{kj}} \right) (C_{kj} - C_{k+1,j}) . \tag{5}$$

For each user category, Expression (5) identifies a unique quantity of CFC use in 1980 and 1990 for any price increment.

For years between 1980 and 1990, the user category demand schedules are assumed to shift horizontally at each possible price increment at a constant annual rate of growth. If we let C_j^{80} and C_j^{90} denote the quantity of CFC demanded by user category j in 1980 and 1990 at the increment ΔP, then the rate of growth in demand is:

$$r = \left(\frac{C_j^{90}}{C_j^{80}} \right)^{0.1} - 1, \tag{6}$$

and the quantity of CFC demanded t years after 1980 is:

$$C_j^t = (1 + r)^t C_j^{80}. \qquad (7)$$

WEIGHTING

The ozone depletion potential of a pound of CFC varies among the various CFC chemicals. To account for these differences, we define a standard unit of measure, the weighted pound. Conceptually, each weighted pound poses the same environmental hazard to the ozone layer. The weighting factors used to convert CFC pounds to weighted pounds in this report are contained in Table 1.1.

Under the production cap policy, all user categories and all types of CFCs would compete in a common market for the restricted amount of CFC production. The price increases generated by this market are specified in terms of price increments (or permit prices) per weighted pound. While all CFC purchasers would pay the same price for a weighted pound, this translates into higher price increases per CFC pound for more heavily weighted CFCs. As a result, incentives for CFC use reductions are greatest where they will do the most good.

Before the demand schedules of individual user categories can be aggregated to predict outcomes in the common market, they must be converted into weighted pound units. In effect, this conversion generates an adjusted set of price-quantity pairs for the user category, analogous to Expression (4):

$$[(0, C_{Bj}^a), (P_{1j}^a, C_{1j}^a), \ldots, (P_{nj}^a, C_{1j}^a)], \qquad (8)$$

where $P^a_{ij} = \Delta P_{ij}/w_j$, $C^a_{ij} = w_j C_{ij}$, and w_j is the CFC weighting factor for the CFC used in the j^{th} user category.

In Expression (8), P^a_{ij} is the critical permit price for a CFC-saving activity[4] and C^a_{ij} is CFC use measured in weighted pounds at the critical permit price. For example, suppose a technical option reduces CFC-12 use by 100 pounds in a user category and has a critical price increment of $1.00 per pound of CFC-12. If implemented, this option would reduce use by 79 weighted pounds, since the weight of CFC-12 is w = 0.79. In a permit market, producers would be required to purchase 0.79 permits for each pound of CFC-12 used. Therefore, the permit price required to induce this activity is $1.27 = 1.00/0.79.

Using these adjusted price and quantity data, we derive an adjusted piecewise linear demand schedule for each user category:

$$C_j(P) = C_{k+1,j} + \left(\frac{P^a_{k+1,j} - P}{P^a_{k+1,j} - P^a_{kj}}\right) (C_{kj} - C_{k+1,j}). \qquad (9)$$

Expression (9), which is analogous to Expression (5), defines CFC demand in user category j, measured in weighted pounds, at any permit price, P, that emerges from the common CFC market.

The weighting factors employed in this report differ in two respects from those in Palmer et al. (1980). First, different CFCs are

[4] For expositional convenience, this appendix refers to regulated increases in the price of CFCs in terms of permit prices. However, the same results would obtain if the price increases were in the form of a CFC tax or an increase in the price charged by CFC manufacturers.

used as the base unit of measure for the weighting factors. Second, the relative weighting factors differ among the CFCs.

In the earlier report, CFC-113 was used as the base unit of measure: one weighted pound was defined to correspond to one pound of CFC-113. In this report, CFC-11 is used as the base unit of measure to be consistent with the weighting factors proposed by EPA. While this revision results in lower numbers to describe CFC use in weighted pounds, the choice of a base unit of measure actually has no economic implications. Thus, aggregate 1980 baseline CFC use is estimated at 455 million "permit" (or weighted) pounds in Palmer et al. (1980) and at 341 million weighted pounds here; but, aside from the minor revisions noted earlier, the underlying CFC use-levels in pounds of CFC are identical.

