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ALUMINUM AS A COMPONENT OF SOLID WASTE AND A RECOVERABLE RESOURCE

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

This study takes a look at aluminum as a component of solid waste and as a recoverable resource. Not only does it present important information about the preservation and wise use of this precious natural resource, but it also considers the many aspects of aluminum recycling that relate to air, water, and land pollution.

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ABSTRACT

This report surveys the production and use of aluminum and its occurrence in solid waste; the aspects related to resource recovery are emphasized. Surveyed are both the primary and secondary aluminum industries, which produce aluminum from virgin materials (i.e. bauxite) and scrap, respectively. Supply and demand analysis is used to analyze fluctuations in scrap prices and implications of increased recovery of aluminum from solid waste.

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INTRODUCTION

Increased recycling is one aspect of the heightened environmental concern in the United States today. The object is to channel the materials and potential energy in refuse away from incinerators, dumps, and landfills, and into the creation of useful products.

Federal action in the recycling area was initiated by the Resource Recovery Act of 1970, which was enacted on October 26, 1970 (Public Law 91-512, 91st Congress, H.R. 11833). The Act calls for the Environmental Protection Agency to report to Congress on the present situation and on the needs and possibilities for increased recycling of solid wastes. This study of aluminum is in support of that legislative mandate. It presents a broad overview of the production and use of aluminum in the United States, with emphasis on aluminum in solid waste (especially municipal refuse) and recycling. The approach is economics oriented, since profit is the main determinant of the degree of resource recovery today.

SUMMARY OF FINDINGS

The Primary Aluminum Industry

The three largest markets for primary aluminum in 1972 were building and construction, transportation, and containers and packaging. Total shipments grew at an average annual rate of 8 percent during the period 1960-72, with individual domestic markets growing at rates ranging from 6.6 percent for consumer durables to 15.5 percent for containers and packaging.

The demand for aluminum is relatively insensitive to price changes in the short run, but fairly sensitive in the long run. The average annual growth rate for aluminum demand is expected to decrease from about 8 percent during the past 25 years to about 6 percent over the next 25 years or so.

The earth has abundant deposits of the necessary raw materials for aluminum production. In fact, aluminum is the most abundant metallic element in the earth's crust. The United States imports most of its bauxite needs. Primary aluminum production uses tremendous amounts of electric energy. Estimates indicate that the average annual cost of additional air and water pollution controls for the primary aluminum industry will reach $50 per ton of production by 1977.

Secondary Aluminum Industry

Scrap recovery has grown at an average annual rate of about 7 percent since 1950. This growth is due largely to a near 8 percent rate of increase in recovery of new scrap (that produced by manufacturing processes). Recovery of old scrap (that salvaged from discarded products) increased at a 5.5 percent average annual rate.

Total domestic scrap recovery has yielded about 25 to 30 percent as much aluminum as primary production in recent years. Recovery of old scrap has accounted for about 20 percent of total scrap recovery. The scrap recovery flow in the United States includes the operations of scrap dealers, secondary smelters, nonintegrated foundries and fabricators, and integrated primary producers. Approximately 70 percent of all scrap recovered, and probably all old scrap, goes to secondary smelters who produce specification secondary aluminum. Nearly 90 percent of this product goes to foundries to make castings, which are used in durable items, primarily automobiles and other transportation products. Recent estimates indicate that only a small fraction (less than 15 percent) of the old aluminum scrap generated is recovered.

Aluminum scrap prices fluctuate widely, a fact that creates uncertainty about future prices, revenues, and profits and tends to discourage capital investment in the scrap business. The wide price fluctuations may be partially explained by price-inelastic demand and supply of scrap.

Estimates indicate that the average annual costs of air pollution controls for secondary smelters would be about $6.34 per ton of production by 1977, considerably less than the estimated costs of pollution controls for primary producers.

Demand for secondary aluminum is expected to grow at an average annual rate of almost 8 percent during the next 25 years or so.

Aluminum in Solid Waste

By weight, aluminum represents a very small fraction of collected municipal refuse (estimates are in the range of approximately 0.5 to 1 percent, or approximately 600,000 to 900,000 tons annually). Much of this aluminum is in container and packaging items. The major solid waste problem associated with aluminum is the littering of such items.

Aluminum is among the most valuable component materials of municipal refuse in terms of scrap price, typically selling for 15 to 20 times the price of scrap steel, glass, or paper. However, costs of separation and scrap processing inhibit aluminum recovery to the point that relatively little aluminum is now diverted from the municipal refuse cycle. Most of that which is diverted is recovered through can reclamation programs aimed at recovering all-aluminum beverage cans.

The effect of an increase in the supply of reclaimed aluminum depends on the nature of demand. A substantial increase in aluminum recovery would very likely result in sharp price declines if accomplished in a short period of time; but if it were accomplished over a long period of time, it is likely that it would have relatively little effect on price because of the probable differences in price elasticities of demand in the short and long run.

THE PRIMARY ALUMINUM INDUSTRY

Production Cycle

Aluminum is produced from alumina, an aluminum oxide refined from bauxite, in an electrolytic process. Costs of production are for alumina (30 percent of the total), other raw materials (15 percent), electricity (16 percent), labor (14 percent), capital (20 percent), and overhead and other operating expenses (5 percent).[1] Electric energy is very important--13,000 to 18,000 kw-hr are used per ton of aluminum output. Technology has not changed significantly since the industry's beginnings in 1888. Bauxite is refined into alumina through a chemical oxidation process, the Bayer process; alumina is then reduced to aluminum by the electrolytic Hall-Heroult process.

Industry Structure

The domestic industry has evolved from a monopoly (pre-World War II) by the Aluminum Company of America (Alcoa) to a structural oligopoly[2] . There are now 12 firms, 3 of which control 68 percent of industry capacity (Alcoa, Reynolds, and Kaiser).

Demand and Markets for Aluminum

Aluminum is a very versatile material, with a wide range of properties and applications. It is a light-weight (low-density) metal with a high strength/weight ratio. It has strong corrosion resistance and good thermal and electrical conductivity. The metal has high reflectivity, is very ductile, and is also nontoxic, easily coated or painted, and is generally easily combined (especially as foil) with a variety of other materials.

A breakdown of the specific markets for aluminum in recent years is given in Table 1.

Aluminum demand is fairly insensitive to short-run price variations (i.e., it is "price-inelastic"), but it is responsive to long-run price changes (i.e., it is "price-elastic" in the long run)[3].

TABLE 1

ALUMINUM PRODUCT SHIPMENTS BY MAJOR MARKET*

	Percent of Total Shipments			1960-1972 Annual Growth Rate (%)
	1960	1966	1972	
Building & Construction	25.7	22.0	26.4	8.3
Transportation	18.1	21.6	18.5	8.3
Consumer Durables	10.8	10.1	9.2	6.6
Electrical	11.2	14.4	12.7	9.2
Machinery & Equipment	7.0	7.2	6.1	6.8
Containers & Packaging	6.8	8.2	15.2	15.5
Exports	13.0	6.5	4.7	-0.8
Other	7.4	10.1	7.1	7.8
TOTAL				8.0

*<u>Aluminum Statistical Review 1972</u> (New York: The Aluminum Association, 1973).

Frequent price changes themselves adversely affect the demand for any material because of the uncertainty they create about the future price, uncertainty which discourages capital investments necessary to use the material. Therefore, in the best long-run interest of the industry, the largest aluminum producers generally try to minimize price fluctuations, particularly short-run price increases. The record of price movements during the period 1961-72 is given in Table 2.

