THE REALITIES OF RECYCLING

Special Report

To the 68th Session

of the Legislature of Minnesota

Minnesota Pollution Control Agency

January 1973

At the Agency meeting on January 8, 1973, MPCA Board members unanimously passed a resolution accepting the factual findings in this staff report and recommended that it be transmitted to members of the Legislature.

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by

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STAFF REPORT

ACKNOWLEDGEMENTS

We would like to express our sincere gratitude to the many MPCA and other staff members who assisted in the preparation of this report. Much to our dismay, state publication regulations prohibit us from mentioning those individuals by name. Thus, to those nameless individuals, we express heartfelt thanks for their assistance in typing, reviewing, and editing and for preparation of the charts, tables and Summary Report. Without them, this report could not have been completed.

We would also like to thank the many authors whose work we drew upon for this report. Any errors are the responsibility of the authors alone.

... And Man created the plastic bag and the tin and aluminum can and the cellophane wrapper and the paper plate, and this was good because Man could then take his automobile and buy all his food in one place and He could save that which was good to eat in the refrigerator and throw away that which had no further use. And soon the earth was covered with plastic bags and aluminum cans and paper plates and disposable bottles and there was nowhere to sit down or walk, and Man shook his head and cried: "Look at this Godawful mess."

Art Buchwald, 1970

THE REALITIES OF RECYCLING

Table of Contents

Table of Contents (cont'd)

Table of Contents (cont'd)

Table of Contents (cont'd)

THE REALITIES OF RECYCLING

List of Tables

List of Tables (cont.)

List of Tables (cont.)

List of Tables (cont.)

THE REALITIES OF RECYCLING

List of Figures

List of Figures (cont.)

CHAPTER 1

INTRODUCTION

Solid waste is the residue of man's economic and social activity -- yesterday's newspaper, the remains of last night's "TV Dinner," the empty beer can, the worn out auto. A hundred years ago, a family bought one weekly newspaper of perhaps four pages; now it gets a daily that may average forty pages -- forty pages that become solid waste in less than twenty-four hours. A few decades ago, we were a family of one car, if any, and the car was likely to be a dearly beloved member of the family, to be parted with quite reluctantly. Now we are likely to be a two car family, unhappy if we can't afford to trade in one of them every other year.[1]

The development of the great American love affair with new products, convenience items and the latest gadgets has changed the United States from a nation of boundless resources to a nation of fouled air, polluted waterways, limited mineral and energy resources and mountains of trash.

As Battelle Institute put it,

> "Much of the world has come to view the average American as a gorging Henry VIII at feast. He grabs, tears out a few chunks, and then throws

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1. Lyons, C. and Morrison, D., "Solid Waste 1: Where Does It All Come From?" Battelle Research Outlook, Vol. 3, November 3, 1971, p. 3.

> whatever is left over his shoulder and reaches for something else, without a care for where things come from or where things go."[2]

But, like millions of other Americans, Minnesotans are changing. The citizenry is very much aware of its environment and is beginning to realize the finite nature of its natural resources. Most of us are now concerned not only that the pile of trash exists, but that it represents natural resources which are being misplaced and perhaps lost forever by incineration, burial and ocean-dumping. Citizens are equally concerned with the quality of the air, land, and water which receive the misplaced resources in an often undesirable form. The simplistic response is to recycle the waste, thereby protecting the supplies of mineral and energy resources, as well as the potential receiving bodies. For many, the recycling of wastes seems to allow unlimited consumption of goods while creating minimal pollution of the environment, reinforcing the age old myth that the world is indeed a horn of plenty.

As a result, there are growing pressures on the state and federal governments to provide funding for various kinds of solid waste recycling ventures. Funding requests are pouring in for proposals of varying magnitude -- from small neighborhood can and bottle collection efforts to massive demonstrations of new resource recovery technologies.

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2. Ibid. p. 4.

But wastes as they are presently being generated are difficult, if not impossible in some cases, to recycle; and many recycling systems themselves are inefficient, costly, and indirectly trade one form of pollution for another. Much has to be done to pave the way for recycling. Certain products have to be redesigned, others eliminated completely, attitudes towards secondary materials must be changed, and governmental obstructions to recycling must be removed. Furthermore, recycling is but one of several alternatives for reducing solid waste. Above all, we must adopt policies which create thrift in resource use.

The 1971 Minnesota Legislature had the foresight to request a study of the resource recovery option for solid waste management. This report analyzes municipal solid waste, defines its magnitude and future trends, discusses the potential of various alternatives for reducing solid waste, including recycling, and makes recommendations for governmental action which will both minimize solid waste and encourage rational use of resources.

CLASSIFICATION AND TERMINOLOGY

Solid waste terminology differs considerably and leads to much confusion in the interpretation of statistical data. For the purposes of this report it has been assumed that solid wastes fall into four general categories: municipal, agricultural, industrial, and mining wastes. This report deals with municipal waste which includes household, commercial and office waste, institutional refuse, yard and garden wastes, and street cleanings.

While the composition of municipal waste varies both seasonally and geographically, an average breakdown is shown in the following table:

TABLE 1 - NATION'S CITIES, MUNICIPAL COMPOSITE, 1969

(Percent by Weight)

Newspapers	10.34%
Magazines	7.47%
Other Paper	11.33%
Containerboard	25.70%
Boxboard	3.95%
All Metals	7.52%
Glass	8.49%
Plastics and Textiles and "other"	5.85%
Wood	2.52%
Food Wastes	9.24%
Yard and Garden Wastes	7.58%
	99.99%

Source: McKinsey & Company, Inc., A Recycling Incentive Tax, November 1971, p. 3-2. Composited from typical compositions for research purposes. Adapted from Remson, Irwin, A. Alexander Fungaroll, and Alonzo W. Lawrence, "Water Movement in an Unsaturated Sanitary Landfill," Journal of the Sanitary Engineering Division, proceedings of the American Society of Civil Engineers, Vol. 94, St. 2, April 1968.

SCOPE OF THE PROBLEM

Minnesota communities face an ever increasing solid waste management burden. Forecasts indicate that waste generation will increase nearly as much in this decade alone as it did altogether in the last fifty years. The responsibility for managing this waste rests with local units of government and, in some Minnesota communities, it is financed by the property tax.

It is estimated that in 1920, municipal waste generation was 2.75 pounds per capita per day.[3] In 1971, the national average for collected municipal waste was 5 pounds per capita per day[4] and forecasts indicate that the figure will rise to at least 8 pounds by 1980.[5]

Even though Minnesotans were somewhat below the national average according to county solid waste management plans presently being submitted to the Minnesota Pollution Control Agency (MPCA), approximately 6.2 billion pounds of municipal solid waste were disposed of in Minnesota in 1972.[6] That

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3. Clark, T. D., "Economic Realities of Reclaiming Natural Resources in Solid Waste," U.S. Environmental Protection Agency, 1971.
4. Dee, N. and Griffin, J., "Collection is the Key," Battelle Research Outlook, Vol. 3, No. 3, (1971), p. 13.
5. Clark, op, cit.
6. Based on 1970 Census figures showing the following population: urban, 2,527,000 and rural, 1,278,000. Further assuming per capita waste: urban, 5 pounds per day and rural, 3.5 pounds per day.

municipal waste, when compacted in standard 15 cubic yard packer trucks, would fill over 800,000 trucks, or enough trucks to fill both lanes of a two lane highway stretching from the Twin Cities to San Francisco, California.[7]

By applying Minnesota's total estimated municipal waste to the national composite in Table 1 the following breakdown of discarded items is obtained:

	In Million Pounds
Containerboard (corrugated)	1,593
Food, yard and garden waste	1,043
Other papers (printing, ledger and other fine papers, sanitary tissue, toweling, etc.)	703
Newsprint	641
Glass	526
Metals	466
Magazines	463
Plastic and textiles	363
Boxboard (e.g., folding cartons, such as cereal boxes, construction paper, poster board)	245
Wood	156

To collect, transport and dispose of the above items, Minnesotans spent $62 million in 1972. Without action to reduce the growth trend, Minnesotans will spend on the order of $111 million in 1980 for the direct costs of collecting, transporting and disposing of municipal refuse <u>plus</u> any increased cost due to inflation and population growth.

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7. Annual municipal waste generation is estimated at one cubic yard per 500 pounds compacted refuse, or 12,488,840 cubic yards.

RESOURCE VERSUS MATERIALS CONSERVATION

Quantitative reduction of solid waste must be based on more than the desire to conserve materials and to reduce the area of land needed for disposal of waste. Rather, it requires consideration of <u>all</u> the impacts on the environment, nonrenewable resources, and society, resulting from solid waste generation. It would be clearly undesirable, for instance, to recycle an abundant material, if the pollution effects, and the requirements for water, energy, and manpower were three times that needed to produce an equivalent quantity of material from virgin resources. Materials conservation is not necessarily identical with resource conservation.

MINERAL AND ENERGY CONSUMPTION

Growth in solid waste generation is symptomatic of continued rapid exponential growth in the consumption of minerals and energy nationally and in the state of Minnesota. Further, it represents a mismanagement of resources that threatens the stability of the state economy and the well-being of Minnesota's citizens. Of particular concern are the projected relationships between domestic supplies of various energy and mineral resources and projected demand in the 1980's. Assuming growth in consumption is not curtailed, the difference in each case between supply and demand must be made up through increased imports. Balance of payments deficits and the price of these imported resources to both industry and the consumer may be great.

For example, Figures 1 - 6 show the supply-demand relationships for iron, aluminum, copper, nickel, lead, and zinc. Similar import projections exist for petroleum and natural gas which together supply 76 percent of the nation's energy needs.

Vital to manufacturing, oil, gas and coal are the "hidden nonrenewable resources" that are unnecessarily lost when a product lasts only a short time and must be recycled, or when items from newspapers to rubber tires are not recycled at all. The need to manage solid waste in a manner which conserves energy resources is apparent when the present domestic supply position is examined.

As predicted by M. King Hubbert in the National Academy of Science's study, Resources and Man, domestic oil production has apparently peaked; and it is now expected that domestic natural gas will also peak in the next few years, even with offshore and Alaskan supplies. (See Figures 7 and 8.) While demand is doubling every 14 to 18 years, domestic supply continues to fall relative to imports. By 1980, even with development of offshore and Alaskan oil resources, imports are expected to climb from 25 percent at present to 50 percent

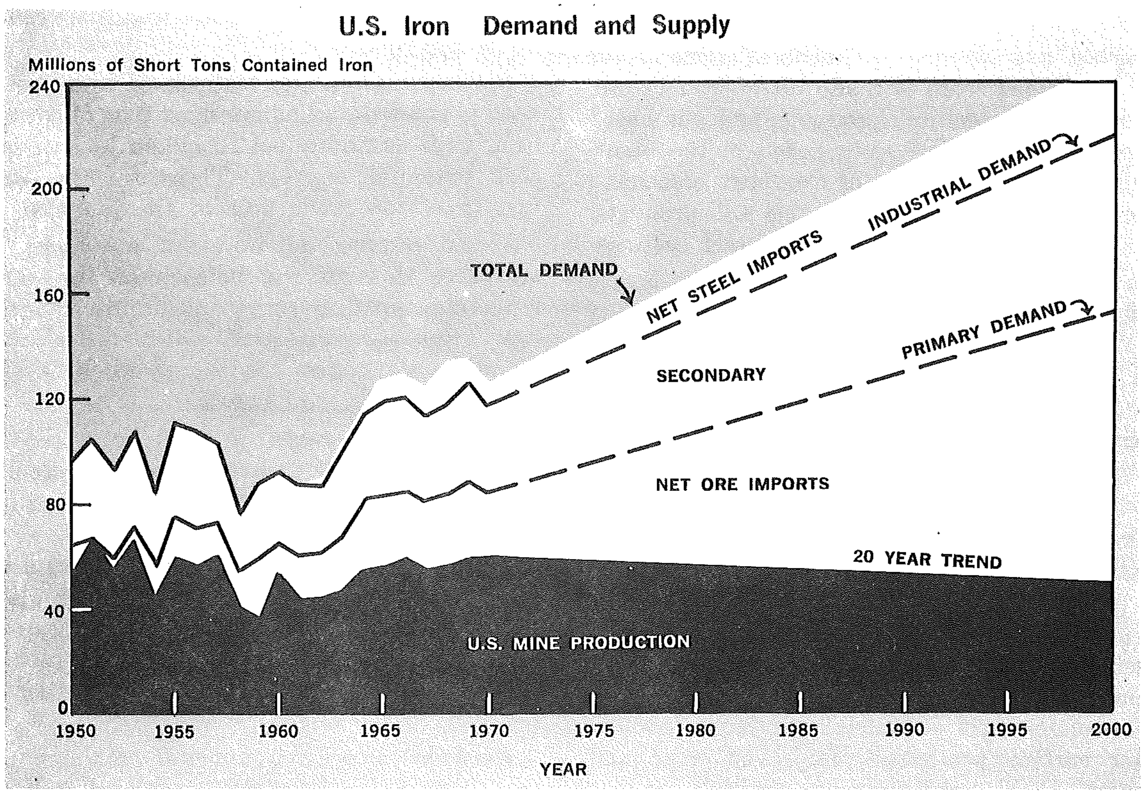


Figure 1

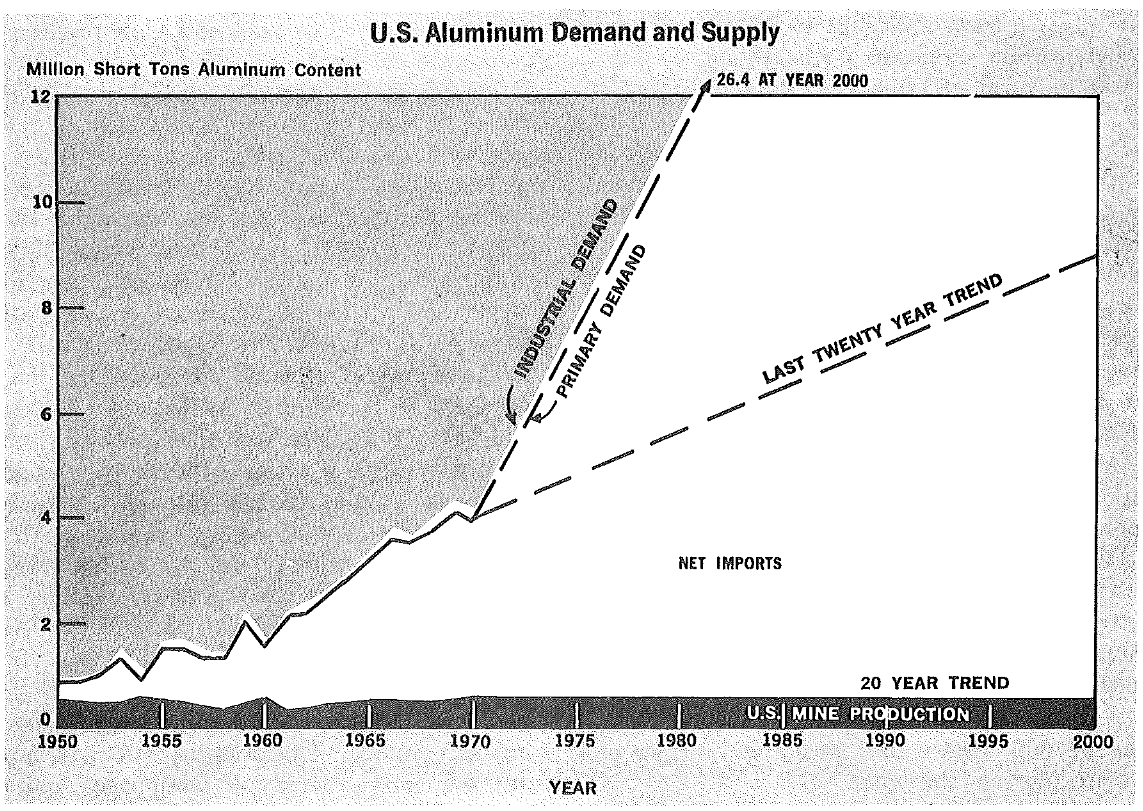


Figure 2

SOURCE: THE NATIONAL COMMISSION ON MATERIALS POLICY
AN INTERIM REPORT APRIL, 1972 pp. 13, 23.