In contrast, the revision in the relative weighting factors among the CFCs does have economic implications. Under EPA's proposed weighting factors, CFC-11 has a lower weighting factor <u>relative</u> to the other CFCs than implied by the previous weights. The economic effect of this revision is that under regulation the price of CFC-11 will rise by relatively less (and the prices of other CFCs by relatively more) than if the earlier weighting factors were used as the basis for policy formation. This revision reflects a change in the scientific basis of the weighting factors. The factors in Palmer et al. (1980) were based solely on the chlorine content of each CFC; the revised factors also account for the expected atmospheric lifetimes of the CFCs.

AGGREGATE CFC DEMAND UNDER ALTERNATIVE SCENARIOS

The aggregate demand for CFCs as a function of the permit price, $C_T^a(P)$, is determined by the horizontal summation of the user category demand schedules:

$$C_T^a(P) = \Sigma_j C_j^a(P). \tag{10}$$

While all six scenarios involve this aggregation procedure, each differs in its assumptions about whether and when various CFC-saving activities are implemented in response to higher prices.

The demand schedules in Scenario I (and our previous report) assume that only the CFC-saving technical options in the Group A user categories are implemented in response to higher prices. For these user categories, estimates of the variables P_{ij}^a and ΔC_{ij}^a are based directly on industry data. For Group B and C user categories, ΔC_{ij} under Scenario I is always zero and CFC use equals the baseline level, regardless of how much CFC prices rise. Scenario I also assumes that final product consumers will not engage in activities to reduce their purchases of CFC-using products.

Given these underlying assumptions, aggregate CFC use in weighted pounds under Scenario I, $C_T^1(P)$, can be written as:

$$C_T^1(P) = C_{BT}^a - \Sigma_j \Sigma_i \Delta C_{ij}^a , \tag{11}$$

where C_{BT}^a = total baseline CFC use, i is summed only over CFC-saving activities that have critical prices less than or equal to the permit price, P,[5] and j is summed only over Group A user categories. Like

[5] That is, the values of the subscript i in Expression (9) are defined by the set $\{i \varepsilon n | P_{ij} \leq P\}$.

the individual user category demand schedules, this aggregate CFC demand schedule is piecewise linear, with slight "kinks" at all the critical permit prices implied by the various user categories.

Scenario II increases the price responsiveness of Scenario I by including technical options for Group C user categories. For each Group C user category, this scenario assumes that at each permit price the percentage reduction in CFC use below baseline levels is the same as the average percentage reduction of the Group A user categories. To compute market outcomes, we define a variable δ, which under Scenario II equals baseline CFC use in the Group C user categories as a fraction of baseline use in Group A. Given the "equal percentage reduction" assumption, the total reduction in CFC use under Scenario II is $(1 + \delta)$ times the reduction under Scenario I at each permit price, P. Therefore, Scenario II aggregate CFC demand in weighted pounds, $C_T^2(P)$, is:

$$C_T^2(P) = C_{BT}^a - (1 + \delta)(C_{BT}^a - C_T^1(P)). \qquad (12)$$

Scenarios III to VI postulate that consumers of residential foam insulation and some flexible foam products switch to non-CFC products as the production cap policy raises the prices of the former goods. These scenarios assume that the amount of CFC used to produce these foam products is a fixed proportion of final product output levels. Therefore, if the permit price is P, the percentage increase in final product prices is $(w_j P/P_c)s_j$, where w_j is the CFC weighting factor, P_c is the baseline CFC price (see Table 1.3), and s_j is the CFC share of total production costs for the user category. Further assuming that final product demand has a constant arc elasticity of demand, $\eta_j < 0$,[6] the CFC demand schedule for these products is:

$$C_j^a(P) = C_{Bj}^a \left[1 + \left[\frac{w_j \cdot P \cdot s_j}{P_c} \right] \eta_j \right] . \qquad (13)$$

For 1990, the aggregate demand schedules of Scenarios III to VI are identical and reflect the same CFC-saving activities: The responsiveness of Group A users is the same as under Scenario I; the responsiveness of Group B users is the same as under Scenario II; and the consumer responses in flexible foams and residential insulation correspond to demand arc elasticities of -1.0 and -0.5, respectively. The 1990 aggregate demand schedule for these scenarios is presented in Table A.2.