Environmental Aspects

At the beginning of the production cycle, restoration of mined-out, open-pit areas is becoming increasingly important in bauxite-producing countries. Once extracted, the refining of bauxite into alumina results in the production of a finely divided residue (red mud tailings). About 5.5 million tons of this waste material are generated annually at eight alumina plants located along the lower Mississippi River, the Gulf Coast, and in Central Arkansas. At most plants, the red mud is impounded in large mud lakes adjacent to the plants, although some is discharged into the Mississippi River and some is used in industrial applications (e.g., cement making).

Air pollution from primary aluminum production consists mainly of particulates and fluorides. Aluminum plants are estimated to have emitted 31,800 tons of particulates in 1967 at a 73 percent level of control. To meet applicable particulate emission standards, the level of control must be raised to approximately 98 percent, a level at which the aluminum industry will incur an estimated annual cost of $44.14 per ton of production in fiscal 1977. This cost will vary considerably, depending on the specific production process used at a given plant.[4] Water pollution controls should be relatively less costly, and together, the average annual cost of additional air and water pollution controls should reach $50 per ton of production by 1977.[5]

Foreign Aspects

The United States imports most of its bauxite needs (about 85-90 percent), mainly from Jamaica, Surinam, and Guyana. The remainder is mined domestically in Arkansas. Alumina needs are met by refining about 80 percent of it domestically and importing the rest. In 1972, U.S. production represented approximately 34 percent of the world's total production of primary aluminum, and the United States and Canada combined accounted for about 43 percent. The United States is a net importer of primary aluminum: for 1962-72, exports averaged about 7.3 percent of total net shipments by U.S. producers, and imports averaged 12.5 percent implying net imports of a little over 5 percent.

TABLE 2

PRICES OF 99%+ VIRGIN ALUMINUM, 1961 - 1972

Year	List price, N.Y.*			Price realization†(¢/lb.)	
	Range of monthly average (¢/lb.)	Number of price changes	Average for the year	Alcan	Alcoa
1961	24.00 - 26.00	2	25.46	22.2	25.3
1962	22.54 - 24.00	1	23.88	21.2	23.9
1963	22.50 - 23.00	3	22.62	20.4	22.2
1964	23.00 - 24.34	6	23.72	23.3	23.2
1965	24.50	1	24.50	24.2	23.5
1966	24.50	0	24.50	24.3	23.9
1967	24.74 - 25.00	2	24.98	24.1	ǂ
1968	25.00 - 26.00	2	25.57	22.0	23.6
1969	26.55 - 28.00	4	27.18	23.0	24.8
1970	28.00 - 29.00	2	28.71	24.5	26.8
1971	29.00	0	29.00	22.7	23.9
1972	25.00 - 29.00	2	26.45	22.6	ǂ

*Source: Metal Statistics 1973 (New York: Fairchaild Publications, 1973).

†The difference between list price and realized price is the discount offered to buyers by producers. Realized prices for Alcan and Alcoa were computed from company statements. (Source: Standard and Poor's Industry Surveys, Metals - Nonferrous: Basic Analysis, 7/12/73 [Section 2], p.M170).

ǂNot available.

Trends

The primary aluminum industry has grown at an average annual rate of 8.2 percent during the period 1947-72. Although the rate is expected to slow somewhat, the industry should continue to grow. The U.S. Bureau of Mines forecasts a "probable" growth in U.S. aluminum demand of 6.1 percent per year during the period 1972-2000.[6] The forecasts for individual markets are given in Table 3.

Aluminum is the most abundant metallic element in the earth's crust and, in general, raw materials for aluminum production should be in plentiful supply for the foreseeable future. The cost of electric energy may rise significantly in the future, thus increasing the cost of aluminum production. Technological changes in the industry can be expected, and they may reduce electric power needs; but major changes are likely to occur gradually.

Competition from substitute materials is a key determining factor of the aluminum industry's future. The traditional rival materials have been steel and copper, and recently plastics have been competing in many present and potential aluminum markets. Much of the aluminum industry's gains over the years have been at the expense of the steel industry, and the two industries are still actively competing in a number of markets: for example, the transportation market (for automotive, rail, and aircraft applications), and the beverage container market. Copper originally held what are now some of the largest markets for aluminum (e.g., electrical applications), and aluminum is presently threatening the market for copper in automobile radiators, air conditioning, and other tubing. Plastics are challenging the hold of aluminum on its largest markets: construction, packaging, and transportation. Other actual or potential competitive materials are magnesium, titanium, and sodium.

THE SECONDARY INDUSTRY

Production Cycle

Secondary aluminum is made from aluminum scrap. Aluminum scrap is characterized as either "new" or "old". New scrap is that generated in a manufacturing process, and old scrap comes from discarded, used products containing aluminum. Annual aluminum scrap recovery figures for 1943-72 are given in Table 4 and are plotted in Figure 1.

Both new and old scrap recovery have shown an upward trend during the post-World War II period, and both were significantly affected by war-related aluminum production. Total scrap recovery increased at an average annual rate of 7.2 percent from 1950 until 1972, largely because of a 7.8 percent average annual rate of increase for new scrap

TABLE 3

FORECASTS OF ALUMINUM DEMAND BY END USE IN THE YEAR 2000*

End use	Aluminum content In thousands of short tons	Ave. annual growth 1972-2000 (%)
Metal		
Construction materials	5,400	5.2
Transportation equipment	6,000	6.9
Electrical equipment	5,000	7.7
Cans and containers	4,000	6.2
Consumer durables	2,500	6.3
Industrial machinery	1,200	5.0
Other	1,800	6.0
Total	25,900	6.3
Non-Metal		
Abrasives	300	4.3
Refractories	1,000	6.4
Industrial chemicals and others	1,200	5.1
Total	2,500	5.1

*Source: Division of Nonferrous Metals, Bureau of Mines, U.S. Department of the Interior.

TABLE 4

ALUMINUM SCRAP RECOVERY, 1943-72*

Year	Amount recovered (In thousands of short tons) Total domestic scrap†	New scrap	Old scrap	Imports‡	Total domestic scrap as a % of domestic primary aluminum production	Old scrap as a % of total
1943	314.0	280.9	33.1	(negligible)	34.1	10.5
1944	325.6	302.7	22.9	1.5	41.9	7.0
1945	298.4	271.1	27.3	4.5	60.3	9.1
1946	278.1	187.5	90.5	13.0	67.8	32.5
1947	344.8	181.0	163.8	14.0	60.3	47.5
1948	286.8	191.1	95.6	64.5	46.0	33.3
1949	180.8	136.2	44.6	36.0	19.9	24.6
1950	243.7	167.3	76.4	61.0	33.8	31.3
1951	292.6	216.0	76.6	18.0	34.9	26.1
1952	304.5	233.3	71.3	6.5	32.4	23.4
1953	368.6	289.6	78.9	24.0	29.4	21.4
1954	313.0	246.6	66.4	7.5	21.4	21.2
1955	414.0	314.5	99.5	19.5	26.4	24.0
1956	428.0	331.0	97.0	10.5	25.4	22.6
1957	445.0	347.5	97.5	12.0	27.0	21.9
1958	354.0	274.5	79.5	9.0	22.6	22.4
1959	449.0	345.0	104.0	10.0	22.9	23.1
1960	438.0	343.0	95.0	4.5	21.7	21.6
1961	485.0	329.5	155.5	5.5	25.4	32.0
1962	582.0	415.5	166.5	6.0	27.4	28.6
1963	654.0	495.0	159.0	8.5	28.2	24.3
1964	707.0	545.0	162.0	7.5	27.6	22.9
1965	829.0	624.0	205.0	24.5	30.0	24.7

TABLE 4

ALUMINUM SCRAP RECOVERY, 1943-72*
(Continued)

Year	Amount recovered (In thousands of short tons) Total domestic scrap†	New scrap	Old scrap	Imports‡	Total domestic scrap as a % of domestic primary aluminum production	Old scrap as a % of total
1966	887.5	700.3	187.3	30.5	29.8	21.1
1967	878.0	703.5	174.5	27.5	26.8	19.8
1968	997.0	816.0	181.0	34.0	30.6	18.1
1969	1150.0	950.0	200.0	26.0	30.3	17.4
1970	1000.0	803.0	197.0	33.0	25.2	19.7
1971	1050.0	834.0	216.0	56.5	26.8	20.6
1972	1126.0	876.0	250.0	47.0	27.3	22.2

*Source: Aluminum Statistical Review 1972 (New York: The Aluminum Association, 1973).