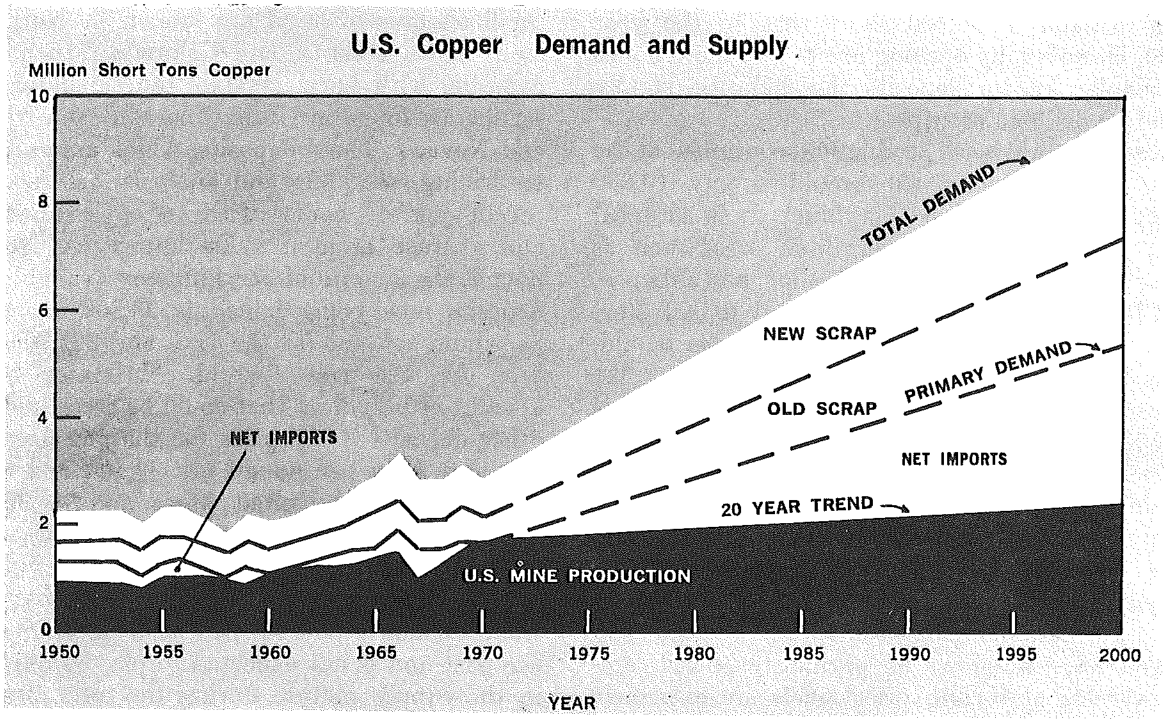


Figure 3

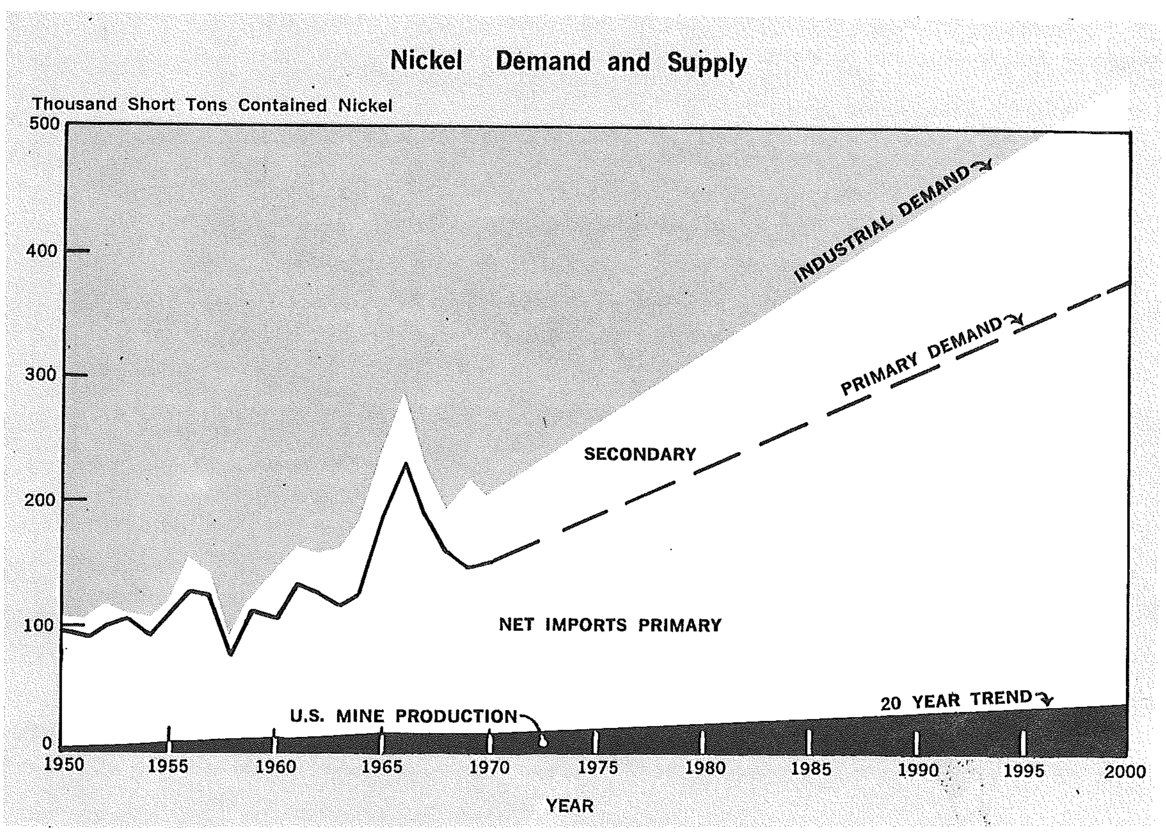


Figure 4

SOURCE: THE NATIONAL COMMISSION ON MATERIALS POLICY
<u>AN INTERIM REPORT</u> APRIL, 1972 pp. 20,25.

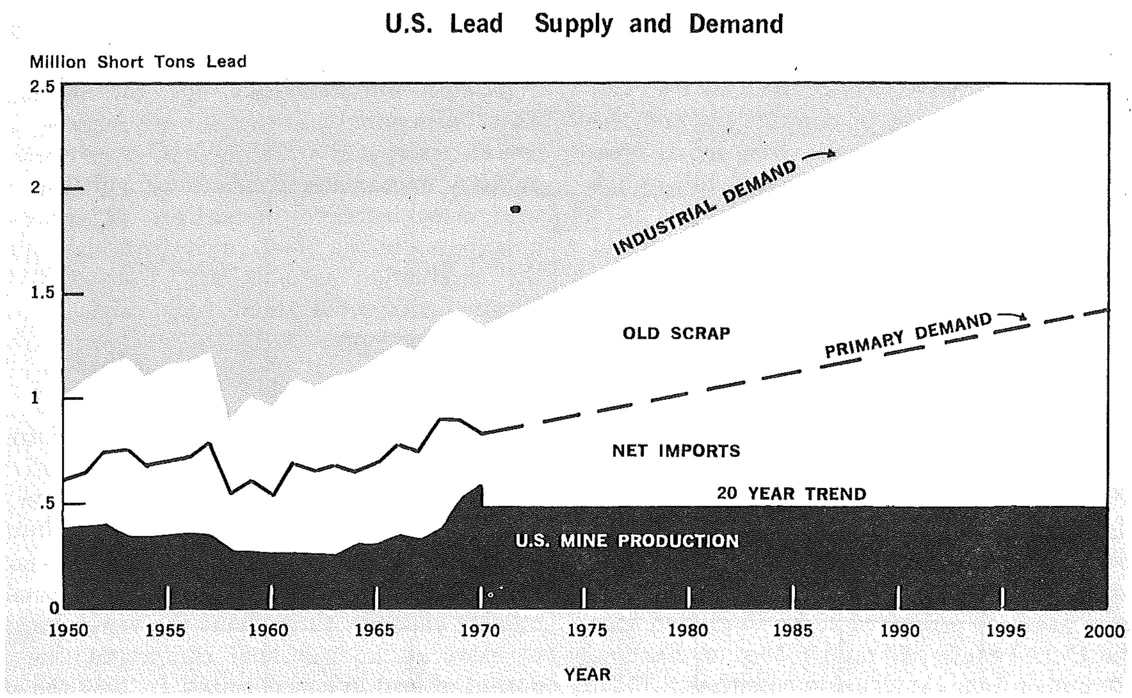


Figure 5

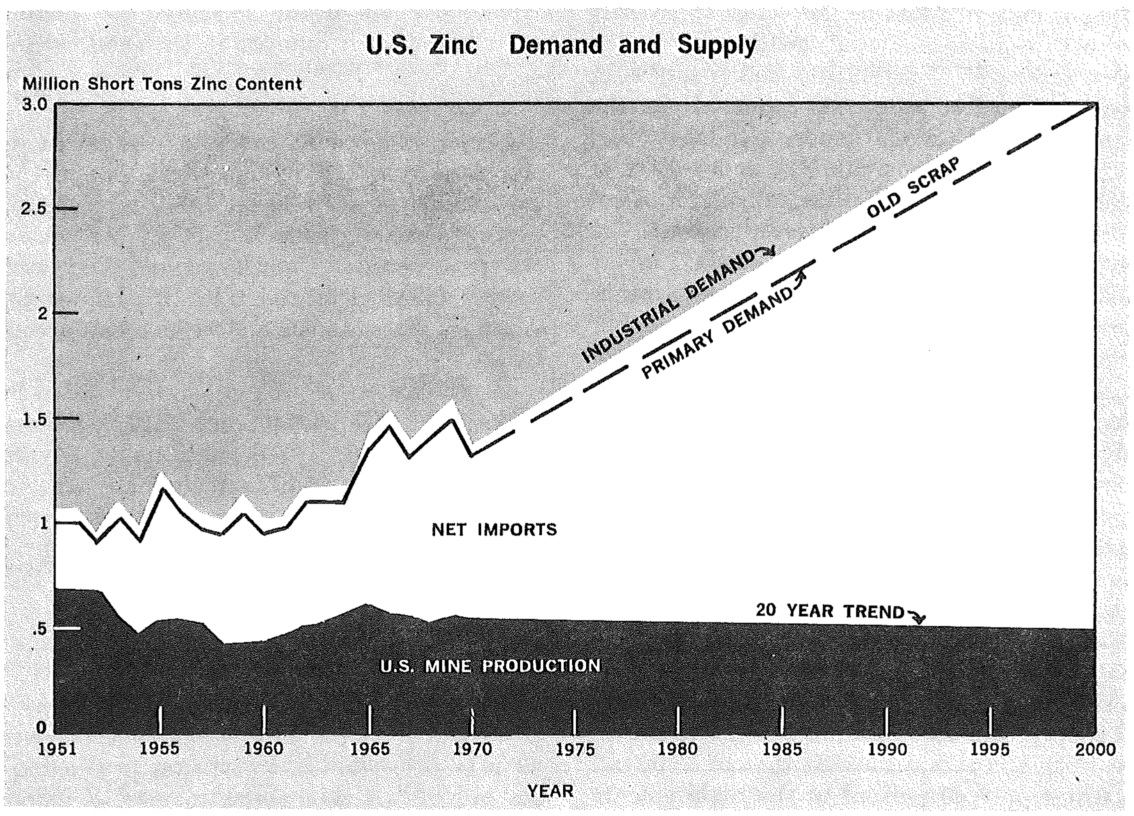


Figure 6

SOURCE: THE NATIONAL COMMISSION ON MATERIALS POLICY
<u>AN INTERIM REPORT</u> APRIL, 1972 pp. 28, 38.

COMPLETE CYCLE OF CRUDE-OIL PRODUCTION IN THE UNITED STATES AND ADJACENT CONTINENTAL SHELVES, EXCLUSIVE OF ALASKA

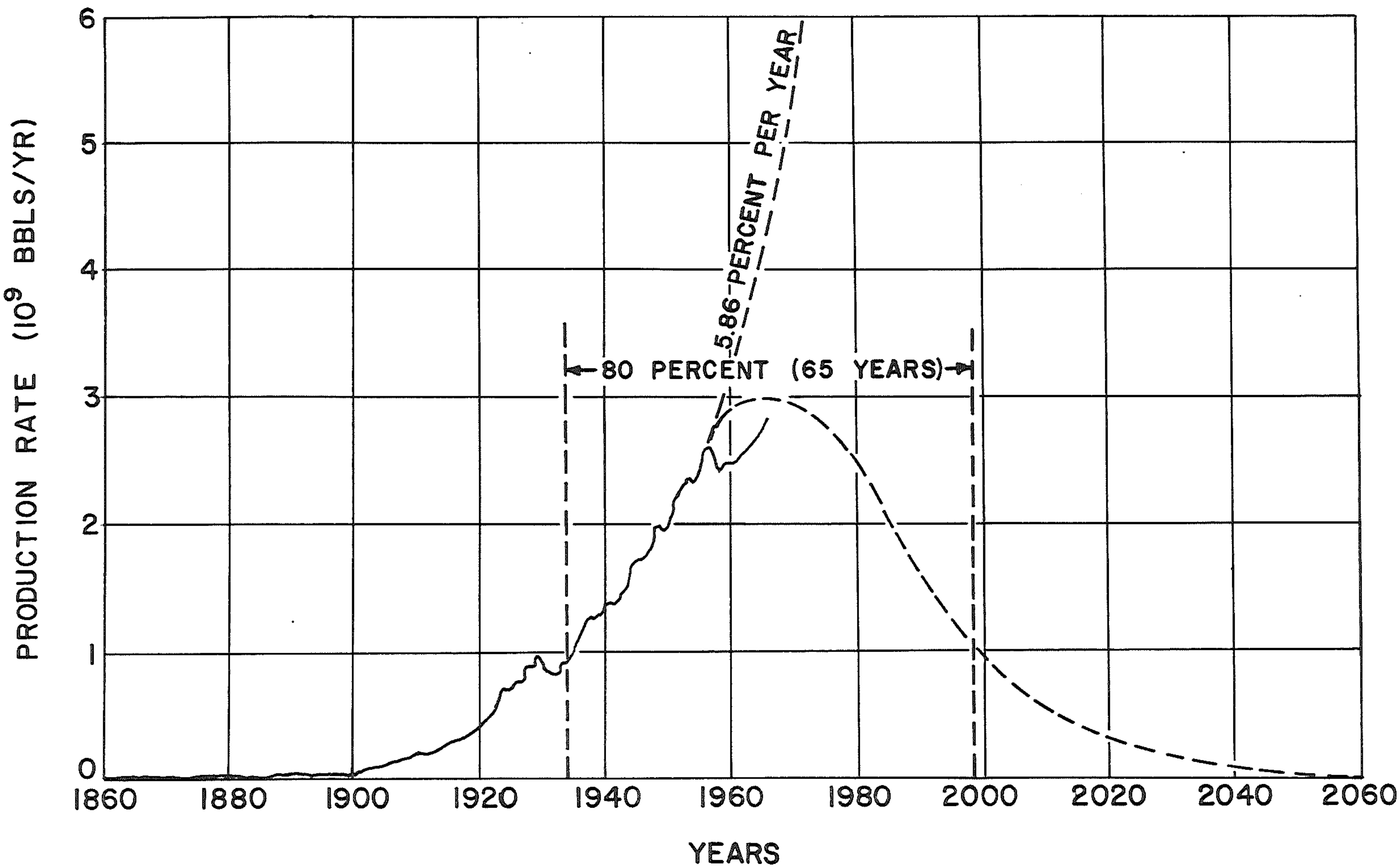
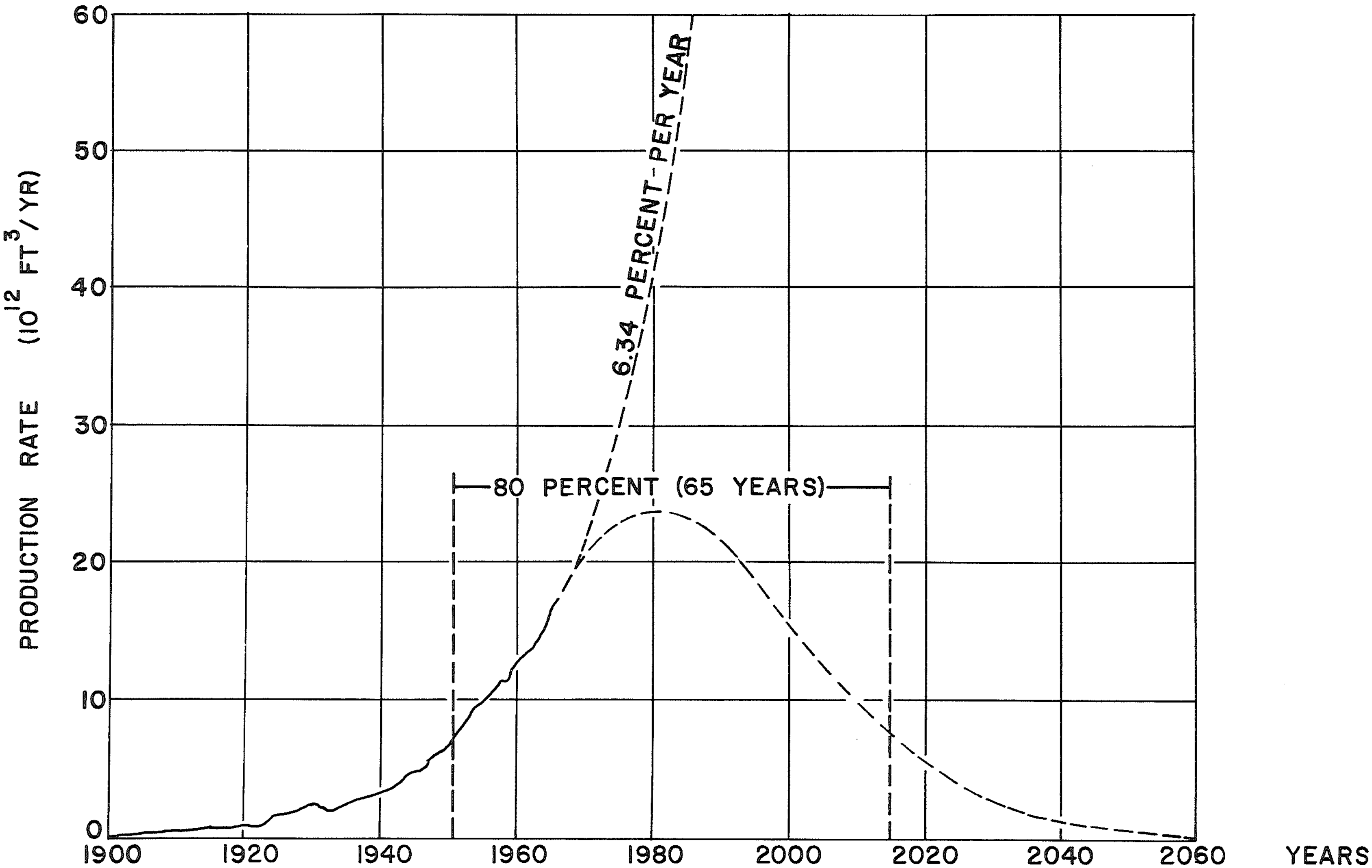


Figure 7

SOURCE: HUBBERT M. KING, "ENERGY RESOURCES," CHAPTER 8 OF RESOURCES AND MAN, 1969, p. 183.

COMPLETE CYCLE OF NATURAL-GAS PRODUCTION IN THE UNITED STATES AND ADJACENT CONTINENTAL SHELVES, EXCLUSIVE OF ALASKA



SOURCE: HUBBERT M. KING, "ENERGY RESOURCES," CHAPTER 8 OF RESOURCES AND MAN, 1969, p. 190.