However, these scenarios differ substantially as regards the timing of Group C and consumer responses in earlier years. Prior to 1990, Scenarios III to VI use the same methodology to estimate CFC reductions for Group C user categories and for consumers, but each scenario assumes different values for the variables δ and η_j:[7]

Scenario III: Assumes δ is the same as under Scenario II for all years and each η_j is zero for 1980 to 1989.

Scenario IV: Assumes δ is the same as under Scenario II and each η_j is at the indicated 1990 level for 1980 to 1989.

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[6] This elasticity is defined as the percentage change in quantity demanded from the baseline level divided by the percentage change in price from the baseline price.

[7] Lower values of δ and η_j correspond to less responsive annual demand schedules. Note that the minimum value of δ (zero) corresponds to zero responsiveness by Group C users; the maximum value of δ corresponds to the "equal percentage reduction" assumption of Scenario II.

Scenario V: Assumes δ is zero until 1986 and gradually increases to the Scenario II level; each η_j is zero until 1990.

Scenario VI: Assumes δ and each η_j are zero in 1980 and as indicated above in 1990. Interim year demand schedules are then calculated using Expressions (6) and (7).

Table A.3 shows the resulting differences in the annual aggregate demand schedules of Scenarios III to VI for 1986, the year when equilibrium prices differ the greatest.

CFC PRICES, RESOURCE COSTS, AND TRANSFER PAYMENTS

The shape of the aggregate demand schedule determines the estimated economic impacts of a production cap policy, including the effects on CFC prices and the magnitude of resource costs and transfer payments. These economic impacts of regulation are illustrated in Fig. A.1, where the curve DD represents a hypothetical demand schedule, C_e represents the CFC production cap constraint, and C_B is baseline CFC use.[8]

The CFC price increment caused by regulation is the price level which clears the market, i.e., that price where the aggregate quantity of CFC demanded just equals the restricted CFC production level. In Fig. A.1, this price increment is illustrated by P_e. The equilibrium price increments calculated for our scenarios are presented in Tables 2.1, 3.1, and 4.1. The form in which higher CFC prices are actually paid (but not necessarily their magnitude) will depend upon how the production cap policy is implemented. If, for example, CFC permits were

[8] For convenience, Fig. A.1 illustrates the demand schedule as a smooth curve. As noted previously, the demand schedules actually used in the market simulation are piecewise linear.

Table A.2

AGGREGATE CFC DEMAND SCHEDULE FOR THE PLAUSIBLE SCENARIOS: 1990

Permit Price [a]	Aggregate CFC Use (millions of weighted pounds)
$0.00	582.7
0.10	531.9
0.16	519.6
0.21	515.0
0.22	514.0
0.24	511.8
0.27	509.9
0.30	502.9
0.34	493.7
0.39	491.0
0.42	489.4
0.60	449.7
0.69	442.0
0.70	441.2
0.73	438.6
0.79	434.1
0.90	422.6
1.16	399.1
1.18	384.4
1.29	380.9
1.42	375.8
1.56	370.4
1.57	369.4
1.67	359.7
1.72	354.6
1.81	352.4
2.01	349.6
2.56	343.7
2.81	341.0

[a]Assumes manufacturers' CFC prices are indicated by Table 1.3 for all years. A permit entitles the holder to use one weighted pound of CFC. Each permit price corresponds to a critical price increment for one or more user categories.