†As reported 1945-54; estimates expanded from reported figures, 1955-70. Also, beginning 1954, figures cover aluminum content and thus are not strictly comparable with data for previous years which covered recoverable aluminum-alloy content. Recovery from sweated pig is included in new scrap during 1945-60, and in old scrap during 1961-72.

‡Recovery from imported scrap equals 90 percent of reported scrap imports.

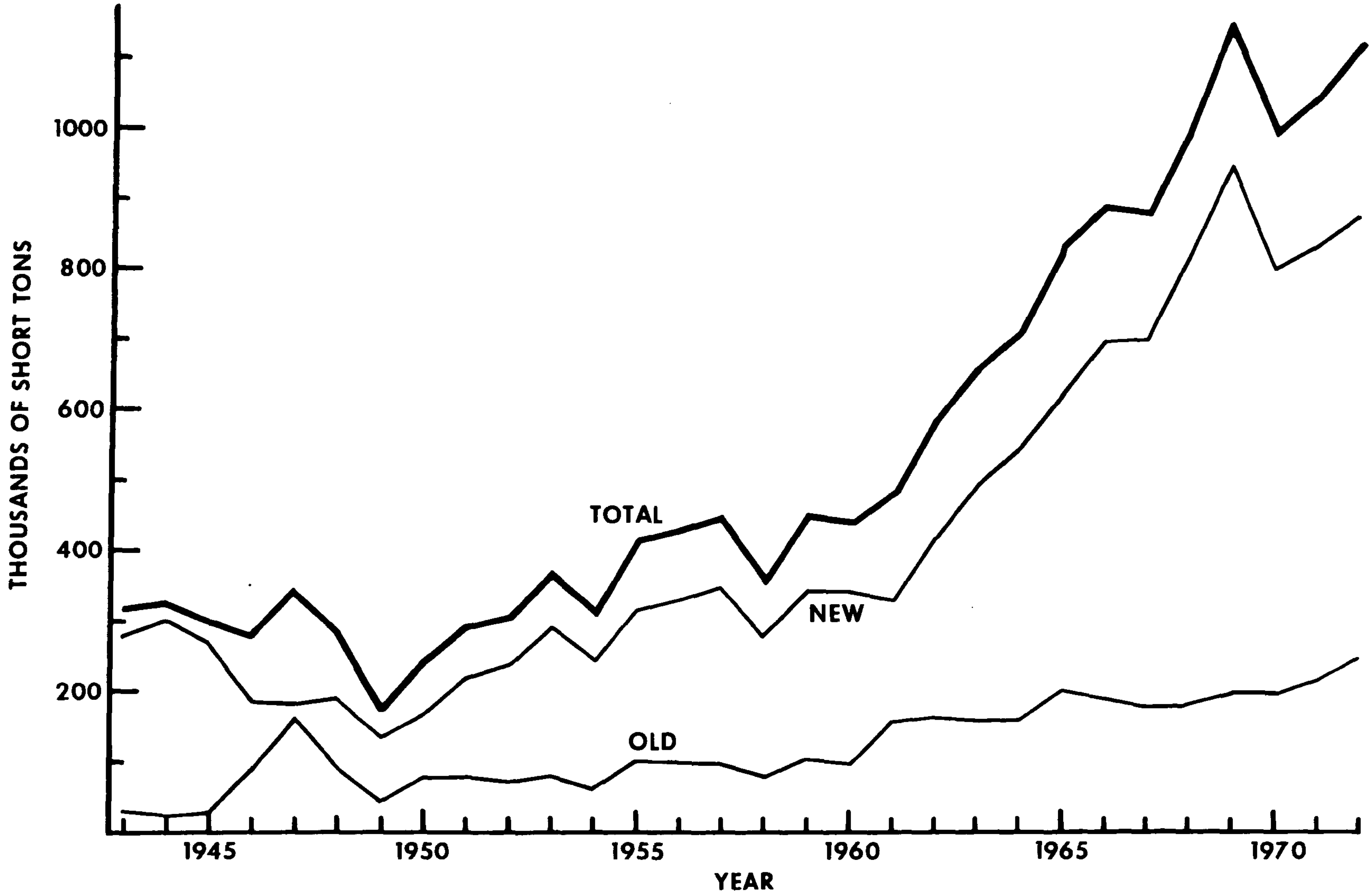


Figure 1. Recovery of aluminum scrap, 1943-72: new scrap, old scrap, and total.

recovery, as old scrap recovery increased at an average annual rate of 5.5 percent. Old scrap's share of total scrap recovery was largest during the immediate post-war years of 1946-50, averaging 33.8 percent, as compared to 22.7 percent for 1951-72.

Scrap Recovery Flow. The production of aluminum from scrap involves several distinct industries: scrap dealers, secondary smelters, non-integrated foundries and fabricators, and the integrated primary producers. How each fits into the total secondary aluminum picture is shown in Figure 2, a schematic diagram of the scrap recovery flow.

New scrap is usually identified as to composition, fairly clean, and generated in volume. It is classified, according to its physical form, into three categories: (a) borings and turnings (from machining and drilling processes), (b) new clippings, forgings, and other solids, and (c) residues such as dross, skimmings, and slag (from various melting operations).

Old aluminum scrap generation and recovery (by product market source) have been estimated in a recent study based on historical production figures for seven market categories of aluminum products and an assumed useful lifespan for each.[7] The quantity of aluminum recovered in each market category was also estimated (Table 5). Although subject to a fairly wide range of error, these estimates do indicate the orders of magnitude involved. Only a relatively small fraction (less than 15 percent) of the old aluminum scrap generated is recovered, and the quantity of unrecovered old scrap is equal to about 30 percent of U.S. domestic production. The three largest sources of the unrecovered old scrap (containers and packaging, transportation, and consumer durables) account for 75 percent of the total not recovered. One source, transportation products, accounts for over half of all old scrap recovered. The smallest quantity of unrecovered old scrap is from the electrical category, which has the highest recovery rate; conversely, the largest quantity of unrecovered scrap is from the category with the lowest recovery rate, containers and packaging.

Aluminum Recovery Industries. The Scrap Industry. The scrap business includes collectors, dealers; brokers and processors. Thousands of scrap collectors seek out scrap materials of all types and sell them to a dealer when they have accumulated a sufficient quantity. New aluminum scrap is usually accumulated by the generators and sold to dealers. Most dealers specialize to some degree, and dealers in aluminum scrap typically specialize in nonferrous metals. Dealers commonly perform the following functions: collection, identification, sorting, processing, packing, storing, and shipping. Identification of scrap composition is very important, and since most aluminum alloys look alike, if the alloy is not indicated or identifiable through the sellers, the dealer must identify it, through his own general knowledge