Figure 8

of total U. S. consumption, creating an estimated $17 billion impact on U. S. balance of payments.[8]

As Admiral Rickover stated in testimony before the House Committee on Interior and Insular Affairs in April of 1972:

> "When we discovered how to unload nature's treasure of fossil fuels, we lost all the instincts for carefully husbanding nature's bounty that we acquired during millenia of living frugally off renewable energy sources. Prudence would have dictated that we regard this as a one-time windfall, and not go on a wild spending spree before we had some assurance of finding man-made alternatives once the treasure had all been dug out. Instead, we took the continuance of fossil fuel energy for granted..."[9]

We have lived luxuriously on our fossil fuel heritage with little thought as to how dependent our industrialized society has become on these irreplaceable resources. But rising imports are not the only cause for concern. Rapid growth in consumption of mineral and energy resources results in an equally rapid expansion in the mining and heavy manufacturing industries, together with associated environmental impact.

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8. Statement of Irwin, II, The Honorable John N., Under Secretary of State; accompanied by James Akins, Director, Office of Fuels and Energy, Fuels and Energy Resources, House of Representatives Hearings, Committee on Interior and Insular Affairs, 92nd Congress, April 10-13, 1972, Part 1, pp. 94, 110.
9. Statement of Rickover, Vice Admiral H. G., U.S. Navy, Chief Naval Reactors Branch, Division of Reactor Development, U.S. Atomic Energy Commission, and Assistant Chief of the Bureau of Ships for Nuclear Propulsion, Navy Department, Fuels and Energy Resources, House of Representatives Hearings, Committee on Interior and Insular Affairs, 92 Congress, April 14, 17, 18, 19, 1972, Part 2, p. 637.

For example, the mining of lower grade mineral ores results in even larger volumes of waste rock per ton of metal produced and requires greater energy expenditures.[10] The depletion of relatively clean and easily accessible oil and gas resources has created a shift to energy sources with more significant actual and potential impact on the environment: strip-mined coal and oil shale from the Rocky Mountain Region, tar sands from Alberta, offshore and Alaskan oil, electrical power from fission reactor operation.

In one of the most dramatic studies published to date, Limits to Growth,[11] an MIT study group has examined current and projected growth trends in population, resource consumption, food per capita, pollution and industrial output per capita. According to their study, if the trends in wasteful resource use, population growth, and environmental degradation *do* continue, catastrophe can be expected to arrive somewhere between the year 2000 and 2100 A.D. Debate over the findings of the study has centered on whether current growth trends can be projected 30 or 100 years into the future, and how effective technology may be in controlling the undesirable by-products of growth. The conservative approach to resource management

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10. Bravard, J. C., Flora, II, H. B. and Portal, Charles, "Energy Expenditures Associated with the Production and Recycle of Metals," Oak Ridge National Laboratory ORNL-NSF-EP-24, November, 1972, pp. 1-2 for U.S. AEC W7405-eng-26. Oak Ridge National Laboratory staff believe that use of 0.3% copper ores instead of 1% copper ores may increase total energy expenditures by 83%, ORNL-NSF-EP-24, p. 1.
11. Meadow, Dennis L., et. al., The Limits to Growth, Potomac Associates, Washington, D. C., 1972.

in the absence of complete information would dictate that it is better to develop an overly thrifty and environmentally conscious society, than one which gambles with environmental and resource stability. Considering the rapid rate of growth in energy and mineral consumption, the state of Minnesota should adopt policies of thrift in the use of mineral and energy resources at the earliest possible date.

The single use and discard practices of our society, the proliferation of nonessential and overpackaged products, and the emphasis on "newness" and short-lifetime products, result from a public lack of awareness of the true costs of:

-- depleting natural resources

-- increasing environmental degradation and the risk of irreparably damaging major environmental systems, and

-- the actual costs of disposing of final products.

Part of the purpose of this report is to examine some of the true costs, and to suggest a set of strategies to minimize them.

MEASURING TRUE COSTS

Given our traditional economic accounting methods, only a portion of the real or total cost of materials is incorporated into the price of the products we purchase and later discard. As Darney and Franklin point out in the recent Environmental Protection Agency (EPA) study of salvage markets,[12] any costs in terms of, for instance, environmental pollution:

> "may be passed along to the population in dirty water, air, and land if the dollar cost of physical control of effluents is not borne by the polluting industry. Thus, the market mechanism is not a sufficient guarantor that those materials will be used that have the lowest total cost. It is in these instances where governmental intervention is desirable so that the best use is made of natural resources."

Rational intervention by government, however, requires that the environmental resource and societal impacts of alternative courses of action be determined. To date, we have been able to do this in only a few areas where the relative impacts of alternatives are clear cut.

Redesign and expansion of current Bureau of the Census economic accounting practices, industrial reporting practices, and financial accounting practices, should be sought, in order to facilitate analysis of the trends and the impacts of materials production, use, and waste generation. In particular, much more specific data is needed on requirements and by-products of producing a given weight of material, or of producing, using, and disposing of a given product unit. The data should include:

-- the requirements for water, energy, and minerals for production and use

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12. Darnay, Arsen and Franklin, William E., Salvage Markets For Materials In Solid Wastes, Project No. (SW-29c), Midwest Research Institute, Kansas City, Mo., Contract No. CPE 69-3, for U.S. EPA, 1972, p. 90.

-- the quantity and quality of manpower for production

-- the average material or product lifetime

-- the environmental by-products of production, use, and disposal of materials or product units.

Where such data is currently available, it is interesting to note the close tie between environmental effects, the depletion of nonrenewable resources, and the production of energy. A careful assessment of the energy required to manufacture, transport, use, and maintain products, whether these be air conditioners or aspirin bottles, seems to be a fairly accurate indicator of true environmental costs and the costs of depletion of nonrenewable resources for which common substitutes do not appear to be readily available at comparable prices.

In addition to improved census information, the potential environmental impact of using and disposing of each of the materials and products under consideration should be established; and the current costs of collection, transportation and disposal of the different materials which enter the solid waste stream should be determined.

CRITERIA FOR EVALUATING ALTERNATIVES

Once the relative cost information is available, programs can be selected which best satisfy the following criteria:[13]

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13. Shilling, S. A., Bengston, R. J., Lindholm, Jr., "Reclamation and Recycling: An Economic Overview," Battelle Research Outlook, Volume 3, No. 3, 1971, p. 24.

1) minimum depletion of natural resources, especially energy resources. (e.g., recycling should not save one material, for example, glass, at the expense of another that is in shorter supply, for example, natural gas).

2) minimum pollution of the environment. (e.g., recycling should not replace a solid waste problem with a water, air, or noise pollution problem having greater impact on the state).

3) minimum economic cost to the people of the state.

Developing the information that will allow alternatives to be rated against these criteria is obviously much more difficult than identifying the criteria. However, in judging alternatives, it is often not necessary to have precise information, and one need only measure relative impacts. Only where the impacts appear equal it is necessary to perform more detailed analysis.

THE STATE'S DIRECTION

There are four avenues for satisfying the criteria outlined above:

1) increasing energy and mineral efficiencies in manufacturing, operating and maintaining products and equipment.

2) recycling materials and designing materials to increase their recyclability.

3) discouraging nonessential uses, such as the extra box around the bottle of shampoo, or the oversized automobile.

4) extending product lifetime.

Private enterprise has shown considerable enthusiasm and given a fair measure of support to materials recycling, and industry also recognizes a direct corporate benefit from efficient use of energy in manufacturing products, and in the operation of company owned machinery and equipment. On the other hand, industry has generally attempted to minimize overall cost in their operations, and this may not always result in the use of energy efficient systems. Both industry and the federal government have neglected to apply these three criteria for evaluating alternatives to the design and operation of recycling facilities. In fact, a number of federally funded recycling operations currently exist around the country which apparently do not satisfy these criteria.[14]

While industries have shown interest in recycling, and in increasing energy efficiency in manufacturing and operation, they have generally not been able to address the problem of nonessential products and materials, and have neglected to encourage extension of product lifetime.

The role of government should be to protect the public welfare or provide services in those areas which cannot be adequately managed through the private sector. Since state government funds available for reducing waste generation are currently very limited, the best application of these funds

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14. Report to the Congress, By the Comptroller General of the United States, "Demonstration Grant Program Has Limited Impact On National Solid Waste Disposal Problem," Environmental Protection Agency, General Accounting Office, February 4, 1972, p. 40.

would be in those areas which are not properly managed by the private sector. In other words, state funds should be applied where they will have the greatest societal benefit.

When potential profits can be realized, private enterprise can easily be encouraged to develop efficient recycling systems and to increase the energy efficiencies of their manufacturing and industrial processes. For example, rate structures may be revised to encourage the use of scrap over virgin materials, and taxes on energy and virgin mineral consumption can be used to make resource consumption more closely reflect social and environmental costs.

The state should not expend its very limited revenue at this time in the subsidization of large scale recycling operations. Rather, whatever revenue is available for reducing solid waste should be used to:

1) revise existing tax and rate structures.

2) insure that all industrial recycling operations satisfy the three criteria discussed previously.

3) develop regulatory mechanisms for reducing nonessential uses.

4) establish standards and regulations which will extend product lifetime.

Preliminary examination of the four avenues considered here seems to indicate that the greatest energy resource savings can be realized not through recycling, but through development of increased efficiencies in manufacturing, operating, and maintaining products and equipment and through extension of product lifetime. As stated in the Office of Emergency Preparedness' Staff Study, The Potential for Energy Conservation:

> "... it should be emphasized that, while there are potential energy savings in recycling, the savings through reuse (as with refillable containers) or through extending the life of a product is much greater. Imaginative design and standardization of product components could facilitate reuse without requiring recycling of the constituent materials."[15]

For instance, if a refrigerator is used for 15 years, instead of 10, its continued use represents a reduction of waste at the source, a form of recycling -- without any collection, processing, reprocessing, fabrication, or redistribution having taken place. Each of these steps requires an energy input. One of the new design criteria should be to make repair of products more attractive than replacement.[16]

Reduction of nonessential uses may prove difficult, in some cases, because of the value judgements involved in defining what is nonessential. Nevertheless, the importance of this form of regulation should not be overlooked, particularly in assessing new technologies or products before they enter the market.

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15. The Office of Emergency Preparedness, The Potential for Energy Conservation, a staff study, October 1972, p. E-24.
16. Darnay and Franklin, op. cit., pp. 94-95.

CHAPTER 2

PRESENT AND FUTURE SOLID WASTE MANAGEMENT TECHNIQUES

For municipal waste the most commonly used solid waste management techniques are disposal techniques. Due to the open burning ban, virtually all of Minnesota's municipal waste is disposed of either by burial in sanitary landfills or, in the case of some office, commercial, institutional, home and apartment complex refuse, incinerated in approved incinerators. These disposal techniques are discussed briefly below.

Sanitary Landfill

A sanitary landfill is a system for final disposal of solid waste on land, in which thin layers of waste are spread and compacted on an inclined, minimized working face in a series of cells with a daily cover of earth provided so that minimal hazard or insult to the environment results.

Sanitary landfills must be carefully designed and engineered to protect against potential leachate contamination of surface and ground water supplies. Of concern as well is the scarcity of suitable landfill sites within economic hauling distance of urban areas where large quantities of solid waste are generated and highly intensive land use situations exist.

While the need for sanitary landfills will remain for the forseeable future, the ultimate, long-range goal should be to minimize as much as possible the <u>amount</u> of renewable and nonrenewable resources buried.

Incineration

Incineration may generally be defined as the controlled combustion of solid, liquid, or gaseous wastes to a residue containing little combustible material. In modern central incineration plants, burning takes place in furnaces lined with refractory and insulated brick, designed to withstand extremely high temperatures ranging from 1500° to 1800° F. The sterile solid residue of non-burnables is discharged, quenched and removed to disposal sites, usually landfills. The residue represents 10 - 20 percent of the original volume and 20 - 30 percent of the original weight. Greater weight and volume reduction can be achieved if wastes are preprocessed to remove metals and glass.

Particulate emissions are associated with incinerators. Cyclone separators, electrostatic precipitators, or fabric filters allow control of these air contaminants, with the latter two techniques being most effective and most costly. The incineration of some plastics, such as polyvinyl chlorides, produces a noxious and corrosive gas in the form of hydrochloric acid (HCl). Another objection to incineration is the high operating and capital costs, leading to total costs ranging from $4 to $15 per ton of refuse processed.[17]

According to the University of Minnesota Consortium on Solid Waste Management,

> "it is unlikely that the present acceptable system of solid waste management which usually consists of burial in sanitary landfills or incineration without heat recovery will be acceptable for very much longer. The present system fails on two counts: it squanders our natural resources, and it degrades our environment."[18]

Resource Recovery

One alternative to disposal is the recycling of solid waste, by no means a new concept. Prehistoric man might well have, after consuming a piece of raw meat, used the bone as a tool or decorative ornament; the American Indians taught the pilgrims to fertilize crops with the use of fish and animal entrails, and thrifty housewives for generations have reused glass containers.

Industry has traditionally reprocessed in-plant or "prompt scrap." For example, in a paper mill the "broke" (scrap paper) is often recovered and used in the paper making process; trimmings in sheet metal operations are often sold to primary metal producers for reprocessing into new intermediate products; waste products from meat processing industries may

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17. University of Minnesota Consortium for the Study of Solid Waste Management, "A Report on Solid Waste Management/Recycling Options," July 12, 1972, p. III-24, and Breidenbach, A., "Composting of Municipal Solid Wastes in the United States," U.S. Environmental Protection Agency, SW-47r, 1971, p. 94.
18. Consortium Study, Ibid., p. Foreword.

be used to produce pet foods; and lemon oil for use in products such as furniture polish, may be recovered from lemon rinds at juice processing facilities.

"Obsolete scrap," (material which has left the manufacturing plant and has served its intended purpose), is also presently being recycled. For example, a supermarket or department store may sell empty corrugated boxes to a waste paper dealer or secondary-fibre user such as Hoerner Waldorf in St. Paul; a printer or envelope company may sell scrap paper in a similar fashion. Lead from spent storage batteries and rubber from worn tires that are recappable are often recycled if customers receive a cash trade-in allowance when buying new tires and batteries. Soft drink bottling plants often remove returnable bottles which are scratched, chipped or broken and return the glass to a glass manufacturer for use as "cullet" in the manufacture of new glass. In Minnesota, automobile hulks are being recycled largely due to the MPCA's automobile recycling program which subsidizes the location, collection and transportation of abandoned auto hulks.

Indeed, in this country a highly sophisticated secondary materials industry has been developed with average annual sales per company of over $7.5 million.[19] (Geographic distribution of the secondary materials industry,and secondary materials sales is shown in Figures 9 and 10). Because of material recovery

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19. Battelle Institute, "A Study to Identify Opportunities for Increased Solid Waste Utilization," Vol. I, June, 1972, p. xii. Prepared for the National Association of Secondary Materials Industries (NASMI).

PERCENTAGE DISTRIBUTION OF SECONDARY MATERIALS SALES, BY REGION

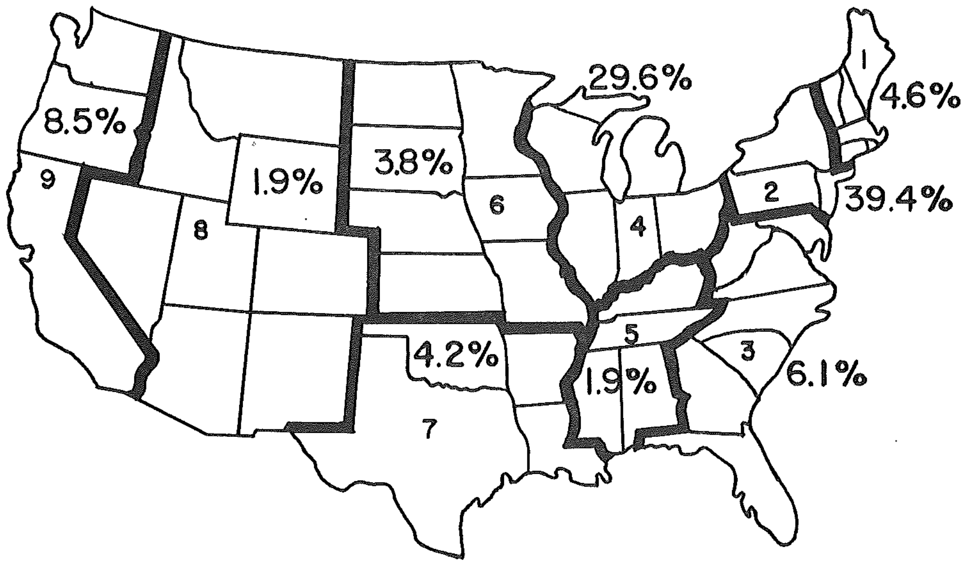

Figure 9

GEOGRAPHIC DISTRIBUTION OF THE SECONDARY MATERIALS INDUSTRY BASED ON NUMBER OF ESTABLISHMENTS

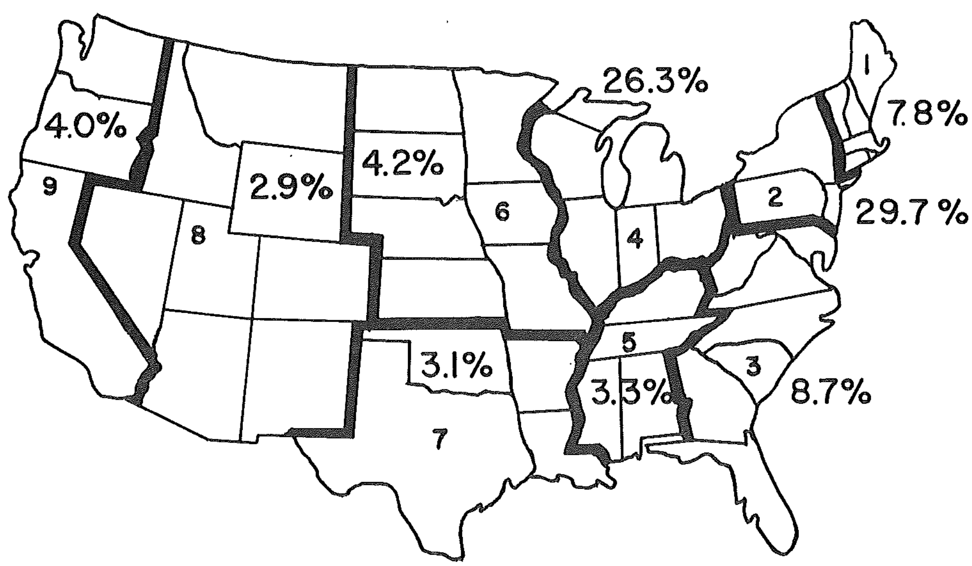

Figure 10

1. New England
2. Middle Atlantic
3. South Atlantic
4. East North Central
5. East South Central
6. West North Central
7. West South Central
8. Mountain
9. Pacific (includes Alaska and Hawaii)

Source: Battelle, "A Study To Identify Opportunities For Increased Solid Waste Utilization," Volume I, p. 36-37, (June, 1972) by the secondary materials industry, the nation was able to use $3.27 billion of secondary aluminum, copper, lead, zinc, nickel, precious metals, paper and textiles in 1969.[20] The recycling rate for these selected materials is shown in Table 2, page 29.