Table A.3

AGGREGATE CFC DEMAND SCHEDULES FOR THE
PLAUSIBLE SCENARIOS: 1986

Permit Price [a]	Aggregate CFC Use (In millions of weighted pounds) Scenario III	Scenario IV	Scenario V	Scenario VI
$0.00	467.3	467.3	467.3	467.3
0.10	429.8	426.2	441.3	435.0
0.16	421.3	416.9	435.5	427.4
0.21	416.8	411.8	432.2	423.1
0.22	415.7	410.6	431.5	422.1
0.24	413.0	407.4	429.5	419.8
0.27	409.8	403.9	427.2	416.9
0.30	402.7	396.0	422.2	411.6
0.34	393.4	385.7	415.7	404.5
0.39	388.5	380.1	412.2	399.8
0.42	386.9	378.3	411.1	397.9
0.60	364.9	354.8	[illegible]	377.8
0.69	359.1	348.5	392.2	371.3
0.70	358.5	347.8	391.8	370.7
0.73	356.7	345.8	390.5	368.9
0.79	353.5	342.4	388.3	365.7
0.90	345.3	333.4	382.7	358.2
1.16	327.4	313.9	370.3	341.3
1.18	316.0	301.4	362.4	333.8
1.29	313.4	298.6	360.6	330.1
1.42	309.6	294.4	358.0	325.2
1.56	305.5	289.9	355.2	319.9
1.57	304.8	289.1	354.7	319.3
1.67	297.7	281.4	349.8	312.9
1.72	294.0	277.3	347.2	309.6
1.81	292.6	275.9	346.3	306.9
2.01	290.6	273.6	344.9	304.5
2.56	286.1	268.8	341.8	298.7
2.81	284.9	267.5	341.0	296.5

[a]Assumes manufacturers' CFC prices are indicated by Table 1.3 for all years. A permit entitles the holder to use one weighted pound of CFC. Each permit price corresponds to a critical price increment for one or more user categories.

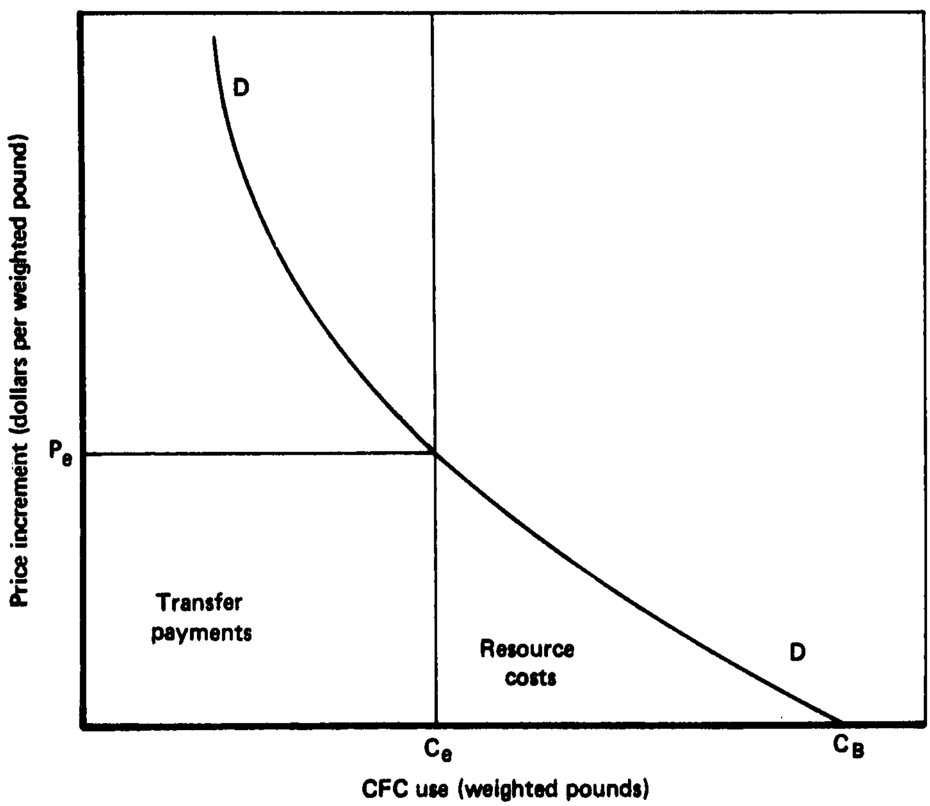

Fig. A.1—A hypothetical aggregate CFC demand schedule distributed among CFC users, higher CFC prices would take the form of a permit price that must be paid to acquire a weighted pound of CFC. If, in contrast, a quota were merely set on the total output of CFC manufacturers, these price increments would take the form of an increase in the CFC prices received by the manufacturers above the baseline level.