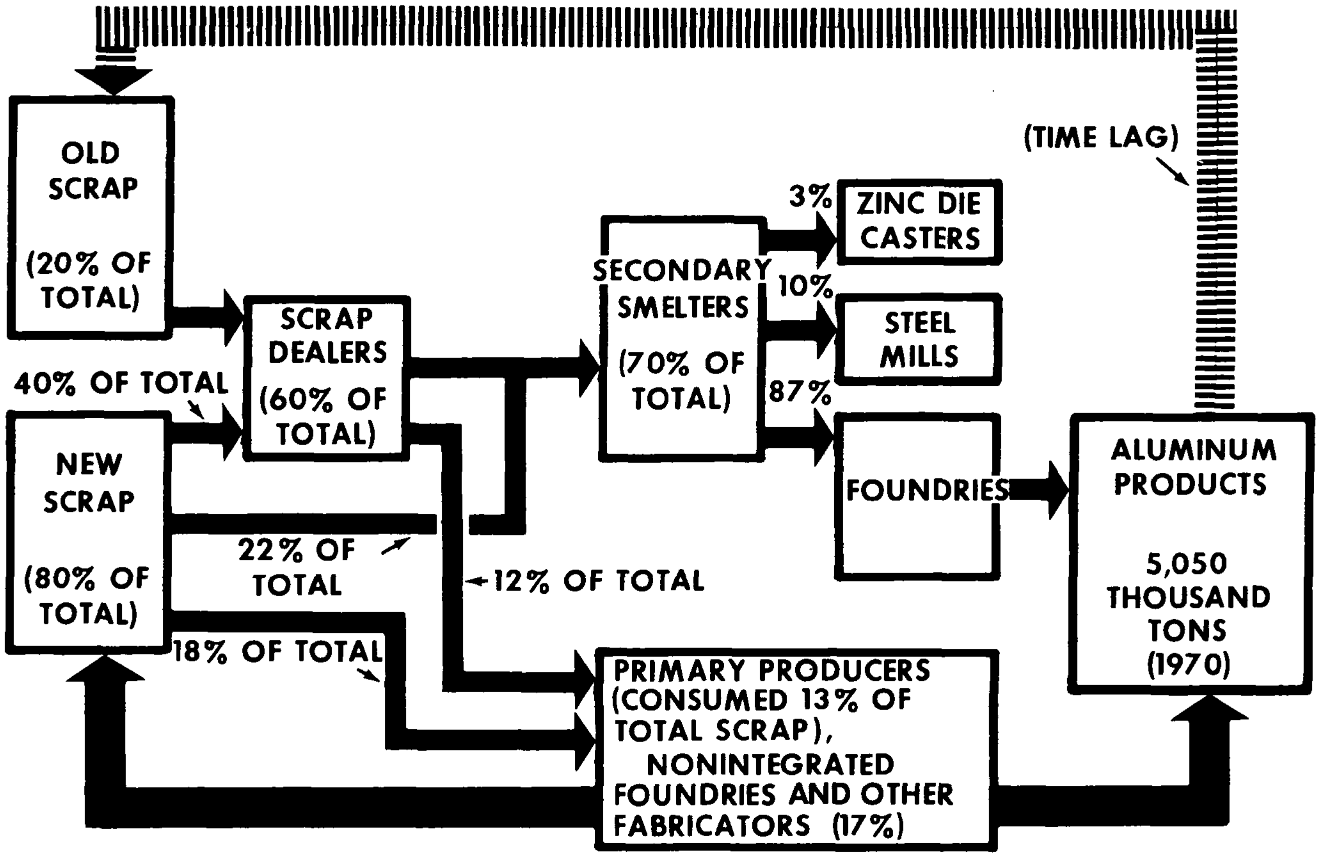


Figure 2. Aluminum scrap recovery flow. (Total scrap recovery for 1970 was 950,000 tons.) Percentages are based on 1967 estimates from Arsen Darney and William E. Franklin, Salvage Markets for Materials in Solid Waste, U.S. Environmental Protection Agency, 1972. (Washington, D.C.: U.S. Government Printing Office), Chapter VI ("Nonferrous Metals").

TABLE 5

OLD ALUMINUM SCRAP RECYCLING, 1969*

Market category	Assumed life span (years)	Estimated discarded aluminum (tons)	Estimated old aluminum recovered (tons)	Estimated percent recovered	Estimated aluminum not recovered (tons)
Building & construction	30	71,000	9,000	12.7	62,000
Transportation	10	329,000	100,000	30.4	229,000
Consumer durables	10	197,000	25,000	12.7	172,000
Electrical	50	7,000	6,500	92.9	500
Machinery and equipment	20	61,000	15,000	24.6	46,000
Containers and packaging	<1	486,000	2,000	0.4	484,000
Other	10	183,000	17,500	9.2	165,500
Total		1,334,000	175,000	13.1	1,159,000

*Source: Tables 13 and B-1 of Study to Identify Opportunities for Increased Solid Waste Utilization, Battelle Memorial Institute, U.S. Environmental Protection Agency, 1972, (National Technical Information Service, PB-212 730).

of the alloys used in the manufacture of various aluminum products, or chemical and spectraprobic tests. Standard identification numbers are used to identify and sort scrap according to about 20 general categories. Once identified and sorted, scrap is processed into a form acceptable to users. Processing involves steps such as cleaning and drying, shredding, crushing, screening, magnetic separation, "sweating", and cable stripping and chopping. Dealers package scrap for shipment by baling or briquetting.

Secondary Smelters. Secondary smelters remelt scrap materials, remove the impurities, and produce specification secondary aluminum. The production process consists of charging scrap into a reverbatory furnace, sampling the molten metal to determine its composition, and introducing any necessary additional compounds (e.g., silicon and copper) and aluminum to bring the melt to specification. Then magnesium is removed and the molten aluminum is degassed.

Foundries. Approximately 90 percent of the output of secondary smelters goes to foundries that make aluminum castings. Castings are produced by three methods: die casting, permanent mold casting, and sand casting. In die casting, molten metal is forced into locked steel die chambers and cooled; the die is unlocked and the casting ejected when the metal has solidified. The castings are then trimmed of excess material and further finished for sale. Die casting is a high-volume, low unit cost method of production. Permanent mold casting has a lower tooling cost and can produce shapes that can't be die cast. Permanent mold castings do require considerable machining, however. The widest application of permanent mold casting is for automotive and diesel pistons. Sand casting is used mainly for unusually large castings or if only a small number of castings are to be made.

Total castings shipments grew at an average annual rate of about 6 percent during 1946-72, mostly because of the tremendous growth in die castings shipments. In recent years, die castings have accounted for a little more than 60 percent of total castings shipments, while permanent semi-permanent mold castings represented almost 25 percent, and sand castings a little less than 15 percent.

Demand for Secondary Aluminum

The demand for secondary aluminum is derived from the demand for products that can be made entirely or in part from secondary aluminum. There are three basic categories of final demand for secondary aluminum: primary products other than castings, deoxidizing uses in steel production, and products that use castings. The first category generally uses exactly identified, segregated, clean, new scrap. This demand for scrap probably represents about 30 percent of total purchased scrap. Aluminum's strong affinity for oxygen makes it a good deoxidizing agent in steel production, and this use accounts for about 7 percent of total recycled purchased scrap (about 10 percent of the output of all secondary smelters). Aluminum castings are the main market for secondary aluminum, and foundries account for about 90 percent of the output of secondary smelters (or 70 percent of all purchased scrap). Castings go into durable items, primarily automobiles and other transportation products. Home appliances and industrial and commercial equipment also use significant quantities of aluminum castings.

Industry Structure, Competition, and Prices

Scrap Dealers. The nonferrous scrap industry is composed of thousands of dealers, each operating in a relatively restricted geographic area (within a 100- to 200-mile radius). The industry appears to be a rather competitive one. There are many firms in the industry, the products are fairly standardized and homogeneous, the industry is not dominated by a few giants, and barriers to entry by new firms are not unusually large.

Aluminum scrap prices fluctuate widely. The record of price movements during 1 53-72 is given in Table 6 and Figure 3.[8] Scrap, prices varied as much as 51 percent from year to year, and the average (absolute) percentage change (year to year) was 13 percent for new clippings and 17 percent for cast aluminum.