The Importance of Market Demand for Recycled Materials[21]

Why aren't larger quantities of material recycled? The reason is that recycled materials must compete with virgin natural resources and the demand for scrap is limited. Several factors affect the competitive position of recycled materials.

The existence of depletion allowances for the extraction of many virgin materials continues to favor processing from virgin resources rather than use of recycled scrap. When this processing does not meet air, water, and solid waste standards -- or when standards are absent or inadequate -- the processor does not pay the full costs of the environmental impact resulting from the use of virgin material. Production of materials from virgin resources often requires many times more energy than production from recycled scrap. The full costs, however, of the production and use of energy associated with pollution or the depletion of nonrenewable resources, have not been fully incorporated into the current price of energy. This in turn has resulted in underpricing for virgin material production. Many raw materials (like bauxite) are now imported

20. Ibid., p. xiii.
21. This section drawn almost entirely from the excellent discussion of market demand by Darnay and Franklin, op. cit., Chapter 10.

TABLE 2 - RECYCLING RATES FOR SELECTED MATERIALS, 1969

Material	Short Tons[a] Available for Recycling, 1969	Short tons Recycled, 1969	Percent Recycled, 1969	Short Tons not Recycled, 1969
Aluminum	2,215,000	1,056,000	48	1,159,000
Copper	2,456,000	1,489,000	61	967,000
Lead	1,406,000	585,000	42	821,000
Zinc	1,271,000	182,000	14	1,089,000
Nickel	106,000	42,200	40	63,900
Stainless Steel	429,000	378,000	88	51,000
Precious Metals[b]	105,000,000 troy ounces	79,000,000 troy ounces	75	26,000,000 troy ounces
Paper	48,200,000	11,400,000	24	36,800,000
Textiles	3,200,000	1,400,000	44	18,000,000

Note: a. Battelle-Columbus estimates.

b. Includes:

	Troy Ounces		
	Available	Recycled	Not Recycled
Gold	2,200,000	1,800,000	400,000
Silver	100,000,000	75,000,000	25,000,000
Platinum	2,300,000	2,200,000	100,000

-- In general, those materials with higher unit prices have higher recycle rates. However, there are other important influences on the recycle rates. The trade-in policy for auto batteries boosts the recycle rate for lead. The sacrificial corrosion of zinc from galvanized steel depresses its recycle rate. The decreasing demand for some grades of new paper and paperboard depresses the recycle rate for paper.

Source: Battelle/NASMI, "A Study to Identify Opportunities for Increased Solid Waste Utilization, *op. cit.*, (footnote 19), p. 29.

even though their use contributes to a foreign trade imbalance. The fact that these true or "external" costs are not incorporated in the price of materials produced from virgin resources has led to greater labor productivity and more rapid technological innovation in processing virgin resources than in scrap processing.

By contrast, secondary materials receive no credit for conserving energy and mineral resources, for contributing favorably to our foreign trade balance, for removing materials from the waste stream, or for providing materials whose processing usually pollutes the environment less than comparable processing of virgin materials. All of these factors contribute to the poor competitive position of scrap materials in present markets. The overall effect is summarized with an example given by Darnay and Franklin in Salvage Markets:

> "a steel producer finds it cheaper (1) to mine, beneficiate, and ship ore; (2) to mine and transport fluxing materials; (3) to produce coke from coal (which was also mined and moved); (4) to produce steel from pig iron from these materials; and (5) to produce steel from pig iron (sometimes using oxygen extracted in air liquefaction plants) than to acquire, remelt, and reformulate steel scrap."[22]

New legislation or regulation, which would reallocate costs to reflect the full costs of virgin material, would greatly improve market demand for many recycled materials.

The expansion of market demand for scrap is essential if any increase in the percentage of materials recycled is to occur. Voluntary return of materials to "recycling centers"

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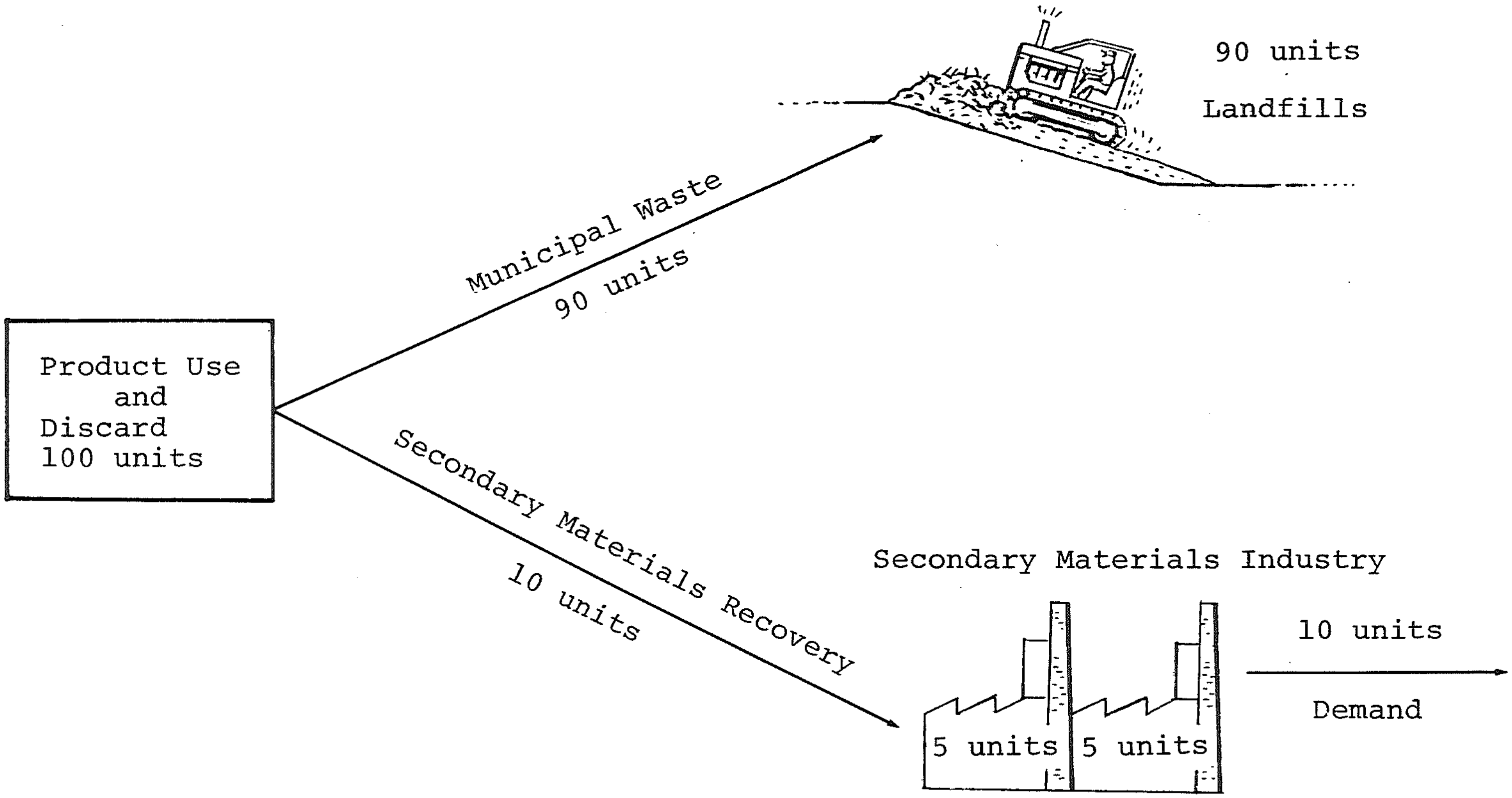
22. Ibid., p. 89.

and sorting, separation, and reprocessing of municipal waste has little impact if the demand for the materials is small or nonexistant. In fact, when a recycling operation is subsidized to produce materials for which there is minimal demand, the operation can be to the detriment of established secondary materials industries. The following hypothetical situations illustrate why demand is the critical aspect of secondary material use. These situations assume conditions of steady need or demand for 100 units of a given product.

Situation One (Figure 11), represents a condition prior to the introduction of a municipal waste resource recovery system, where for each 100 units that enter the waste stream, there is a market demand of 10 units for recycled material. This demand is supplied through the operations of a secondary materials industry.

In Situation Two (Figure 12), market demand for recycled materials remains at only 10 units. Now, however, community interest in recycling has resulted in the addition of a municipal waste resource recovery system which recovers 5 units of recycled material. Since demand exists for only 10 units, and since the secondary materials industry cannot compete with the subsidized municipal system, the traditional secondary materials operation loses markets for 5 units. Thus, 5 units, no longer economically recoverable by industry are diverted instead into the waste stream. Ninety-five units now enter the waste stream instead of 90, so that the startling

SECONDARY MATERIALS INDUSTRY
(Prior to Introduction of Municipal
Waste Resource Recovery)

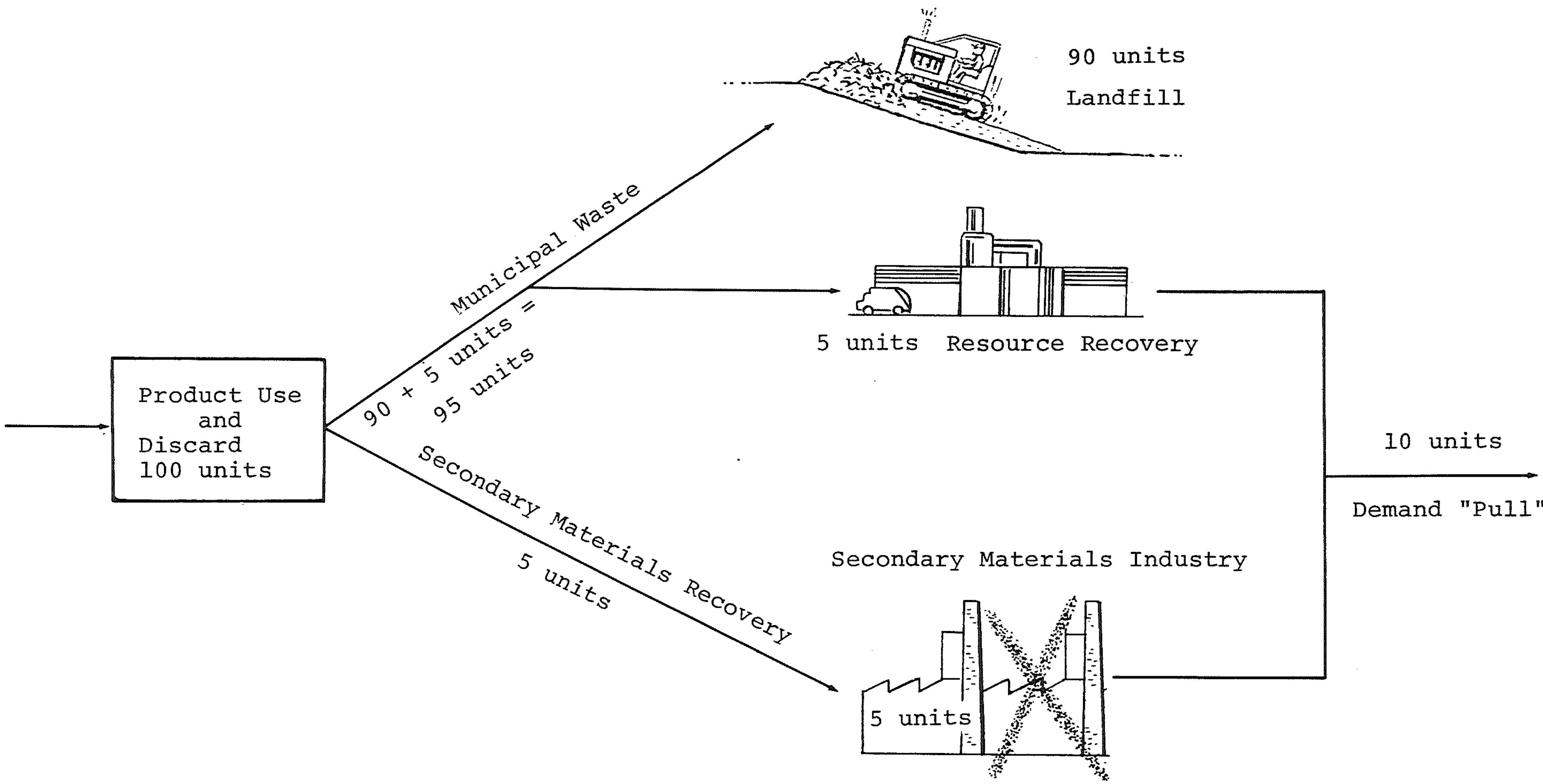


Situation One: Demand for Recycled Material 10 units,
Recycle by Secondary Materials Industry Only.

Figure 11

Adapted from Darnay and Franklin, <u>Salvage Markets</u>, <u>op</u>. <u>cit</u>., Figure 23, p. 95-1.

POTENTIAL DECLINE OF SECONDARY MATERIALS INDUSTRY
(Resulting From Resource Recovery From Municipal Waste)



Situation Two: Demand For Recycled Materials, Constant At 10 Units, Recycle of Municipal Wastes Through A Resource Recovery System, 5 Units.

Figure 12

Adapted from Darnay and Franklin, <u>Salvage Markets</u>, <u>Ibid</u>., Figure 24, p. 95-2.

result is that recovery of 5 units from the new system results in no greater reduction in solid waste than was realized in Situation One. In addition, the subsidized municipal system is likely to be less economical than the original secondary materials industry operation.

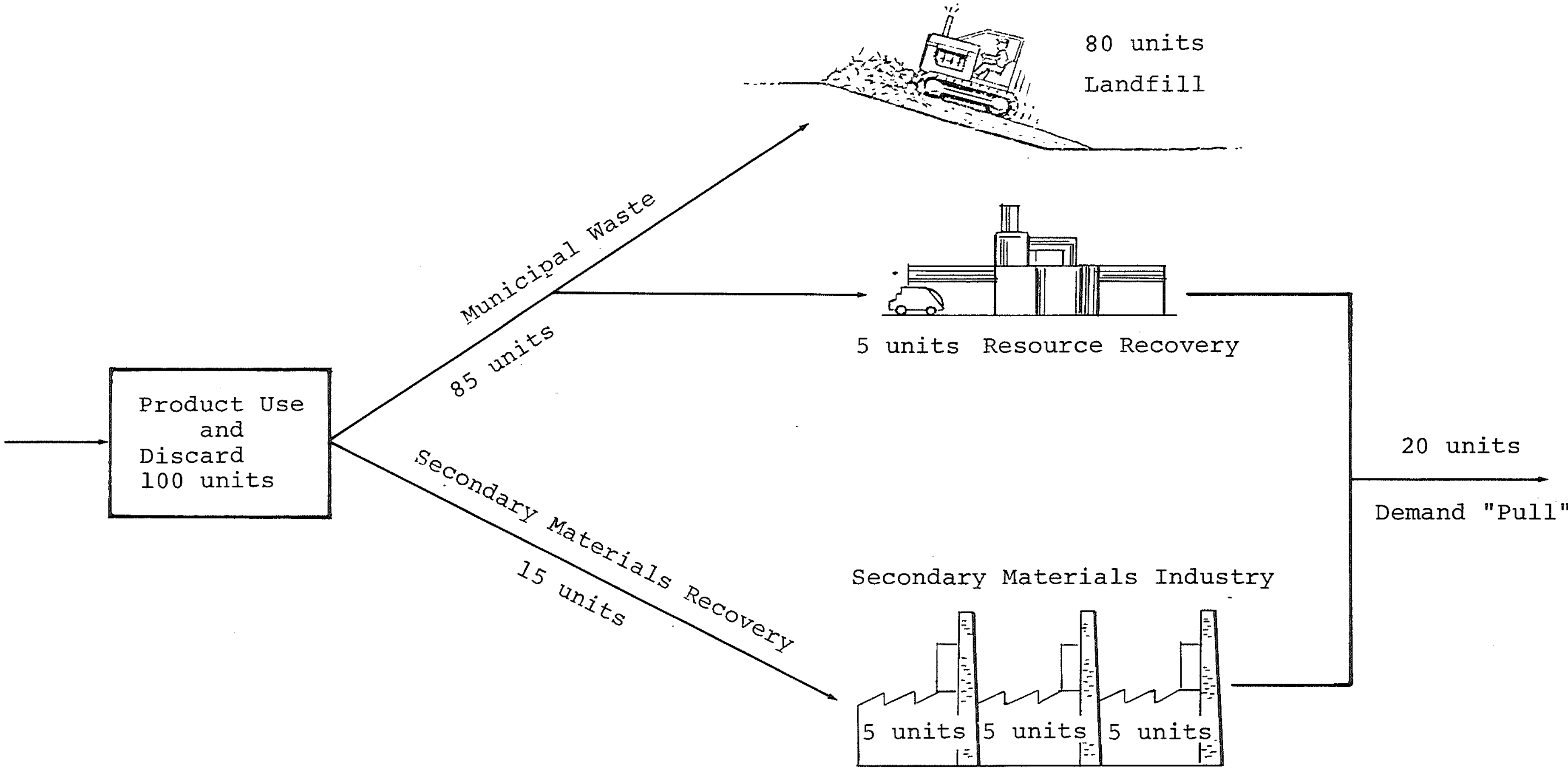
The point of Situation Two is that creation of a large waste processing facility does not necessarily lead to greater recovery of secondary materials and may lead to greater quantities of solid waste entering the municipal waste stream. Demand for recycled materials must increase at the same time or in advance of resource recovery or the total quantity of waste ultimately disposed of will not change.