The resource costs of the policy reflect the cost of activities undertaken to reduce CFC use--whether by regulated firms or, in the cases of flexible foam and residential insulation, by consumers. Recall that the critical price increment of an activity (i.e., the CFC price increase which results in its voluntary implementation) is determined by the cost of the activity per pound of CFC use reduction. Thus, the resource cost of a unit reduction in CFC use in Fig. A.1 is illustrated by the height of the derived CFC demand schedule. It follows that the total resource costs of the policy are illustrated by the area under the demand curve and between C_e and C_B in Fig. A.1.[9]

Resource costs for each user category are determined similarly by the area under the user category demand schedules. Estimates of resource costs in a user category reflect both the costs borne by firms that implement technical options and the costs borne by consumers who switch from products in that category to non-CFC substitutes. Given the piecewise linear specification of demand schedules in our simulations

[9] When the price of a productive input increases, less of the input is used because (1) producers seek ways to manufacture the final product using less of the more costly input and (2) consumers turn to relatively less costly final products. Both of these effects are summarized in an input demand schedule, such as the one illustrated in Fig. A.1. Thus, the indicated Resource Cost area in Fig. A.1 reflects the costs borne by both consumers and producers to reduce CFC use. For further discussion of the relationship between consumer losses and the derived demand for an input, see Wisecarver (1974).

and the equilibrium price increment, $P_e = P^a_{kj}$, resource costs in user category j are given by the following formula:

$$RC_j = \sum_{i=1}^{k} \tfrac{1}{2}(P^a_{ij} + P^a_{i-1,j})\Delta C^a_{ij}, \tag{14}$$

where all variables are defined as in Expression (8).

Aggregate resource costs, RC_T, are the sum of resource costs over all user categories:[10]

$$RC_T = \Sigma_j RC_j. \tag{15}$$

The transfer payments that result from the regulatory policy simply equal the equilibrium price increment times the quantity of CFC demanded. Thus, for user category j:

$$TP_j = P_e C^a_j(P), \tag{16}$$

and for all CFC users:

$$TP_T = \Sigma_j TP_j. \tag{17}$$

Conceptually, this report treats transfer payments as a transfer of wealth away from regulated firms and consumers. If EPA instituted a permit system and initially sold permits for the production cap through

[10] In this report, all measures of cumulative resource costs and transfer payments are discounted. Discounting is necessary because the time profile of annual costs and transfer payments differs among our scenarios and because firms are not indifferent to when regulatory expenses are incurred. If regulatory expenses are incurred immediately, rather than deferred, a firm must forego the interest income that would have been earned had it invested in an alternative income-generating activity. Throughout this report, we employ a discount rate of 11 percent in real terms. This rate is intended to reflect the current real yield on nonconstruction investment in the United States. For further discussion, see Palmer et al. (1980, pp. 32-33).

an auction, our estimates of transfer payments would take the form of money that is paid to the government by CFC users for their initial allocation of permits. Alternatively, if a quota were established on the total output of CFC manufacturers and permits were not issued, transfer payments would represent a transfer of wealth from CFC users and their customers to CFC manufacturers.

However, the distributive effects of transfer payments depend critically on how the policy is actually implemented. In particular, policies can be designed to compensate for or prevent these large wealth transfers. An economic analysis of the distributive and allocative effects of alternative "compensation policies" is beyond the scope of this report. However, this task is the subject of ongoing research for the EPA, which will be published in a later Rand report.

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This report projects the economic costs of a regulatory cap that would restrict total U.S. annual chlorofluorocarbon (CFC) production to the 1980 levels. Alternative cost estimates reflect alternative hypotheses about U.S. industries' responses to high CFC prices. Six scenarios are developed with different assumptions regarding elasticities of demand for the final products and the availablity of substitute technologies. Cost estimates range between $1.3 billion and $3 billion in transfer payments and between $184 million and $341 million in resource costs. The most reasonable estimate, with assumptions likely to reflect actual market outcomes, is $1.8 billion in transfer payments and $275 million in resource costs.

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