Secondary Smelters. Secondary smelters are located in industrial areas such as those surrounding Chicago, Cleveland, New York, Philadelphia, and Los Angeles, near their main customers (foundries) and scrap sources. Although shipping costs do tend to create oligopolistic regional submarkets, there is some nationwide competition. Nationwide concentration ratios are as follows:[9]

Largest firms	Percent of total industry production
2	30
6	60
19	75
31	90

The price history of secondary ingots during 1957-69 is given in Table 7.[10] The largest year-to-year (annual average) price change was the 9.8 percent increase from 1964 to 1965, and the average (absolute) percentage change year-to-year was 4 percent.

TABLE 6

SCRAP ALUMINUM PRICES: NEW CLIPPINGS
AND CAST ALUMINUM SCRAP*

Year	New clippings				Cast aluminum scrap			
	Range		Average	Percent change	Range		Average	Percent change
	High	Low			High	Low		
1953	14.00	10.50	12.57		10.00	7.50	9.10	
1954	14.50	11.25	13.12	4.4	11.00	8.75	10.14	11.4
1955	20.36	14.79	17.93	36.7	17.75	11.29	15.34	51.3
1956	20.50	14.85	16.99	-5.2	17.00	11.44	13.99	-8.8
1957	14.88	13.75	14.07	-17.2	11.64	10.25	10.86	-22.4
1958	13.52	12.75	12.97	-7.8	10.34	9.25	9.76	-10.1
1959	15.25	13.25	14.40	11.0	11.50	9.75	10.75	10.1
1960	15.25	11.75	13.55	-6.3	11.50	8.75	10.25	-4.7
1961	12.50	11.50	11.92	-12.0	9.75	8.75	9.40	-8.3
1962	11.50	10.00	11.05	-7.3	9.25	7.25	8.70	-7.5
1963	12.12	10.00	11.56	4.6	8.75	7.25	8.33	-4.3
1964	12.37	12.12	12.29	6.3	10.87	8.75	10.13	21.6
1965	16.42	12.37	14.68	19.4	13.23	10.87	12.15	19.9
1966	14.15	11.25	12.76	-13.1	11.25	9.21	10.30	-15.2
1967	11.50	9.25	10.49	-17.8	11.25	7.25	8.40	-18.5
1968	11.35	9.75	10.08	-3.9	9.50	8.00	8.41	0.1
1969	14.75	10.02	13.04	29.4	12.50	8.27	11.48	36.5
1970	12.49	8.75	10.94	-16.1	11.24	7.25	9.79	-14.7
1971	8.75	7.25	8.34	-23.8	7.75	5.25	7.00	-28.5
1972	7.75	7.25	7.52	-9.8	5.75	5.25	5.52	-21.1

*Source: Metal Statistics 1973 (New York: Fairchild Publications, 1973), pp. 77-8. Prices are dealers' buying prices in New York; monthly averages are compiled from quotations published daily in the American Metal Market. Prices are in cents per pound.

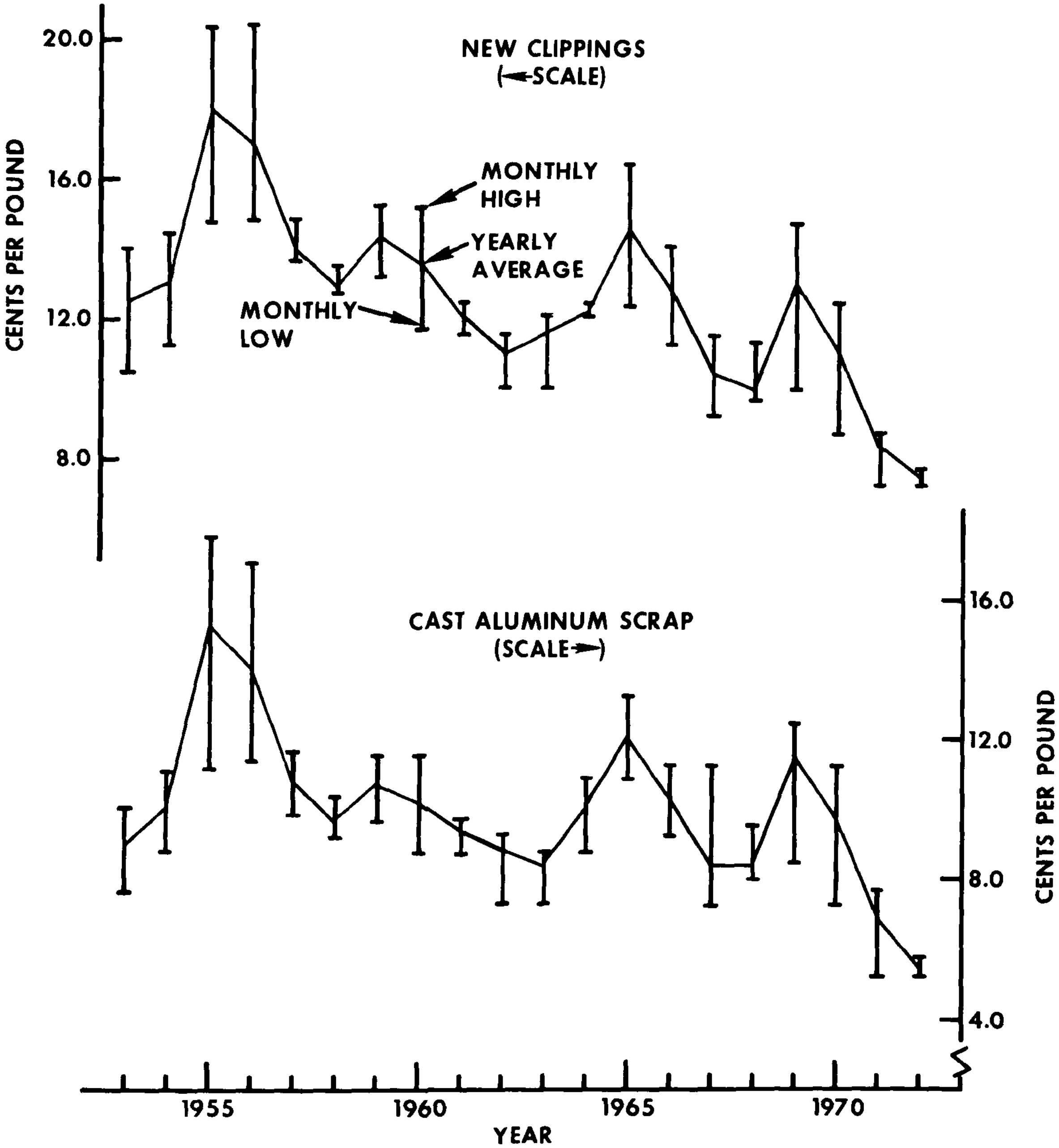


Figure 3. Aluminum scrap prices.

TABLE 7

SECONDARY ALUMINUM INGOT PRICES*

Year	Range High	Range Low	Average	Percent change
1957	23.46	21.62	22.70	
1958	22.87	21.75	22.06	-2.8
1959	24.82	22.25	23.44	6.3
1960	25.50	23.50	24.67	5.2
1961	23.50	21.77	22.56	-8.6
1962	21.50	20.17	21.20	-6.0
1963	21.75	20.25	21.01	-0.9
1964	22.72	21.75	22.05	5.0
1965	24.75	22.75	24.21	9.8
1966	24.75	24.68	24.74	2.2
1967	24.75	24.75	24.75	0.0
1968	25.50	24.75	25.02	1.1
1969	27.00	26.00	26.82	7.2
1970	28.00	27.00	27.72	3.4
1971	28.00	27.03	27.92	0.7
1972	28.00	27.00	27.72	-0.7

*Source: Metal Statistics 1973 (New York: Fairchild Publications, 1973), p.78. Monthly averages compiled from daily quotations published in American Metal Market. Prices are in cents per pound for No. 380 alloy.