In Situation Three (Figure 13), the market demand has risen to 20 units and there is ample room for expansion of both municipal resource recovery operations and the secondary materials industry.

The EPA study of salvage markets concludes:

> "At present, it appears that far too few people recognize the importance of the demand parameter and far too many place blind faith in technology and capital to increase the supplies of secondary materials not needed or demanded by the materials processing sectors under current economic relationships and industry structures. Recognition of demand as an unforgiving system element in the whole recycling question is simply not present to the degree necessary in the current rush to 'recycle resources.' What looms then is a potential imbalance of supply and a shift or dislocation of supply of secondary materials from

FAVORABLE RESOURCE RECOVERY
(Resulting from an Improvement in Market
Demand for Recycled Materials)



Situation Three: Demand For Recycled Materials Increased To 20 Units As A Result Of An Improvement In The Competitive Position Of Recycled Material Relative To Virgin Material. (This might occur for example, through removal of depletion allowances for extraction and utilization of virgin resources.)

Figure 13

Adapted from Darnay and Franklin, Salvage Markets, Ibid., Figure 25, p. 95-3.

"'traditional' systems to waste management systems and an even greater burden on solid waste management systems as a whole. Simplistic assumptions about demand 'taking care of itself' or being simple to change are not realistic. This 'supply push' approach is analogous to 'pushing on a string' when in fact, it appears that 'demand pull' would more effectively bring about the desired increase of secondary materials consumption."[23]

New Techniques For Resource Recovery

"In general, within commerce and industry, wherever there are waste streams of fairly large volume and constant composition, recycling is common. It is when the materials are widely dispersed into the hands of individual consumers that the system breaks down."[24]

Once the materials are mixed and placed in the trash containers they become extremely difficult to recycle. While there are special technical problems involved in reclaiming resources from heterogeneous mixtures of municipal refuse, several new techniques are being considered. In order to measure the actual, total societal costs or benefits of these techniques, each should be evaluated in terms of the criteria outlined in Chapter 1.

Composting

After removal of inorganic material such as glass, metal, rubber and plastic, organic matter is partially decomposed by

23. Darnay and Franklin, *op. cit.*, pp. 94-95.
24. Schilling, Bengston, Lindholm, *op. cit.*, p. 22.

aerobic microorganisms in a closed, controlled system. Such a process typically produces a sanitary humus-like material for ultimate use as a soil conditioner rather than a fertilizer. According to the U.S. Environmental Protection Agency, the final compost product enhances the physical properties of soil, increases its porosity, raises moisture-absorption and holding ability, prevents the leaching out of nutrients including fertilizers, and increases the biological activity in the soil, thereby, stimulating plant growth. Despite its attributes, compost itself cannot provide the higher nutrient values of artificial chemical fertilizers.[25]

Composting is not presently a viable solid waste management option because of the difficulty in separating inorganic material, lack of markets for the final compost product, and process costs which are substantially higher than alternative disposal methods. Since 1951, 18 municipal composting plants have been built in the United States, but as of November, 1972, only five receiving subsidy were still in operation. (See Table 3).

Despite the lack of success with municipal composting plants, the federal government, realizing the future potential for this form of resource recovery, announced on October 26, 1972, a $9 million grant to the State of Delaware for another experimental composting facility.

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25. Breidenbach, *op. cit.*, p. 103.

TABLE 3 - MUNICIPAL SOLID WASTE COMPOSTING PLANTS IN THE UNITED STATES

Location	Company	Process	Capacity ton/day	Type waste	Began operating	Status
Altoona, Pennsylvania	Altoona FAM, Inc.	Fairfield-Hardy	45	Garbage, paper	1951	Operating
Boulder, Colorado	Harry Gorby	Windrow	100	Mixed refuse	1965	Closed
Gainesville, Florida	Gainesville Municipal Waste Conversion Authority	Metrowaste Conversion	150	Mixed refuse, digested sludge	1968	Closed
Houston, Texas	Metropolitan Waste Conversion Corp.	Metrowaste Conversion	360	Mixed refuse, raw sludge	1966	Operating
Houston, Texas	United Compost Services, Inc.	Snell	300	Mixed refuse	1966	Closed (1966)
Johnson City, Tennessee	Joint USPHS-TVA	Windrow	52	Mixed refuse, raw sludge	1967	Closed
Largo, Florida	Peninsular Organics, Inc.	Metrowaste Conversion	50	Mixed refuse, digested sludge	1963	Closed (1967)
Norman, Oklahoma	International Disposal Corp.	Naturizer	35	Mixed refuse	1959	Closed (1964)
Mobile, Alabama	City of Mobile	Windrow	300	Mixed refuse, digested sludge	1966	Operating intermittently
New York, New York	Ecology, Inc.	Varro	150	Mixed refuse		Operating
Phoenix, Arizona	Arizona Biochemical Co.	Dano	300	Mixed refuse	1963	Closed (1965)

Sacramento Co., California	Dano of America, Inc.	Dano	40	Mixed refuse	1956	Closed (1963)
San Fernando, California	International Disposal Corp.	Naturizer	70	Mixed refuse	1963	Closed (1964)
San Juan, Puerto Rico	Fairfield Engineering Co.	Fairfield-Hardy	150	Mixed refuse	1969	Operating intermittently
Springfield, Massachusetts	Springfield Organic Fertilizer Co.	Frazer-Eweson	20	Garbage	1954 1961	Closed (1962)
St. Petersburg, Florida	Westinghouse Corp.	Naturizer	105	Mixed refuse	1966	Closed
Williamston, Michigan	City of Williamston	Riker	4	Garbage, raw sludge, corn cobs	1955	Closed (1962)
Wilmington, Ohio	Good Riddance, Inc.	Windrow	20	Mixed refuse	1963	Closed (1965)

Source: "Composting of Municipal Solid Wastes in the United States" (SW-41r), U.S. Environmental Protection Agency, 1971 and letter dated November 9, 1972 from Mr. John Bertke, U.S.E.P.A., Office of Solid Waste Management Programs, Processing and Disposal Division.

Systems To Recover Energy From Solid Waste

In many European countries, where fuel costs are traditionally higher than in the U.S. or Canada, systems to recover electricity and steam from the combustion of solid waste have been in operation for a number of years. Now, with fuel costs in the U.S. expected to rise dramatically over the next 15 years, this form of resource recovery is becoming economically attractive to industries and municipalities.

A brief review of some existing and proposed systems follows. While recovery of energy from solid waste is more desirable than incineration without energy recovery, it is important to note that this form of "resource recovery" should not be considered a substitute for recycling of materials, or the extension of product lifetime, since the energy savings by comparison are relatively minor. Further, energy recovery from solid waste may produce serious air contaminants,[26] and tends to preclude reuse or recycling of many materials.

Incineration With Energy Recovery In Vienna, Austria a district heating plant has been designed to produce 200 megawatts with refuse contributing 25 to 30 percent of the heat required.[27]

The U.S. Environmental Protection Agency has announced several experiments in which refuse is to be mixed with coal in

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26. Even production of carbon dioxide could ultimately become a problem through the so-called "greenhouse effect."
27. Swaty, P., "Waste Heats Vienna," Energy International, December, 1970, pp. 18-23.

quantities which result in only a minor reduction in electric generation (if any) while allowing the heat generated from the refuse to be utilized.

One such system receiving EPA support is operated by Union Electric Company, in St. Louis, Missouri. The Company has modified a steam electric power plant to burn a mix of 10 to 15 percent shredded solid waste and 85 to 90 percent pulverized coal.

A similar experiment using industrial waste as a power plant fuel is being conducted in Fort Wayne, Indiana. Here, below grade fibrous material, along with small quantities of wood, leather, and carbonaceous materials, is recovered from waste by a paper recycling company. The material is then pressed into "cubettes." Two combustion tests using a three to one ratio of coal to "cubettes" have shown no operating difficulties. Potentially, 120 tons per day of coal equivalent could be recovered in this manner in the Fort Wayne area.[28] (By contrast, the 1360 MW Becker Plant in Sherburne County, Minnesota will use roughly 17,600 tons of coal per day).

The Environmental Protection Agency is also supporting an experimental system--dubbed the CPU-400. Designed by Combustion Power Company, Inc. and manufactured by General Electric, Pratt-Whitney and Westinghouse, this system consists

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28. Perry, Harry, Conservation of Energy prepared at the request of Henry M. Jackson, Chairman, Committee on Interior and Insular Affairs, U.S. Senate, pursuant to S. Res. 45, A Nation Fuels and Energy Policy, Serial No. 92-18, August, 1972, p. 59.

of a gas turbine costing $1.8 million. The blades of the gas turbine compress air which gets hot enough to melt sand in a chamber. After being ground up by a shredder, the garbage is fed onto the boiling sand. The garbage must be cleaned of metal, glass and rocks in the shredding process, so that the remaining organic material will burn at a predictable rate. The extremely high heat breaks down sulfur dioxide and hydrochloric acid normally released from plastics in the garbage. The CPU-400 has a capacity of 400 tons a day, the refuse of roughly 160,000 people. Taking the heating value of dry garbage at 6,300 Btu/pound, the burning of the garbage should yield roughly 15 megawatts of power.[29]

In Hempstead, Long Island, an incinerator has been built which produces steam to generate internal power needs and to desalinate water for boiler feed. In Nashville, Tennessee an incinerator, scheduled for completion in early 1974, is designed to provide central heating and air conditioning to 27 office buildings in the downtown area. The Nashville incinerator will burn 360 tons of solid waste per day and the resulting steam will provide heat and/or drive centrifugal refrigeration units.

It is important to note that waste preprocessing, such as the removal of incombustible materials, corrosive substances and metallic resources, is necessary for systems which recover energy from incineration.

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29. Ibid. pp. 58-59.

Pyrolysis In this process solid wastes are heated to high temperatures in the absence of oxygen, which converts the wastes to storeable liquid and gaseous fuels and other commercially valuable products. According to the University Consortium for the Study of Solid Waste Management, "initial studies suggest that as much as 80 percent of the energy in solid wastes may be recovered in the fuels produced."[30]

Preprocessing of the waste is necessary to remove bulky incombustible items (e.g., refrigerators), potentially harmful and corrosive substances (e.g., polyvinyl chlorides) and to recover metallic resources which might otherwise be lost as gaseous oxide at high furnace temperatures. Because preprocessing requires considerable amounts of energy, home separation of materials prior to collection is desirable, according to the University of Minnesota Consortium for the Study of Solid Waste Management. Such home separation could significantly reduce the energy input necessary for preprocessing waste for pyrolysis treatment.

In a pyrolysis unit preprocessed solid waste is passed through a series of reactors where it is pyrolyzed under controlled temperature and pressure conditions. The final products of this system are a gaseous or liquid fuel, depending on the design, and a solid residue which may be useful as an aggregate material or perhaps a soil conditioner.[31]

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30. Consortium Study, _op. cit._, p. IV-50.
31. _Ibid._, pp. III-24, 25, IV-50 - 53.

For municipal refuse, 810,000 Btu can be recovered per ton of waste pyrolyzed, while, for industrial waste, 1,690,000 Btu per ton can be recovered. Residential, commercial and industrial waste is estimated to be about 350 million tons per year.[32] If this quantity could be pyrolyzed, it would represent roughly 0.62 percent of total U.S. energy demand in 1971 or the equivalent of 17 million tons of coal.[33]

While recapping and reuse of rubber from tires would be more desirable than their pyrolysis, pyrolysis of the one million tires scrapped would produce $24.6(10^{12})$ Btu, equivalent to one million tons of coal.[34]

A potential drawback exists with these energy recovery systems because they are almost totally reliant on the high Btu content of paper and plastic waste. Future trends in paper consumption, pulp demand and supply, which will be discussed later in this report, indicate that it may be necessary to reclaim paper as pulp fibre for reuse as paper rather than for a one-time reuse as energy. According to the University Consortium on Solid Waste, "if we do not recycle larger fractions of paper products we can expect an increase in the cost of pulp which in turn will encourage the use of paper substitutes, made from non-renewable resources such as plastics."[35]

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32. Perry, op. cit., p. 58.
33. Ibid.
34. Held, J., et. al. have analyzed the potential for energy recovery from waste rubber for the University of Minnesota Consortium for the Study of Solid Waste Management/Recycling Options, July 1972.
35. Consortium Report, op. cit., p. IV-30.

The combustion of plastic wastes represents a loss of nonrenewable petroleum resource, and may produce undesirable air pollutants (see Chapter 4 page 100). Reuse of plastic represents a far greater energy saving than combustion for heat recovery purposes. Further, it can be seen from Table 5, page 56 that greater energy savings can be realized through paper recycle than paper combustion to recover heat.

Anaerobic Digestion To Produce Methane[36] In a recent article in Environment Magazine[37] it was proposed that organic and urban waste be converted by anaerobic action (the reaction of microorganisms in the absence of air) into methane and sludge. Anaerobic action occurs spontaneously in sewage and compost; but in commercial production of methane by this method, the natural process would have to be speeded up.

The potential for methane from this source is large since 1.5 billion tons of solid waste produced each year could generate as much as 30 trillion cubic feet of gas -- an amount larger than current gas consumption in the United States. For 100,000 cattle, the 150,000 tons of dry organic waste generated per year would yield 3 billion cubic feet of methane.[38]

The University of Minnesota Consortium for Solid Waste Management has examined the potential for methane recovery

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36. Here methane is considered to be equivalent to natural gas.
37. Bohn, H. L., "A Clean New Gas", Vol. 13, No. 10. pp. 4-9.
38. Perry, op. cit., p. 60.

from this process in Minnesota and concludes:

> "A process of anaerobic digestion to produce methane from agricultural wastes holds the possibility of allowing approximately 40 percent of this energy to be harvested while allowing the soil conditioning and mineral wealth of the now reduced mass of residue to be returned to the soil. We estimate that Minnesota could produce 4.9(10^{14}) Btu/year in the form of methane in this way. In 1970, the state's methane consumption was 3.4(10^{14}) Btu."[39]

Energy recovery by anaerobic digestion appears to have the least impact on the environment and offers the largest energy recovery of any of the other systems discussed above.

However, this system relies on accumulation of large volumes of urban and agricultural wastes which are difficult to return to the land economically. Furthermore, the collection of these wastes for large methane generators could pose major economic and transportation problems, because of the very high volumes of these wastes relative to their Btu content. It is recommended that this form of energy recovery be investigated further, particularly the potential costs and benefits of small generators associated with sewage plants, canning operations, feedlots, farming operations, and septic tanks.

The Solid Waste Consortium concludes their discussion of energy recovery from solid waste with the following warning:

> "The rate of production of these renewable resources has an upper limit. The energy

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39. Consortium Report, *op. cit.*, p. II-11.

> content represents a substantial fraction of the State's energy needs with our present population and per capita consumption. They will be negligible with a few more doubling of the State's energy budget."[40]

For example, by 1990, assuming the current growth in demand for methane continues, the demand for this fuel would be roughly twice the absolute quantity of methane that could be generated from organic wastes. The implementation of an effective energy conservation program could prevent this from happening.

Hydrasposal*/Fibreclaim* System

After a minimum of preprocessing, such as the removal of water heaters, refrigerators, tree stumps, rubber tires, etc., mixed municipal waste is fed into a wet pulping machine with a high speed cutting rotor in the bottom of the tub. Water is added to the refuse where the materials are converted to a water slurry by the high speed cutting action of the rotor. Bits of metal, tin cans, and other non-pulpable and non-friable materials are ejected through an opening in the side of the pulping tub and ferrous metals are recovered by means of a magnetic separator. The remaining material is incinerated or buried in a landfill. The water slurry containing all pulpable material is pumped through several

40. Ibid., p. II-12.
Source: Hydrasposal*/Fibreclaim* System Information Sheet, The Black Clawson Company, 200 Park Avenue, New York, N.Y.
* Trademark of the Black Clawson Company

process stages and long paper-making fibres are mechanically separated from coarse organics such as rubber, textiles, leather, yard waste, food waste, paper coatings and fillers, etc. After dewatering and drying, the reclaimed paper pulp is sold to a nearby roofing manufacturer for use in the manufacture of dry felt for asphalt roofing. The non-recoverable organics in the slurry are dewatered and incinerated in a fluid bed reactor with the incinerator residue being buried in a landfill.

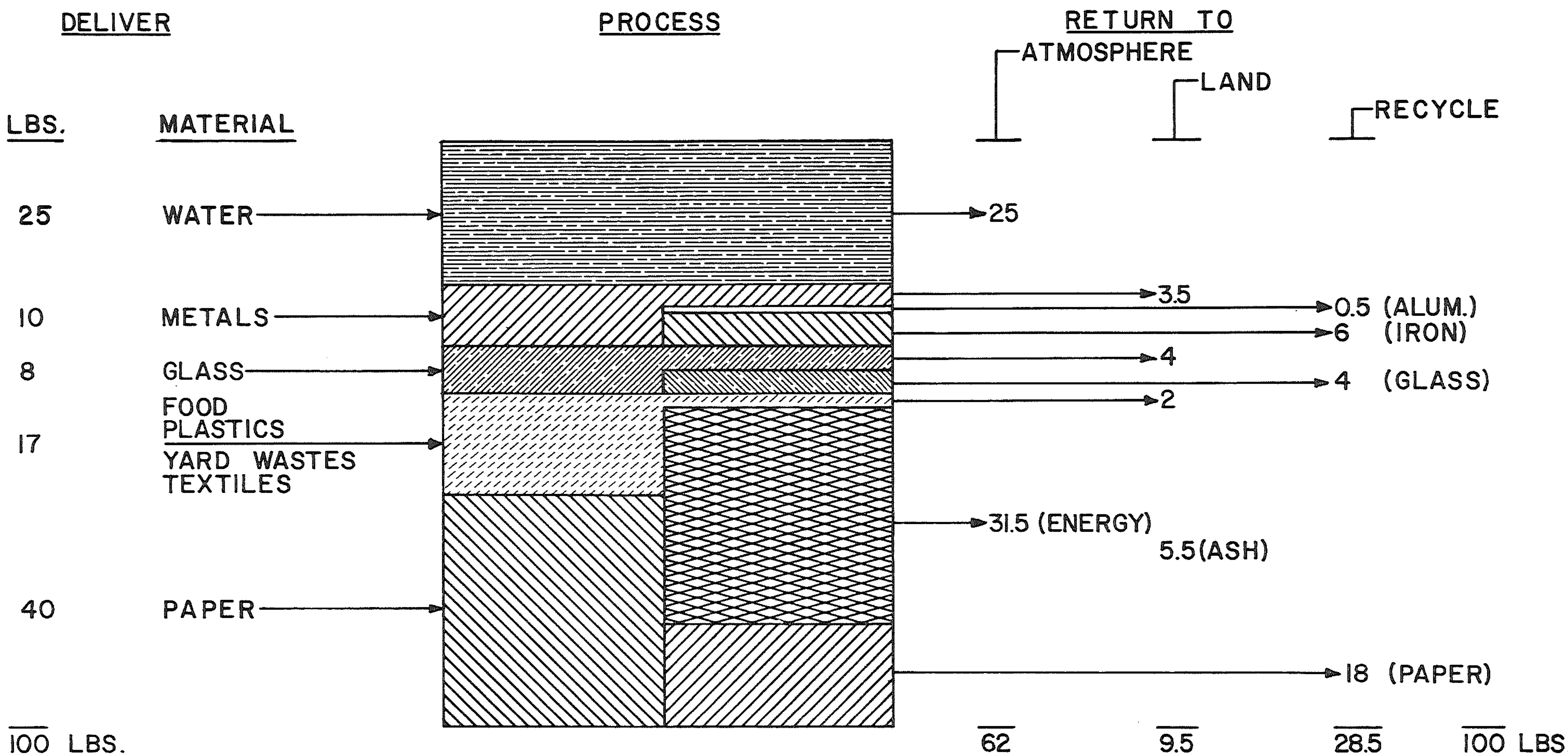
For every 100 pounds of material entering this process, 62 pounds are returned to the atmosphere in the form of waste heat and water, 9.5 pounds are buried in landfills and, theoretically, 28.5 pounds can be reclaimed. Of the 28.5 pounds to be reclaimed, the breakdown is as follows: paper, 18 pounds; iron, 6 pounds; glass, 4 pounds; aluminum, 0.5 pounds. (See Table 4).

The federal government has provided two-thirds funding for a demonstration of the hydrasposal/fibreclaim process at Franklin, Ohio. This pilot plant uses the energy equivalent of approximately 23.4 gallons of oil per ton of waste for its operation.[41] Thus, its current operation results in a substantial environmental impact from energy production

41. Hannon, Bruce, "System Energy and Recycling: A Study of the Beverage Industry", in Hearings before the Subcommittee on the Environment in S. 1377 and S 3058, March 6, 10, 13, 1972, Serial No. 92-60, p. 331. Separation and sorting is roughly 2,464,000 Btu/ton of waste. Using $5.8(10^6)$ Btu/barrel of oil as the conversion factor, this becomes the equivalent of 23.4 gallons of oil.

MATERIAL BALANCE

HYDRASPOSAL / FIBRECLAIM



SOURCE: THE BLACK CLAWSON COMPANY
200 PARK AVENUE
NEW YORK, NEW YORK

TABLE 4

and a significant loss of nonrenewable fuel resources.

While the plant is designed with a capacity of 150 tons per 24 hours, the facility is presently processing only 35 - 50 tons per eight hour day, reclaiming only paper and ferrous metal. Initial economic data indicates that because economy of scale plays such a major role in this system, plants with a daily capacity of 500 tons or more are necessary for economic competition with incineration at current prices. The net process costs (after the sale of reclaimed paper fibre and iron) are approximately $35 per ton of refuse processed. Process costs are expected to be reduced somewhat when the plant is able to operate at full capacity and when glass and aluminum recovery systems become operable.[42]

It also bears repeating that any benefit to be derived from this system depends on the presence of adequate markets for the recycled materials, with a large enough market demand that for the material it can be sold without interferring with the secondary materials industry. (See Chapter 1, page 28.)

Volunteer Recycling

Due to public environmental awareness, many individuals are at present voluntarily separating recyclable materials such as cans, bottles, newspapers, cardboard, and aluminum

42. Telephone conversation, November 24, 1972, between J. Burke, MPCA, and D. Arella, U.S. Environmental Protection Agency; Project Engineer for Franklin, Ohio Demonstration Project.

food trays, from their home refuse. After separation, these materials must be properly prepared for delivery to a collection center. Newspapers and cardboard generally must be bundled and tied. Cans must be rinsed clean, paper lables must be removed, bottoms and tops must be removed and placed inside, after which the containers must be flattened, and further sorted by metallic content. Glass must be rinsed clean, all metal caps and closures must be removed and glass must be sorted by color.

Once material has been sorted and prepared, the individual delivers it to a collection center where the material undergoes further preprocessing prior to sale. For example, if the appropriate equipment is available, the collection center may crush glass and bale newspapers, cardboard, and cans to reduce volume and thereby lower the cost of transporting the reclaimed material to markets. While prices may fluctuate, average market prices in Minnesota during the past year have been as follows: newspaper, \$6 to \$8 per ton; clear and amber glass, \$10 to \$20 per ton; green glass, \$5 per ton;[43] bi-metal and tri-metal cans,[44] \$5 to \$10 per ton; aluminum cans and household scrap, 5¢ to 8¢ per pound.

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43. While there are no green glass furnaces in Minnesota, the Metropolitan Recycling Center (St. Paul) buys green glass for resale to a firm in Streator, Illinois.
44. An example of a "bi-metal" can is a combination steel/tin beverage container which is not self-opening. An example of a "tri-metal" can is a "pop-top" self-opening container made with an aluminum top and tin/steel bottom and sides.

During the past year, MPCA staff attempted to compile and maintain a state-wide list of collection centers; however, it was found that the high mortality rate and sporadic nature of such centers made it virtually impossible to maintain accurate and current information with the limited staff time available. Of the 49 collection centers identified by the MPCA in June, 1972, less than half were still operating in December, 1972.[45]

While there has been no shortage of voluntary contributions of recyclable materials, the lack of success experienced by many volunteer collection centers in Minnesota can generally be attributed to:

1) lack of sufficient, long-term volunteer operating labor,

2) inability to handle large volumes necessary to recover operating and transportation costs, and

3) lack of markets within economic hauling distance, particularly in rural areas.

One of the collection centers still in operation is the Metropolitan Recycling Center[46] in St. Paul which opened in October, 1971. Metropolitan Recycling Center, an effort sponsored jointly by the Occupational Training Center, Theodore

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45. MPCA staff telephone survey conducted November 27 thru December 11, 1972.
46. Because MPCA staff was unable to obtain detailed operating information from the Metropolitan Recycling Center, the above information was taken from MRC's progress report dated June 1, 1972 and "Project Recycle," Minneapolis Tribune Picture Magazine, August 27, 1972.

Hamm Company and Coca-Cola Midwest, Inc., is unique from other volunteer recycling centers in several ways. While MRC relies almost totally on volunteer contributions of recyclable materials, it is a financially subsidized operation with a full-time, paid staff, many of whom are handicapped persons. With Hamm's and Coca-Cola's initial financial assistance of approximately $100,000, MRC has developed into a large scale collection and processing facility handling over 100,000 pounds of recyclable material per week while providing sheltered employment to handicapped persons. Even though MRC's volume is considerably higher than most volunteer recycling centers in the state, the operation continues to require and receive financial subsidy from Hamm's and Coca-Cola in addition to several private foundations. While the MRC has demonstrated success in providing sheltered employment for handicapped persons, it has definitely not demonstrated the economic feasibility necessary for successful resource recovery systems. Neither has it resulted in a significant reduction in solid waste. In fact, more than 100 such centers would be required to collect and process all bottles and cans discarded annually in the state. (See Appendix C, p. C-40.)

To use the words of Mr. Thomas Quimby, a Visiting Scholar at Resources For the Future, Inc., Washington, D. C., volunteer recycling centers are an "emotionally satisfying, but blind, cul de sac,"[47] whose major contribution is not the reduction of solid waste nor the conservation of natural resources. Instead, such centers serve as a valuable educational device for changing traditional, socio-psychological attitudes towards secondary materials. Consumers are learning that the quality of recycled materials is not inferior and that the use of the adjective "secondary" refers only to the source of the material.

The University of Minnesota Consortium for the Study of Solid Waste Management recommended, and MPCA staff concurs, that the state should not assist in the development of volunteer recycling centers:

> "We must encourage efficient, rational, conserving schemes for recycling valuable materials from the solid waste stream. We hold that volunteer recycling centers do not provide a meaningful solution to this problem. While such centers maintain and nurture interest in the conservation of resources, they are inefficient (perhaps a recycling efficiency of about 5% can be achieved) and may consume more energy in their operation than they save."[48]

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47. Quinby, Thomas, H.E., "The Economics of Paper Recycling," a presentation to the New York Chamber of Commerce Seminar on Recycling of Paper, October 20, 1971.
48. Consortium Study, op. cit., p. II-14.

CHAPTER 3

ENERGY REQUIREMENTS FOR SELECTED COMPONENTS IN THE SOLID WASTE STREAM

The strong correlation between energy production, resource conservation, and environmental impact creates a need for information on the energy requirements of solid waste components in order to assess the total environmental impact resulting from given products or materials. Awareness of the importance of determining energy requirements has developed only recently so that information is generally unavailable for many of the components. Nevertheless, several independent studies have been completed and are examined in this chapter.

Table 5 shows estimates of the energy required to manufacture and recycle various materials which ultimately make their way into the solid waste stream. From Table 5 it appears that:

1) The energy requirement for producing one ton of virgin aluminum may be from 3 to 11 times more than the energy required to produce one ton of virgin steel.

2) Steel and aluminum production from recycled scrap requires much less energy than production from virgin ores.

3) The potential energy saving from recycling paper may be greater than that derived from burning it to generate power.[49]

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49. For example, using the SRI figure of $23.3(10^6)$ Btu/ton for paper and Hirst's estimate of 60% of virgin paper for recycled paper, we have a net saving of $(23.3) - (.60)(23.3) = 9.3(10^6)$ Btu/ton. Using Baile's figure for paper combustion at $15.9(10^6)$ Btu/ton and assuming a 40% efficiency of energy recovery, recoverable energy from combustion becomes $6.4(10^6)$ Btu/ton. Thus, the net energy saving from recycling vs. combustion would be $2.9(10^6)$ Btu/ton.

TABLE 5 - ENERGY REQUIREMENTS IN (10^6) Btu/TON (SELECTED STUDIES)

	virgin glass	glass recycle	virgin steel	steel recycle	virgin aluminum	aluminum recycle	virgin copper	copper recycle	virgin paper	paper recycle	paper combustion	virgin plastic	plastic recycle	plastic combustion	virgin rubber	rubber recycle	rubber combustion	mechanical separation
SRI-OST Study	14-18		26.0		75	8.5	>40.1		23.3									
ORNL-NSF-EP 24			15.9	5.7	175.4	4.4-6.8	46.2-84.5	5.3										
Commoner,B.			9.23		59.7													
Hirst,E.				7-15% of vgn.		< 5% of vgn.		~5% of vgn.		60-70% of vgn.								0.51
Hunt, R. G.	16.2	15.2-16.7	23	6					42 blcd.	24 blcd.		Polystyrene foam meat trays → 79.0	23.8					
Baile,R.C.											15.9			20-23			20-23	
Bell,J.											15.1			28.7			22.7	
Hannon,B.	17.7	18.0	49.5		168.1					63% of vgn.								
Makhijani Lichtenberg	22.8		39.9		225.1		68.2		20.1			8.18						
Reid,W.T.											>18.0							
Forbes					54.6													
Berry,R.S.					56.0													
Silverman,A.							33.7											
Harris,C.					54.6	2.7												
Hickman, H.J.									27.1	21.3		~41.7						
Franklin,W.E. Hunt,R.G.												~60.2						

SEE APPENDIX B FOR FURTHER REFERENCE ON TABLE 5

These three findings, when applied to the criteria of Chapter 1, would suggest:

1) "Throw-away" products should not be made of aluminum.

2) Recycling of steel and aluminum should be encouraged.

3) Recycling of paper should be preferred over incineration to generate power.

These findings will be considered in more detail in Chapter 4.

Energy requirements have been determined for plastic and paper meat trays and egg cartons. These are summarized in Table 6. By including the energy contained in polystyrene as a part of the calculation, one has a more accurate measure of how much "nonrenewable" energy is required for this product. The fact that the plastic meat trays and egg cartons are petroleum products, and therefore "nonrenewable", and that plastic has a greater potential for interfering with biological and geological systems because of its synthetic nature (see Chapter 4, page 99), suggests that paper meat trays and egg cartons are to be preferred over plastic trays and egg cartons.

This relationship appears to hold only when we are comparing paper vs. plastic products with approximately the same life span. Paper packaging of all sorts is preferred over plastic packaging, unless the plastic packaging is used several times. For example, Table 7 compares the plastic returnable milk

TABLE 6 - ENERGY REQUIREMENTS FOR PLASTIC AND PAPER MEAT TRAYS AND EGG CARTONS/TRAY IN Btu's

2" x 6" Egg Carton

	Paper	Foamed Polystyrene Plastic
Hickman Study*	895	2159 (combustion energy included)

8 - S Meat Trays

	Paper	Foamed Polystyrene Plastic
Hickman Study	758	1051 (combustion energy included)
MRI Study**	952	1278.9 (combustion energy included)
		829.5 (combustion energy excluded)

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* See note 15, Appendix B, p. B-18.
** See note 16, Appendix B, p. B-18.

bottle to the plastic-coated paper milk carton. In this case, the energy saving by using plastic returnables instead of paper is 2.27 to 1. This is not true if the plastic milk bottles are of the throw-away variety.

The desirability of the use of plastic returnables relative to the use of glass returnable bottles is more difficult to assess. While the plastic returnable is likely to be filled many more times than the glass returnable, the ultimate impact of plastic containers on the environment may be potentially more serious.

Energy requirements have also now been determined for beverage containers, and the findings are summarized in Table 8. Both glass and can "single use" container systems have essentially the same energy requirements. However, the life of the glass container system can be extended through the returnable system so that a soft drink bottle, if made of slightly thicker glass than the throw-away, endures 15 returns, on the national average, and a beer bottle -- 19 returns. The resulting energy saving over the throw-away can and bottle is on the order of 3 or 4 to 1. Plastic throw-aways vs. plastic returnables probably would show similar energy savings to that for the milk containers considered above.

These findings suggest that there is a significant energy saving and a reduced environmental impact associated with the use of returnable containers vs. the use of non-returnables, even if non-returnables are recycled. Returnable beverage

TABLE 7 - ENERGY REQUIREMENTS FOR PAPER, GLASS, AND PLASTIC MILK CONTAINERS (1/2 GALLON)

	Nonreturnable System	Returnable System
Paper	16,380 Btu/gallon	--
Glass (33 fills)	--	12,955 Btu/gallon
Plastic (50 fills)	17,100 Btu/gallon	7,220 Btu/gallon

Source: Hannon, *op. cit.*, (footnote 41), p. 339-40.

TABLE 8 - ENERGY REQUIREMENT FOR
GLASS AND METAL BEVERAGE CONTAINERS (Btu/GALLON)*

Soft Drink Containers[a]

16 oz. returnable bottles vs. 16 oz. throw-away bottles

	With 30% Recycled	Without Recycling
Returnable System (8 fills)	19,970	19,220
Throw-away System	62,035	58,100
Energy Ratio (8 fills)	1:3.11	1:3.02
Energy Ratio for National Average (15 fills)	1:4.60	1:4.42

12 oz. returnable bottles vs. 12 oz. cans (no recycling)

Returnable System (15 fills)		17,820
Bimetal Can System		51,830
Aluminum Can System		68,934
Energy Ratio	1:2.91	(returnables to bimetal cans)
	1:1.33	(bimetal can to aluminum cans)
	1:3.87	(returnables to aluminum cans)

16 oz. throw-away bottles vs. 12 oz. cans

Energy Ratio	1:0.89	(i.e., cans less consumptive)

Beer Containers[b]

12 oz. returnable bottles vs. 12 oz. throw-aways

	Returnable System	Throw-away System
Glass Bottle for National Average (19 fills)	13,895	46,770
Can	--	52,390
Energy Ratio	1:3.37	(returnable to throw-away bottle)
	1:3.77	(returnable to can)
	1:1.12	(throw-away bottle to can)

* Hannon, *op. cit.*
Source: a. *Ibid.*, (Table 7), pp. 335-337.
b. *Ibid.*, p. 341.

containers, therefore, should be much preferred over non-returnable beverage containers. Energy savings can also be realized by the use of larger containers -- 12 ounce containers have 10.3 percent less efficient surface area to volume of contents ratio than the larger 16 fluid ounce containers.[50] For this reason, a monetary incentive based on the size of containers is suggested.