Foundries. The aluminum castings industry is made up of independent "custom" shops, and "captive" shops. Captive shops are foundries owned and operated by large manufacturing firms, mainly in the automotive and appliance industries. In recent years, these foundries have produced about half of all aluminum castings in the United States. Overall, the industry is fairly competitive, with over a thousand shops nationwide and no dominating giants. Foundries tend to locate in industrial areas, and die casting shops in particular are concentrated in the Great Lakes region from Chicago to Cleveland.

External Competition

Competition with the Primary Industry. Although the primary and secondary aluminum industries both produce alloys of the same basic metal, competition between them is limited by the narrow product line of the secondary smelter. Most aluminum products are not and cannot be made from secondary aluminum as it is produced today. However, the primary producers can and do produce the same specification ingot as that produced by the secondary industry. Consequently, competition between the primary and secondary producers is a relatively much more important factor for the secondary producers. In the secondary industry's main market, castings, secondary producers have been supplying about three-fourths of the metal, and primary producers one-fourth. In steel deoxidizing, the needs have been met by about equal shares of primary and secondary metal.[11] Competition from the primary producers increases in slack times for the primary industry.

Secondary smelters also compete with the primary industry for scrap input. In recent years, the primary producers have consumed about 20 percent of purchased new scrap in the United States, although this figure varied between about 9 percent (in 1962-63) and 40 percent (in 1953).[12]

Imports/Exports. Foreign trade is a fairly minor factor in the U.S. secondary aluminum industry. For the period 1962-72, recovery from imported scrap averaged about 3 percent of total domestic recovery, and exports averaged about 6 percent. Exports of aluminum castings were less than 1 percent of total castings shipments. Foreign trade in secondary ingots is also slight. In addition, there is trade in finished durable goods that contain aluminum castings (e.g., automobiles).

Environmental Considerations: Air Pollution

Scrap Processing. In the past, considerable air pollution was generated in burning off combustible contaminants. This burning violates the air pollution codes recently adopted by many communities, however, and compliance makes the recovery of combustibles-contaminated scrap more costly.

Secondary Smelters. In addition to any emissions from scrap processing, the secondary smelter's furnace operations can also be a source of air pollution, primarily from the processes of degassing, magnesium removal, and cleansing of the molten metal. These steps are usually accomplished by bubbling chlorine through the molten metal, a process that results in gaseous and particulate emissions such as chlorine, hydrochloric acid, magnesium chloride, aluminum chloride and aluminum oxide. Hydrochloric acid and chlorine gas are highly acidic and present potential corrosion and health hazards. The other three compounds are particulates.

Two approaches to air pollution control by secondary smelters are input substitution and installation of emission control equipment. Chlorine-compound emissions can be avoided by using chlorine substitutes. Nitrogen can be used for degassing, and aluminum fluoride for magnesium removal and general cleansing, although these substitutes tend to be more expensive and less effective than chlorine.

On the other hand, though, the acidic gases, the submicron particle size and hygroscopic nature (i.e., absorbing or attracting moisture from the air) of much of the particulates have created problems for control equipment manufacturers. The smelter's "batch" process method adds to the difficulties since emission levels fluctuate widely, depending on the production step. Assuming, nevertheless, that the pollution control equipment approach is the predominant one taken (installation of specially designed wet scrubbers), it has been estimated that the average cost of standards compliance would be about $6.34 per ton of secondary aluminum.[13]

Trends

The rate of aluminum scrap generation depends on present and past aluminum production. Production is expected to continue to grow at a 6 to 7 percent annual rate, implying a similar growth in scrap generation, assuming the historical relationship of new scrap generation to aluminum production is maintained. On the demand side, the Bureau of Mines forecasts that secondary aluminum demand through the year 2000 will probably grow at an average annual rate of 7.7 percent.[14] This demand for secondary aluminum relative to its most immediate substitute, primary aluminum, should not be adversely affected by environmental control costs, as the above estimates indicate.

Scrap Price Fluctuations

The extreme price fluctuations that aluminum scrap is subject to create a great deal of uncertainty as to what future price levels will be. This uncertainty about prices translates into revenue and profit uncertainty, which tends to discourage capital investment in the scrap business. Aluminum scrap price fluctuations are thus important determinants of scrap recovery. To better understand them, the following discussion considers some basic causes of relatively large price changes.

Scrap prices are determined by the market forces of supply and demand. In the short run, the demand for scrap, like the demand for aluminum in general, is probably relatively insensitive to price changes (i.e., it is price inelastic). On the supply side, it would appear that in the short run, the scrap recovery rate is also relatively insensitive to price changes. That is to say, both the short-run demand and supply curves[15] should be relatively steeply sloped. Markets in which both supply and demand are price inelastic are subject to relatively large potential price changes, since shifts in either curve (caused by changes in one or more of the factors held constant in constructing the curves) will result in relatively large changes in the equilibrium price. This is shown diagrammatically in Figure 4, where equal horizontal shifts in demand produce a larger price change in a market of price-inelastic supply and demand than in a price-elastic one, and similarly for equal horizontal shifts in supply.

Relatively price-inelastic supply and demand provide, of course, only a partial explanation of the wide fluctuations in aluminum scrap prices. Other important factors are changes in the basic conditions that produce supply and demand shifts, and the nature of scrap inventory policies. These policies can either moderate or accentuate price movements. By adding to inventories in the face of slack demand and drawing down inventories when demand is strong, suppliers can moderate price movements that are due to changes in demand. Conversely, if suppliers draw down inventories when demand weakens and add to inventories when demand increases, price fluctuations will be accentuated.