The energy requirement for recycling non-returnable glass bottles has been calculated at 5,977 Btu per gallon, while the energy requirement for manufacturing glass bottles from virgin materials is given as 1,755 Btu per gallon.[51] These figures indicate that recycling throw-away bottles is presently undesirable from an energy standpoint by the ratio of 3.4 to 1. This ratio may eventually become more favorable with improved technology.

The energy ratio for using waste glass instead of crushed stone for asphalt is 60 to 1.[52] The use of waste glass for "glasphalt", therefore, is considered clearly undesirable in terms of the quantity of energy consumed.

Tables 9 and 10 provide a partial breakdown on the percent of various energy forms used in manufacturing containers. Total 1970 energy used in the U.S. beverage container system

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50. Harris, Carolyn, The Environment and Packaging: An Economic and Legislative Analysis, Environmental Protection Administration of the City of New York, March, 1972, p. 16.
51. Hannon, op. cit., p. 334.
52. Ibid.

TABLE 9 - PERCENT OF TOTAL RESOURCE ENERGY FOR THE SOFT DRINK INDUSTRY (16 OZ. GLASS CONTAINERS), WITH 30 PERCENT RECYCLING OF THROW-AWAY AND RETURNABLES [a]

System	Energy Source			
	Fuel Oil	Gasoline	Gas	Oil
Returnable	19%	19%	41%	21%
Throw-away	10%	7%	63%	20%

TABLE 10 - ELECTRICAL POWER AS PERCENT OF TOTAL ENERGY REQUIREMENTS FOR BEVERAGE CONTAINER MANUFACTURE

Container	Electrical Power*
Bimetal can system	34%
16 oz. returnable bottle system (no remelt)	17.6%
16 oz. throw-away bottle system (no remelt)	18.4%
Aluminum shapes	72%
Paper for paper containers	22%

* Estimates of error ±3%

Source: a. *Ibid.*, (Table 8), p. 344
b. *Ibid.*

accounted for 0.34 percent of the total U.S. energy demand. If the beverage industry were converted to all returnables, the total energy used by the beverage container industry could be reduced by 55 percent.[53]

An analysis of the energy requirements for automobile production with and without recycling has recently been completed by Professors R. Stephen Berry and Margaret Fels of the University of Chicago. They find that approximately 27 million Btu per automobile (about 22 percent of the energy required to produce the car without recycling) could be saved over current practices through optimal recycling. At eight million cars a year, this amounts to 0.35 percent of total U.S. energy demand in 1971.[54] This savings is actually considered to be greater (by perhaps as much as five times) since this figure does not include certain indirect energy costs.[55]

Such a finding makes Minnesota's auto recycling program highly desirable from both a mineral and energy conservation viewpoint. This program is an example of resource recovery at its best, and is proving the value of a materials "user charge" as a mechanism for promoting resource conservation.

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53. *Ibid.*, p. 347.
54. Roughly equivalent to the total energy saving possible from a nationwide ban on non-returnable beverage containers.
55. Office of Emergency Preparedness, *op. cit.*, p. E-19.

CHAPTER 4

SELECTED COMPONENTS IN THE MUNICIPAL WASTE STREAM

Paper

Paper and paperboard products comprise the majority of municipal waste with estimates ranging from 46 to 68 percent.[56] Regardless of which figures are used, it is clear that various grades of paper make up at least half of total municipal waste.

Minnesota's waste paper generation is estimated as follows:*

	(in million pounds)
Containerboard (e.g., corrugated)	1,593
Writing, printing & tissue, etc.	703
Newsprint	641
Magazines	463
Boxboard	245

Paper waste in the municipal waste stream can be classified in two general categories -- packaging items and non-packaging items. Packaging paper such as corrugated boxes, cereal and other food containers, shoe boxes, and cigarette papers, accounts for approximately half of all paper consumption.

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56. McKinsey, op. cit., p. 3-2.

* Estimate obtained by applying percentages in Table 1, page 4, to total Minnesota waste generation of 6.2 billion pounds. These figures appear to be more accurate than those which are obtained by multiplying population by 500 lb. per capita paper consumption. The latter calculation indicates that paper represents roughly 27% of municipal waste, a percentage which is far below the 46-68% range cited above.

It has been found that packaging materials very quickly enter the solid waste stream, frequently within the same month of use, and nearly always within the same year.[57] Further, paper and paperboard constituted 55 percent of all packaging materials consumed in 1966.[58] Thus, packaging paper accounts for a major portion of paper in the solid waste stream.

Non-packaging paper includes such items as roofing felt, construction paper and board, printing papers, stationery, newsprint, and sanitary tissues. While packaging paper very quickly enters the waste stream, it is difficult to determine the product life-time for non-packaging paper items. Newsprint and sanitary tissues, like packaging items, might enter the waste stream within hours of use by the consumer. On the other hand, non-packaging paper used in building construction will not enter the waste stream until the building is torn down; indeed, printing paper used in hardbound books and permanent documents may never become solid waste.

However, once paper and paperboard products have served their ultimate purpose and enter the waste stream, a decision must be made as to whether the paper is disposed of by burial or incineration, or whether it is to be reclaimed as energy or pulp. The discussion in Chapter 3, page 55 has already shown that greater energy savings may be realized by recycling paper

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57. Vaughan, R., The Role of Non-Packaging Paper in Solid Waste Management 1966 to 1976, prepared by Midwest Research Institute for U.S. EPA, 1971, Foreword.
58. Darnay and Franklin, The Role of Packaging In Solid Waste Management, Midwest Research Institute, for Bureau of Solid Waste Management of U.S. HEW, Contract No. PH 86-67-114, (SW-5c) 1969, p. 15.

as pulp, as opposed to incineration to produce energy. Uncertainties regarding future pulp supply and demand relationships, discussed later in this section, further support the recycling of waste paper for pulp reclamation.

Production and Consumption

In 1970, domestic paper and paperboard production totalled over 52 million short tons, according to the American Paper Institute,[59] while domestic consumption, which includes imports, actually exceeded that amount by approximately one million tons.[60] (Consumption is calculated as domestic production plus imports minus exports; therefore, if imports exceed exports, it is possible for consumption to exceed domestic production.) Table 11 provides a breakdown of domestic paper production by grades.

Paper consumption in the U.S. has experienced phenomenal growth during this century. By way of comparison, in 1900 the average American used 50 pounds of paper each year; in 1970 consumption had risen to more than 500 pounds for each man, woman and child in the country. The National Academy of Science and the paper industry project a doubling in paper and paperboard use by 1985 with consumption at 100 million tons per year, or roughly 1,000 pounds per capita.[61]

59. American Paper Institute, "1970, A Test of Stamina", 1970.
60. Harris, C. op. cit., p. 51.
61. National Academy of Sciences, National Academy of Engineering, "Policies for Solid Waste Management," for Public Health Service, Bureau of Solid Waste Management, Publication No. 2018, 1970. cited by Bank of America Report "Paper Recycling: A Report on Its Economic and Ecological Implications," December, 1971.

TABLE 11 - PAPER AND PAPERBOARD PRODUCTION - 1970

PAPER	Production (est. in 1000 short tons)	Per Cent of Total Production
Newsprint	3,309	6.3
Uncoated Groundwood	1,165	2.2
Coated Paper	3,237	6.2
Uncoated Book Paper	2,572	4.9
Writing & Related Papers	2,811	5.4
Bleached Bristols (Manila folders, etc.)	1,060	2.0
Unbleached Kraft Packaging & Industrial Converting Paper	3,723	7.1
Other Packaging & Industrial Converting Paper	1,192	2.3
Special Industrial Paper	403	0.8
Tissue Paper	3,671	7.0
Total Paper	23,143	44.2
PAPERBOARD		
Unbleached Kraft Linerboard	10,839	20.7
Other Unbleached Kraft Paperboard	679	1.3
Solid Bleached Paperboard	3,567	6.8
Semi-chemical Paperboard	3,469	6.6
Combination Paperboard	6,875	13.1
Total Paperboard	25,429	48.5
CONSTRUCTION AND OTHER PAPERBOARD AND PAPER	3,812	7.3
TOTAL PAPER AND PAPERBOARD	52,384	100.0

Source: 1970, A Test of Stamina, prepared by the American Paper Institute.

Source of Pulp Fibre

Approximately 22 percent (or roughly 12 million tons) of the 1970 domestic paper supply was derived from paper residuals, compared to the 35 percent recycling level achieved during World War II.[62] (In contrast, Japan and some other European nations have achieved recycling levels on the order of 50 percent.[63]) Up to 25 percent is obtained from wood waste products such as wood chips, saw dust, and other "prompt" scraps generated in lumber and plywood production. The remainder, some 53 percent, is produced from pulpwood trees grown exclusively for pulp and paper purposes.[64]

It is interesting to note that the conservationists' claim, "recycling one ton of waste paper saves 17 trees," is imprecise and somewhat misleading. Different species of pulpwood trees produce varying amounts of pulp. One mature tree from a virgin forest might supply several tons of pulp, while two second growth trees of average size in the Pacific Northwest will supply one ton. While the conservationists' claim appears to have been calculated for some of the Eastern Canadian pulpwood species, such claims fail to point out that trees used for pulp supply are grown exclusively for that purpose. In fact, "tree farms" produce tree crops just as other farms produce corn or alfalfa for animal feed; such crops would not exist if there

62. Harris, C., op. cit., p. 51.
63. Consortium Report, op. cit., p. IV-29.
64. American Paper Institute, "The Paper Industry's Part in Protecting the Environment," 1971, p. 21.

were no market for the final product. Due to the current sources of wood fiber used for paper and paperboard production, it is apparent that virgin forests would not be saved at present by an increase in paper recycling.[65] However, future relationships between supply and demand may prove conservationists correct.

Future Supply and Demand

There are wide differences of opinion among the public and private sectors regarding future pulpwood supply and demand. The U.S. Department of Commerce' position, shared by many in the paper industry, is that adequate pulpwood supply exists to meet demand until at least 1980, and with increased intensive forest management, through at least the year 2000.[66] On the other hand, the Forest Products Laboratory in the U.S. Forest Service forsees the possibility that without increased recycling of waste paper, the United States may become a "net user" of trees by 1985.[67] The Forest Products Laboratory predicts that even with advances in improved tree farming methods, more efficient utilization of wood scraps and development of faster growing trees, the U.S. may require more pulpwood than it can grow per year by 1985.[68]

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65. Bank of America, op. cit., p. 12.
66. Post, H. and Downey, R., "The Disposal of Newspapers and Containerboard," Pulp, Paper and Board, U.S. Department of Commerce, October, 1970, p. 9.
67. Bank of America Report, op. cit.,
68. U.S. Department of Agriculture, Forest Service, "Increased Wood Fibre Recycling: A Must," p. 3.

After reviewing various pulpwood supply and demand estimates, the University of Minnesota Solid Waste Consortium concluded that future pulp shortages will exist and that increased recycling of paper products for the recovery of pulp is essential.[69] In the absence of increased paper recycling, the Consortium predicts an increase in the cost of pulp which will in turn encourage the use of paper substitutes made from nonrenewable resources.

If the 1985 pulp shortage predictions of the U.S. Forest Service, National Academy of Science and others are correct, future demand will require one or a combination of the following:

1) Technological advances beyond present expectations (e.g., increase yield per acre by shortening growth period).

2) Utilization of virgin forests.

3) Use of additional lands for tree farming.

4) Increase in imports of pulp, pulpwood and/or finished products.

5) Use of plastic substitutes.

6) Increase in waste paper recycling.

Not to be forgotten is the possibility that pulp demand itself might be lessened by discouraging nonessential use of paper and paperboard, particularly in the area of packaging.

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69. Consortium Study, op. cit., p. IV-30.

Pulp demand could also be reduced in other areas. For example, 60 percent of the average newspaper content is advertising;[70] while reduction in advertising might not be palatable to newspaper owners, it could result in a substantial reduction in newprint consumption. Technological advances for information systems such as microfilm, microfiche, microphotography etc., might also reduce pulp demand considerably.[71]

It is abundantly clear that the debate over future pulpwood supply and demand needs to be resolved. Regardless of the final disposition, increased recycling could reduce the burden on the nation's forests and lands devoted to tree farming, while also reducing the amount of solid waste which must be collected and disposed. In fact, the National Academy of Science predicts that if the World War II level of 35 percent paper recycling could be achieved by 1985, it would:[72]

1) release 91.5 million acres of forest land for other uses, and

2) reduce the solid waste load in some areas by as much as 25 percent.

Waste paper recycling, however, is a very complicated business and to understand the complications it is necessary

70. Darnay and Franklin, "The Role of Non-Packaging Paper in Solid Waste Management 1966-1976, *op. cit.*, p. 15.
71. *Ibid*, p. 21.
72. Public Health Service Publication No. 2018: 1970, *op. cit.*

to have a basic knowledge of pulp processes, paper grades and paper characteristics.

Paper-Making Processes[73]

The quality of the final paper product is determined cheifly by the kind of wood used, hardwood or softwood, and the method of pulping, mechanical or chemical.

The groundwood mechanical process, which produces newsprint, magazine stock and other "low grade" papers, involves grinding cleaned, peeled logs to a wood fiber containing virtually all the components in the original wood. Lignin, which is not removed in this process, binds fibers together and is responsible for the strength and rigidity of wood; its presence, however, in paper products causes yellowing and brittleness. To counteract the yellowing, blue dyes are often added which gives newsprint its grayish cast.[74]

Higher grades of pulp containing almost entirely cellulose fibers are produced by chemical treatments which remove lignin, gums, resins, and other wood components. The two principal methods of chemical treatment are known as the sulfite process and the sulfate, or Kraft process. During both processes wood chips are "cooked" under pressure with chemical substances; lime and sulfurous acid are used to produce sulfite pulp; and mixtures of caustic soda and sodium sulfide

73. The material in this section, except where otherwise noted, is taken from the Bank of America Report, "Paper Recycling: A Report on Its Economic and Ecological Implications," op. cit.
74. Battelle/NASMI Study, op. cit., p. 94.

are used for Kraft. Both produce a noxious liquor (liquid waste) as a result of the cooking process, however, for economic reasons, the spent cooking liquor is often recovered for reuse.[75] More expensive to control are the gaseous wastes produced by the chemical pulping processes.[76]

Pulp produced by the groundwood mechanical process generally contains shorter and weaker fibers, while the higher grade sulfite and Kraft pulps provide greater strength and longer fibers. It is important to note that when lower grade pulp, is mixed in any appreciable amount with a higher grade pulp, the quality of the latter is degraded. Alternatively, a small percentage of high quality pulp mixed with a lower grade pulp can somewhat improve the overall quality of the pulp. By blending various combinations of pulps and by adding certain chemicals, various paper characteristics necessary in the final product, can be achieved.

The following characteristics are typically used to classify paper by grades:

1) Opacity - a measure of the capacity to obstruct light from passing through paper.

2) Brightness - a measure of whiteness.

3) Smoothness - texture and abrasiveness of the paper.

4) Tear Strength and Bursting Strength - capacities dependent upon fiber length and internal bonding, respectively.

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75. Bower, B. T., et. al., "Residuals Management in the Pulp and Paper Industry," Natural Resources Journal, University of New Mexico School of Law, Vol. 11, No. 4, Oct. 1971, p. 604.
76. Quimby, op. cit., p. 14.

5) Caliper - thickness per sheet, measured in ten thousandths of an inch.

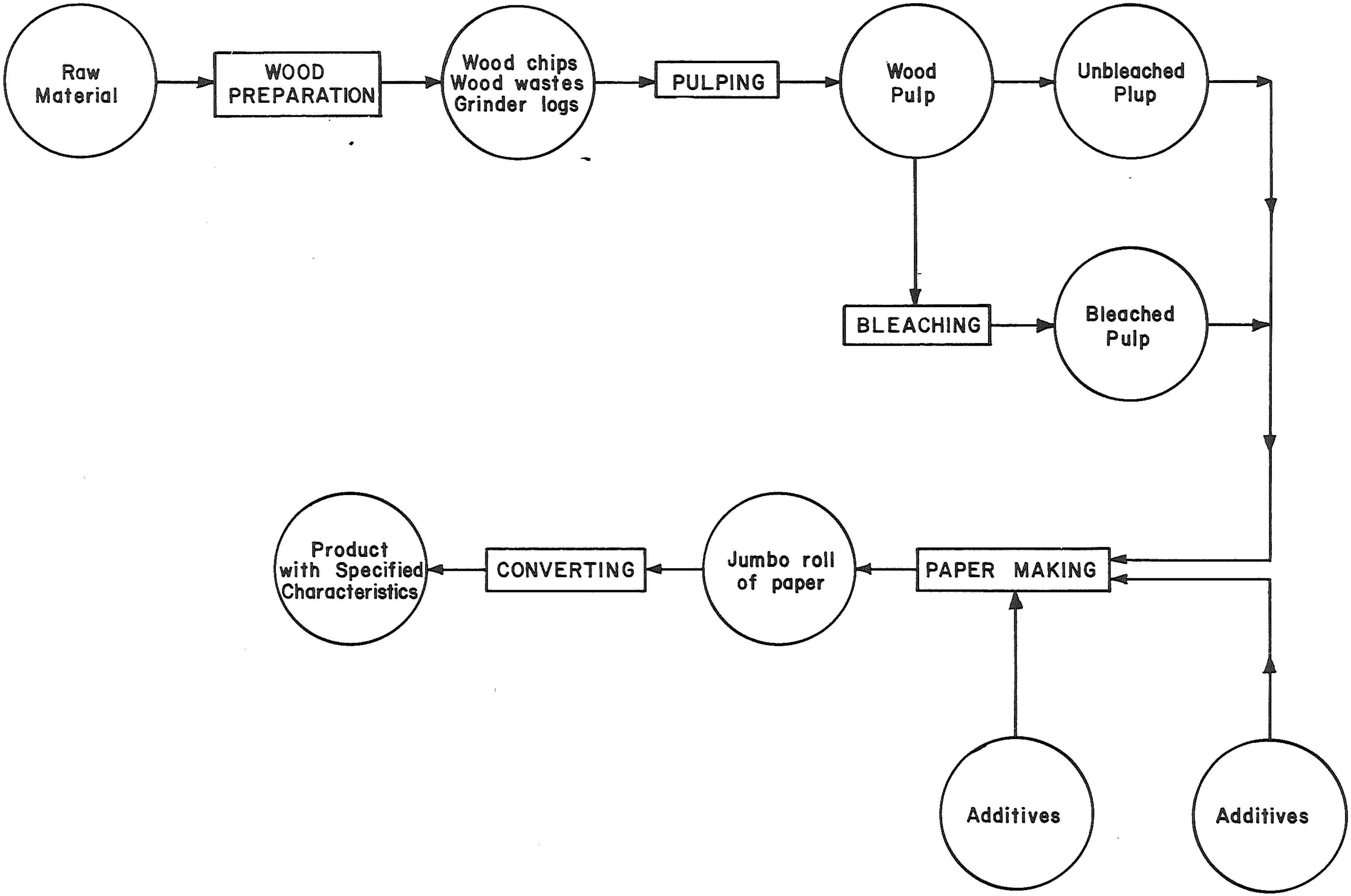
6) Basis weight - weight per unit area.