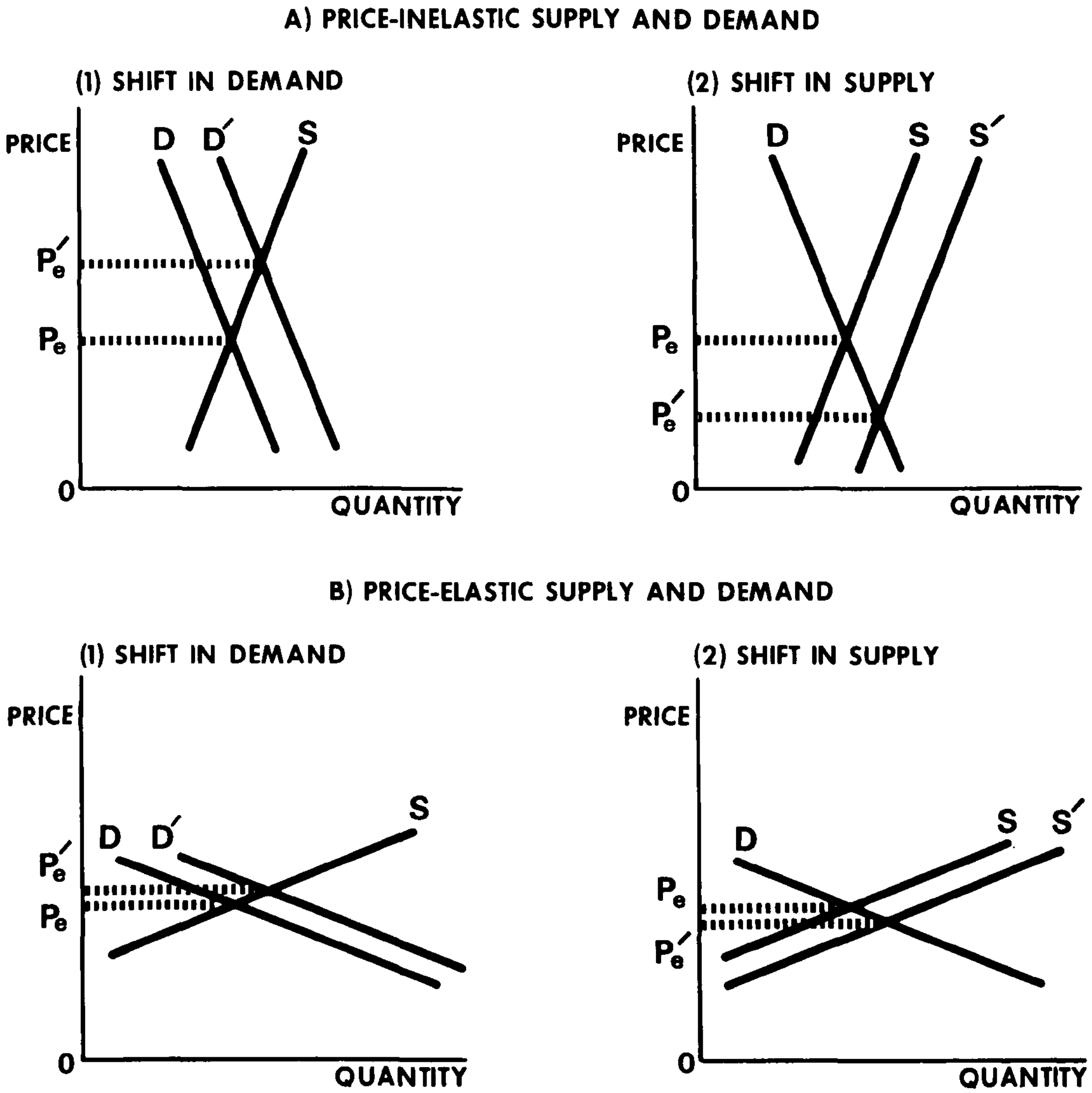
ALUMINUM IN SOLID WASTE

Quantity and Sources

By weight, aluminum represents a very small fraction of collected municipal refuse; recent estimates range from about 0.5 to 1 percent.[16] Still, because the total is so great, these small fractions translate into fairly large quantities of aluminum, on the order of 600,000 to 900,000 tons. Most of this aluminum is in the form of containers and packaging, although as much as one-third of it may be in discarded consumer durables (appliances, pots and pans, lawn furniture, etc.).

Disposal Problems

The major solid waste problem associated with aluminum-containing products is litter of beverage containers and packaging. In



D = ORIGINAL DEMAND CURVE

S = ORIGINAL SUPPLY CURVE

D′= NEW DEMAND CURVE

S′= NEW SUPPLY CURVE

P_e = ORIGINAL MARKET EQUILIBRIUM PRICE

P_e' = NEW MARKET EQUILIBRIUM PRICE

Figure 4. Equilibrium price changes and price elasticities of supply and demand.

addition to the quantitative significance of these items in litter, aluminum contributes to their conspicuousness and persistence by its high reflectivity and corrosion resistence.

Aluminum does not appear to cause any significant problems in sanitary landfilling or incineration of solid waste. In landfills, aluminum does not degrade or contribute to gas or leachate production. Since aluminum is noncombustible, most of it remains in the incinerator residue, but some, particularly foil, rapidly oxidizes and goes up the stack as particulates. Also, because of aluminum's relatively low melting temperature (1220°F), aluminum can melt and pile up on or under incinerator grates.

Aluminum Recovery from Solid Waste

The Current Situation. Aluminum is among the most valuable component materials of municipal refuse in terms of scrap price. Aluminum scrap normally sells for 15 to 20 times the price of scrap steel, glass, or paper. This high scrap price means that although by weight there is only about 1 percent as much aluminum as other scrap material in solid waste, the potential revenue from the aluminum (estimated to be about $126 million[17]) is as much as one-fourth the potential value of scrap steel, glass, and paper. Nevertheless, the costs of recovery are such that relatively little aluminum is now diverted from the municipal refuse cycle.

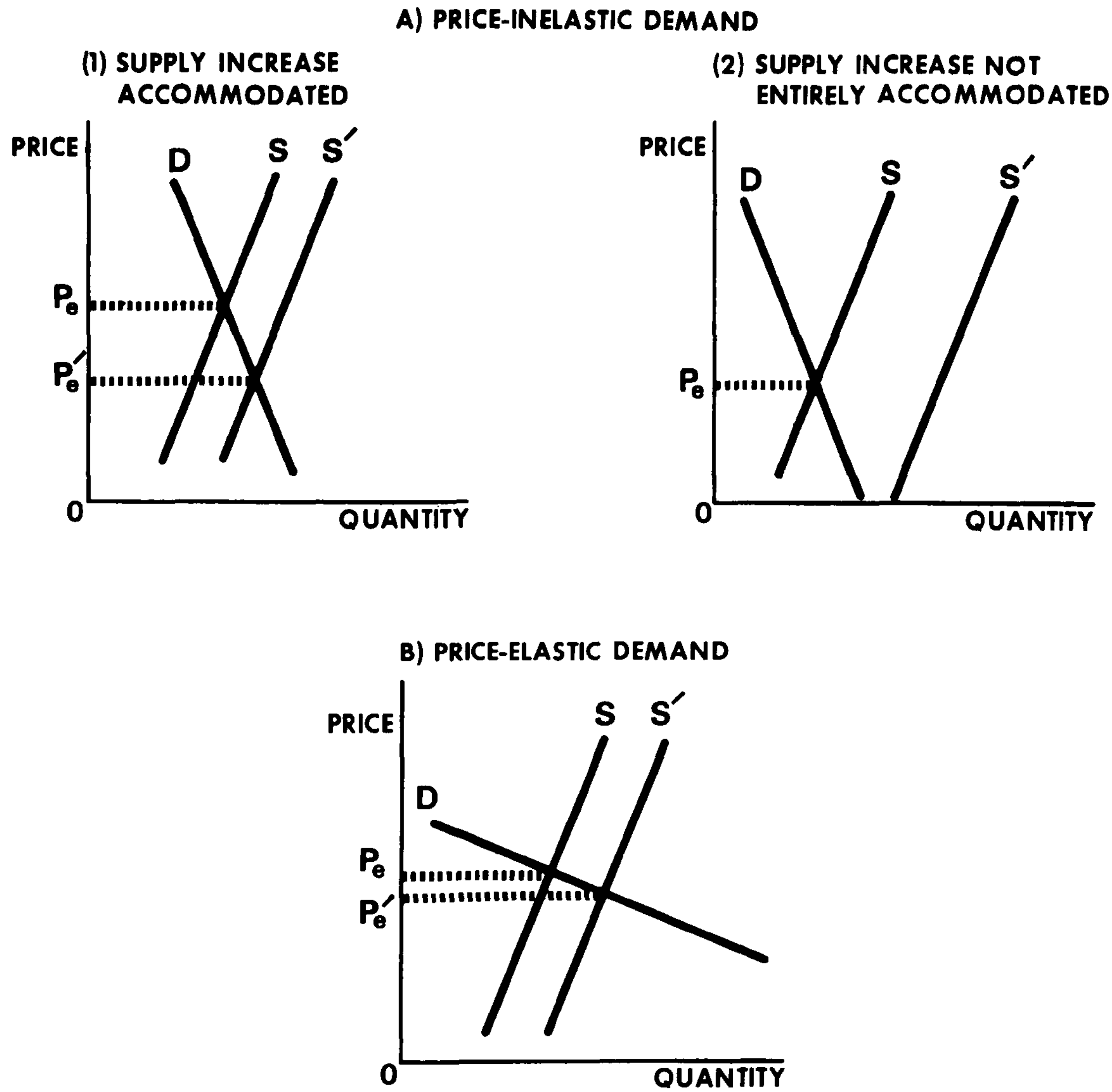
Most of that which is being diverted is recovered through can reclamation programs aimed at all-aluminum beverage cans. These programs were begun on an experimental basis in 1967 and became firmly established in 1970. Operated by the three largest primary producers, in cooperation with various breweries and beer and soft drink distributors, individuals are paid 10¢ per pound for all-aluminum cans delivered to collection centers. By late 1973, there were 1,400 collection centers in 45 states, and the number was still growing. In 1972, the programs accounted for approximately 15 percent of the all-aluminum cans shipped,[18] for which the sponsors paid out a little more than $5 million. Practically all of the recovered metal is recycled back into can stock. Economically, while the profit-or-loss performance no doubt varies, the public relations value of the programs is such that their existence would probably be justified even when operating at a loss. The favorable publicity generated by the programs is very important, since legislative pressures for restrictions on nonreturnable beverage containers mounted in the early 1970's at all levels of government and threatened one of the aluminum industry's largest and fastest growing markets.

Other than the can programs, recovery of aluminum from municipal refuse is only in the planning stage. Separation is a necessary first step in recovery, and two possibilities here are general "source separation" and recovery from mixed refuse. It is often suggested that households separate their trash into various components (newspapers, bottles and jars, cans, etc.). One category could be items that are mainly aluminum. A major problem with such schemes, however, is getting households to cooperate.[19] Alternatively, aluminum and other materials could be recovered from mixed refuse by comprehensive resource recovery systems.[20] Aluminum would be recovered either from the raw refuse or incinerator residue using processes based on the metal's inherent characteristics (noncombustible, inorganic, nonmagnetic, and of low density).

Economic Implications of Increased Recovery. Separation and processing costs are major inhibitors of aluminum recovery from municipal refuse at the present time. Aluminum is a small fraction of refuse, it is intermixed and dispersed through the refuse, and it is generally highly contaminated (with dirt, oil, grease, food particles, teflon, enamel and paint coatings on containers, steel in bi-metal cans, and various laminations in packaging). Also, if recovery were through traditional secondary aluminum channels, secondary smelter operations could be affected in important ways that increased their costs. Recovery of large amounts of aluminum from refuse could significantly alter the new/old scrap ratio. And since much of the aluminum in refuse is in container and packaging products made from high-magnesium alloys, increased magnesium removal might be necessary, a process made more expensive by recent air pollution standards. Another inhibiting factor is the uncertainty caused by widely fluctuating scrap prices. (It should be noted that the price has been constant in the can programs, a fact that no doubt has contributed to their success.)

Demand aspects of increased recovery of aluminum from solid waste should also be considered, since the effects of an increase in supply[21] depend upon the nature of demand. A steeply-sloped demand curve (i.e., price-inelastic demand) would imply that a relatively sharp drop in the price would accompany an increase in supply. Moreover, in some situations, it is possible that even if the price were to fall to zero, the market might not be cleared and excess supply would remain. A fairly flat demand curve (i.e., price-elastic demand) would, on the other hand, imply that an increase in supply would have relatively little effect on price. These three cases are illustrated in Figure 5.

One determinant of the price-elasticity of demand is the relevant time period involved. In general, the demand for aluminum is more price elastic as the time period increases. This implies that if aluminum recovery were to increase substantially in a fairly short period of time, there would be a consequent sharp drop in price. If, on the other hand, aluminum recovery increased substantially but



D = DEMAND CURVE
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Figure 5. Market analysis of an increase in supply.

rather gradually over a long period of time, there would probably be relatively little effect on price because of the price-elastic long-run demand.

The specific uses and markets for an increased supply of reclaimed aluminum are difficult to identify with a high degree of certainty. Numerous constantly changing factors affect each of a multitude of specific materials-use decisions in a highly industrialized, technologically advanced economy. However, such uses probably would include the traditional markets for secondary aluminum, for which demand prospects appear to be favorable. In addition, important new markets may be found. Following the can programs, it may be possible to recycle container and packaging aluminum into sheet alloys and products. Further in the future, markets may develop in uses now dominated by other materials, and in completely new products yet to be discovered.

FOOTNOTES

[1]Percentages are for an "average" firm (Aluminum: Profile of an Industry [New York: METALS WEEK, 1969], p. 151).

[2]A structural oligopoly is an industry composed of relatively few firms, with the largest three to five firms producing most of the industry's total output.

[3]See Merton J. Peck, Competition in the Aluminum Industry (Cambridge, Mass.: Harvard University Press, 1961).

[4]Environmental Protection Agency, The Economics of Clean Air: Annual Report to the Congress of the United States, 1972 (Washington: U.S. Government Printing Office).

[5]The Economic Impact of Pollution Control: A Summary of Recent Studies. Prepared for the Council on Environmental Quality, the Department of Commerce, and the Environmental Protection Agency (Washington, D.C.: U.S. Government Printing Office, March 1972).

[6]Personal Communication. J. W. Stamper, Division of Nonferrous Metals, Bureau of Mines, U.S. Department of the Interior, to R. J. Talley, Solid and Hazardous Waste Research Laboratory, NERC-Cincinnati (U.S. Environmental Protection Agency), December 17, 1973.

[7]Battelle Memorial Institute. A Study to Identify Opportunities for Increased Solid Waste Utilization, Volume II ("Aluminum"). U.S. Environmental Protection Agency, 1972. (National Technical Information Service PB-212-730).

[8]Published scrap prices, although typically differing from the prices at which transactions actually take place, should reflect the direction and order of magnitude of changes in transaction prices.

[9]Siebert, D. L., Impact of technology on the commercial secondary aluminum industry, Bureau of Mines Information Circular 8445, U.S. Department of Interior (Washington D.C.: U.S. Government Printing Office, 1970), p.60.

[10]Published prices (the qualification for published scrap prices applies here also).

[11]Siebert, op.cit., p.28.

[12]Aluminum Statistical Review 1972. (New York: The Aluminum Association, 1973).

[13]The Economics of Clean Air, op.cit., p.4-156.

[14]Personal communication, J. W. Stamper to R. J. Talley, op.cit.

[15]A demand curve shows the relationship between market price and the quantity of a good that consumers would want to buy at each price, holding everything else (other prices, tastes, incomes, wealth, etc.) constant. A supply curve shows the relationship between market price and the quantity of a good that producers would want to supply at each price, holding everything else (technology, wage rates, etc.) constant.

[16]"Municipal Solid Waste .... Its Volume, Composition and Value", NCRR Bulletin, Vol. III, No. 2, Spring 1973.

[17]Ibid.

[18]Personal communication. J. C. Dale, Environmental Services, The Aluminum Association, to R. J. Talley, Solid and Hazardous Waste Research Laboratory, NERC-Cincinnati (U.S. Environmental Protection Agency), December 10, 1973.

[19]See, for example, Solid Waste Report, 1/10/72, p.5.

[20]See, for example, Resource Recovery: Catalog of Processes, Midwest Research Institute, 1973 (Springfield, Va.: National Technical Information Service, PB-214-148).

[21]An "increase in supply" means a rightward shift in the supply curve. This may result from, for example, improvements in resource recovery technology, or the introduction of government measures encouraging resource recovery.

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16. ABSTRACT

This report surveys the production and use of aluminum and its occurrence in solid waste; the aspects related to resource recovery are emphasized. Surveyed are both the primary and secondary aluminum industries, which produce aluminum from virgin materials (i.e., bauxite) and scrap, respectively. Supply and demand anaylsis is used to analyze fluctuations in scrap prices and implications of increased recovery of aluminum from solid waste.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Aluminum Industry* Metal Scrap* Demand (Economics) Supply (Economics) Refuse*	Recycling Resource Recovery Solid Waste Mixed Municipal Refuse	13B
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