7) Relative humidity - moisture content relative to humidity of surroundings.

To achieve a given set of characteristics, fiber may be bleached after pulping to obtain necessary whiteness, or dyes may be added to produce colored paper; fillers such as clay may be added to produce shiny-surfaced paper with opacity, smoothness and affinity for ink; titanium dioxide may be used to improve brightness and opacity; and rosin size may be added to create water repellency.

The treated fibers are then processed through several spreading and drying stages before the paper is wound into multi-ton rolls.

Before ultimate conversion, consumption and disposal in the waste stream, paper receives further contaminants such as ink, hot-adhesive bindings, staples, latex glues, and in the case of milk cartons and other food packaging, polyethylene coatings. Thus, as shall be discussed later, the waste paper recycler has several problems when dealing with "obsolete" or post-consumer paper scrap. Often he does not know the type of wood used to produce the pulp or the pulping method; neither does he know what additives and contaminants were used during the processing stages. (See Figure 14 - a flow diagram of the paper making process.)



PAPER MAKING, GENERAL FLOW DIAGRAM

FIGURE 14

Source: Bower, B. T., et al, "Residual Management in the Pulp and Paper Industry," Natural Resources Journal, University of New Mexico School of Law, Vol. 11, No. 4, October, 1971.

Paper Recycling

Paper Grades and Contaminants

Any discussion of paper recycling is complicated by the fact that there are so many grades of paper; some of these can be substituted for wood pulp in certain applications, while others cannot. The paper industry generally classifies its products in two broad categories: paper and paperboard. While there are some exceptions to the rule, the categories generally differ in weight, thickness and rigidity, with paperboard being the thickest, heaviest and most rigid of the two. In 1970 paper accounted for about 44 percent of total U.S. production while paperboard accounted for approximately 49 percent.[77] The table presented earlier on page 68 shows the various types of paper and paperboard being produced. Each type has its own specific set of characteristics that determine its potential for reuse. (See Appendix C-1 - C-6 for discussion of various paper and paperboard grades.)

There is often a paper broker serving as "middle man" between the waste paper generator and the waste paper user. (See figure 15 for flow of virgin and recycled paper.) To obtain the highest possible market values, the paper broker is generally responsible for sorting paper by grades, for

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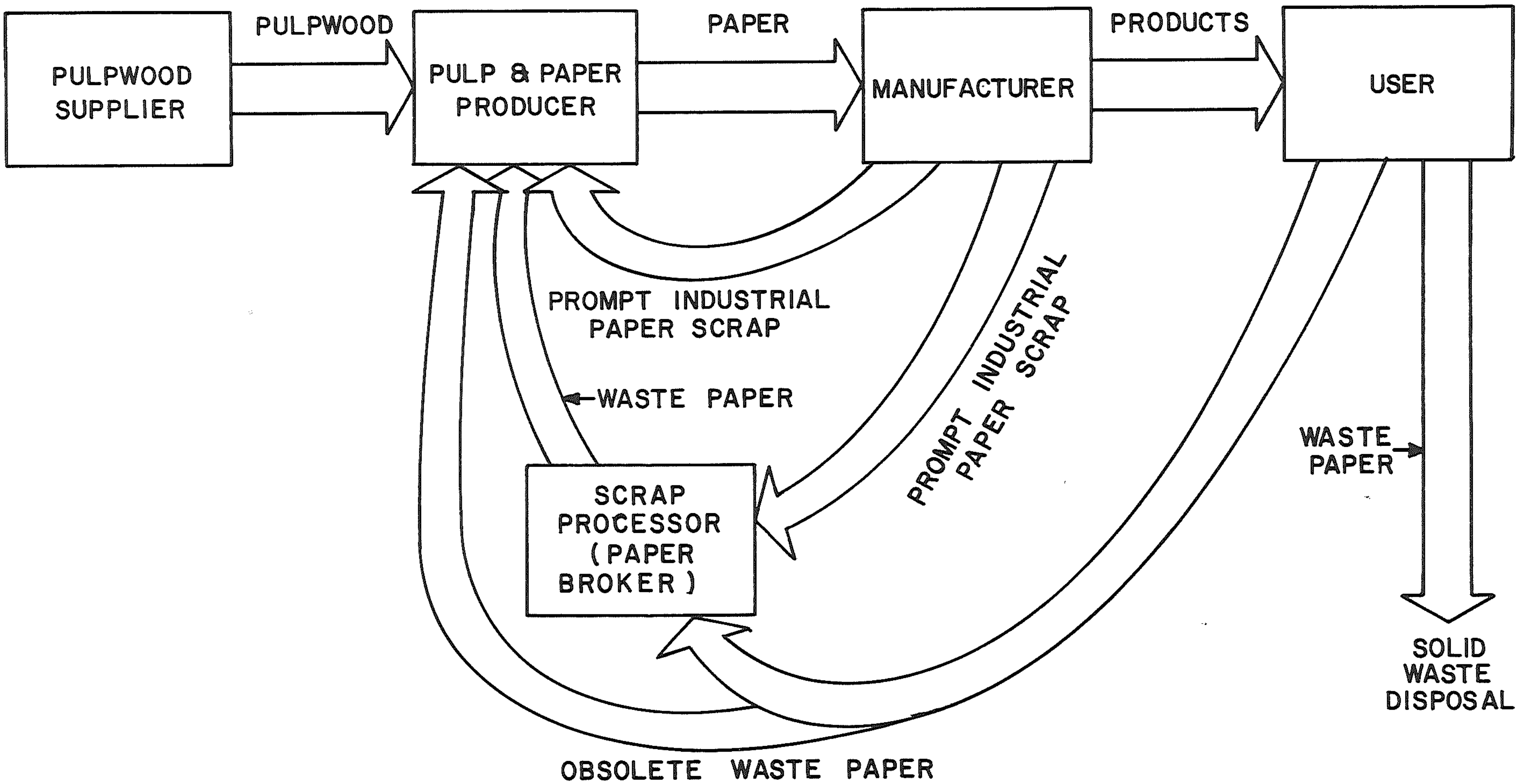
77. Battelle/NASMI Study, op. cit., Volume VIII, page 77-98.



FLOW OF VIRGIN AND RECYCLED PAPER

SOURCE: Adapted from Battelle / NASMI, Volume I, Op. cit.

Figure 15

removing as much as possible the "intentional contaminants" and for separating out those papers containing "unintentional contaminants."

Table 12 shows the major contaminants found in waste paper. Plastic binders, rubber bands, paper clips and the like constitute "unintentional" contaminants, which in most cases can easily be removed. "Intentional" contaminants, such as glassine or cellophane windows in envelopes, hot melt and pressure sensitive glues, non-soluble inks, foil laminates and polyethylene liners pose a more serious problem. British paper technologists refer to intentional contaminants as "pernicious contraries" - foreign matter that cannot satisfactorily be separated from paper fibers during the cleaning process.[78] Since it is virtually impossible to remove some of the intentional contaminants, they should not be used in products if the paper fiber is to be reclaimed.

After the paper broker and/or the waste paper user have removed contaminants from the waste paper, it must be sorted by grade with particular attention paid to the original method of pulping; for example, newsprint made from mechanical groundwood pulp must be separated from higher grade pulps to avoid degradation of the latter. Most of this grade sorting is presently done by hand - obviously an uneconomical situation -

78. Quimby, *op. cit.*, p. 5.

TABLE 12 - MAJOR CONTAMINANTS IN WASTE PAPER

SHINY PAPERS Glassine Wax Ink Wads Fluorescent Lacquered	**ASPHALT & CARBON PAPERS** Insulation Bags Carbonless paper Bags with Black Liners Tar Laminated Boxes
GLUES & TAPES Hot Melt Adhesives Pressure Sensitive Tar Tapes Gummed Labels	**COATED & TREATED PAPERS** Photographic Blueprint Parchment Foil Wet Strength Filter
BINDINGS Thread Metal Plastic Rope Lates	**JUNK** Wire Wood Glass Metals Twine Paper Clips Rubber Bands Staples
PLASTICS Films Synthetic Papers Plastic Foam Coated Boxes Shrink-wraps Cellophane	

Source: "Toby Trashound says, 'Keep These Out of Paper Stock!'" American Paper Institute, Inc., 1970, Distributed by Paperstock Conservation Committee. Cited by Battelle/NASMI, *op. cit.* Vol. XIII, p. 107.

however, work is being conducted to develop sophisticated mechanical sorting devices.

It is important to note that tedious sorting of paper grades does not occur during the wet separation process at the Franklin, Ohio hydrasposal plant, (discussed in chapter 2, pages 47-50). Thus, the entire batch of paper fiber recovered from the Franklin plant is reduced to the lowest paper grade in the mixed municipal refuse input. Further, there appears to be very limited market potential for such fiber, and, therefore, limited potential for the system itself. Mr. Thomas Quimby, a visiting scholar at Resources for the Future, Washington, D.C., estimates that paper fiber reclaimed by wet separation processes has potential use in less than 10 percent of the total paper market.[79]

The Process

Sorted waste paper is usually shredded, water is added and the material is repulped in hydrapulpers. Both during and after the repulping process, the fibers are subjected to a series of treatments called "de-inking", a term which refers to the removal of various additives (e.g., rosins, dye, etc.), used during the original paper making process. The reprocessed paper fiber is then subjected to the normal production processes mentioned earlier.

79. Quimby, *op. cit.*, p. 6.

The gaseous residuals from chemical pulping processes (which are expensive to control) are completely absent in waste paper recycling operations. On the other hand, in recycling operations there is a substantial increase in dissolved and suspended solids in the liquid effluent. Note the following hypothetical example for manufacturing one ton of newsprint:

> "...the manufacture of a ton of newsprint with a brightness specification of 58 from 75 percent stone ground wood, 25 percent kraft pulp generates about 30 pounds of gaseous residuals and about 340 pounds of liquid residuals. By using waste newsprint as a raw material for the same brightness specification, the generation of gaseous residuals is reduced 100 percent. There is a 100 percent increase in dissolved and suspended solids in this example. <u>It is likely that the costs of managing the 30 pounds of gaseous residuals so that they are not offensive to the environment exceed the costs of managing the additional liquid residuals generated by the substitution of waste paper for virgin pulp</u>." [80] (emphasis added)

Another interesting comparison between virgin and secondary fiber processes is revealed in plant and capital equipment costs. It appears that such costs for processing pulp wood run 50 percent higher than for processing waste paper.[81]

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80. Quimby, *op. cit.*, p. 15.
81. *Ibid*, p. 13.

Sources of Waste Paper

About 22 percent of our annual paper supply is already being recycled as was stated earlier. In general, such recycling occurs when there are large, homogeneous flows of paper located within economic hauling distance of a potential user. Paper recycling occurs at four stages - production, conversion, distribution and post consumption.[82] It appears that the 22 percent recycling rate above is derived from the following sources:[83] 3 percent from mill operations, 7 percent from conversion operations, 1 percent from distribution operations, 8 percent from commercial post-consumer waste and 3 percent from residential post-consumer waste.

During the paper production stage, residuals (or scrap) are generated at the rate of perhaps 2.5 to 3.0 percent of the total production run. This scrap, dubbed by the paper industry as "mill broke", is put back into the pulper and reused. Since the reuse of mill broke can be considered as a form of recycling, virtually all paper could bear somewhat misleading labels indicating recycled content. As can be seen in the following example, it is important to note the distinction between mill broke and other stages of paper recycling.

82. Source for the remainder of this section, except where otherwise noted, is Quimby, op. cit., p. 7-10.
83. Interpretation of estimates made by Quimby, Ibid.

In 1971, President Nixon announced that to alleviate municipal waste problems, 14 federal paper procurement specifications had been revised to include recycled content. Unfortunately, 10 of the 14 revised specifications required only a minimum recycled content of 3 percent, making it possible for paper mills to meet specifications by the use of mill broke. As a result, the required recycled content subsequently had to be raised in order to potentially reduce municipal waste.

During the conversion stage, the multi-ton rolls of paper are made into various products - folding boxboard is used for shoe boxes, cereal boxes, etc; newsprint becomes newspapers; linerboard is glued to corrugating medium to become corrugated shipping cases. Residuals generation from conversion operations may run from a low 1.5 percent in newspaper printing to a high of perhaps 20 percent in the folding carton industry. It is estimated that approximately 80 percent of paper and paperboard conversion residuals were recycled in 1969. Such recycling, of course, prevents the waste from entering the waste stream.

Recycling of obsolete and unsold inventories of paper and paper products also occurs at the paper distribution stage. Perhaps the most significant example is over-issue newspapers which amounted to approximately 425,000 tons in 1969. As with mill broke and conversion scrap, "overissue news has highly desirable salvage characteristics and does not require special incentives to keep it from going into the solid waste stream."[84]

Providing that demand itself is increased, perhaps the greatest potential for increased secondary fiber utilization exists in the fourth category - post-consumer waste. Increased recycling in this category also offers the greatest potential for reduction of materials in the municipal waste stream.

Post-consumer waste comes from two sources, residential and commercial. It is estimated for 1969 that 1.6 million tons, mostly newspaper, was recycled from residential waste. Another 4.4 million tons, largely corrugated shipping containers and mixed waste paper, were recycled from commercial sources. To put these figures in perspective, the American Paper Institute estimates that the 1969 recycling rate for newspapers and corrugated boxes was 23 percent and 25 percent, respectively.[85]

With the exception of newspaper which can easily be kept separate from other household refuse, little potential appears to exist for increased recycling of residential paper waste. Other residential papers such as food packaging, brown kraft bags, writing papers, corrugated boxes, etc., lack the

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84. Quimby, *op. cit.*
85. "The Paper Industry's Part in Protecting the Environment," *op. cit.*

desirable raw material characteristics of mass and homogeneity. In addition, these papers are most likely to be contaminated with food and other wastes. Only very limited potential exists for reclamation of fibers in mixed residential refuse by the use of wet separation processes discussed earlier. Providing that demand for secondary newsprint fiber can be increased, it appears desirable to deal with residential paper by:

1) separating and collecting newsprint for reuse and, perhaps in the future

2) utilize the remainder in composting or energy recovery systems.

In addition, it is important to note that the amount of paper in residential waste could itself be reduced. Since packaging paper accounts for a major portion of that half of municipal waste which is paper, restrictions on unnecessary packaging could reduce the solid waste load considerably. Consumers could also discourage unnecessary packaging by using their purchasing power to discriminate against over-packaged products like the plastic shampoo tube wrapped in a box.

Potential for recovery of post-consumer waste paper from the commercial sector[86] seems much greater. Approximately 45 percent of all paper and paperboard waste is

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86. "Commercial sector", as used here, includes business establishments, industry, and government.

generated in the commercial sector, or 15 to 20 million tons. Of this, four to five million tons are presently being recycled by prudent business managers.

The Wells Fargo Bank in San Francisco, for example, recycles over 400 tons of sorted high grade waste paper each year. According to the Bank, their Data Processing Center alone annually salvages 150 of its 250 tons of paper waste providing the bank with savings of approximately $16,800.[87]

Because the waste paper stream in the commercial sector provides desirable raw material characteristics -- mass and homogeneity -- it is a likely target for increased recycling. Businesses considering the salvage of waste paper should, however, first revise procurement specifications to avoid the purchase and use of papers containing intentional contaminants such as glassine window envelopes, non-soluble adhesives, carbonless papers, etc. It is also desirable to establish a method for sorting waste paper at the source of generation (e.g., worker's desk). Segregation at the generator level minimizes the mixing of paper grades and allows for separation of paper contaminants thereby increasing the scrap value of the waste paper.

The State of Minnesota and private businesses should examine internal operations to determine potentials for waste paper recovery by:

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87. Letter dated July 21, 1971 from Douglas Brown, Public Relations Department to J. Burke, MPCA. Reported savings based on decreased scavenger costs and increased earnings from sale of waste paper.

1) determining local market demand for various paper grades,

2) identifying, within internal operations, large, homogeneous flows of marketable paper,

3) studying methods and economics of collection, sorting and sale of reclaimed materials.

Major Constraints to Increased Paper Recycling

Lack of Demand for Recycled Paper Products

As with other secondary materials, consumers have traditionally attached a low value to recycled papers. To some extent, recent environmental awareness is changing this attitude. For example, some businesses, elected officials, government offices and individuals are beginning to express a preference for stationery and other writing papers made from recycled fiber. The federal government recently revised paper specifications to include a limited amount of recycled content; the State of Minnesota should also revise paper specifications, adopting a policy of including maximum amounts of recycled content wherever possible. (Careful attention must be given to the definition of recycled content. See Appendix C-7 and C-8 for General Services Administration definitions.)

Also of concern is the fact that demand for combination paperboard cartons, potentially a major user of recycled fiber, has not increased at the rate of that for virgin fiber cartons.[88]

88. Batelle/NASMI Study, op. cit., Vol. XIII, Table II.

This may be due to the fact that recycled fibers are not as strong as virgin fiber.

It cannot be stressed too much, that demand for recycled paper products is the key to increased secondary fiber utilization.

Lack of New Products Made From Recycled Paper

The only significant new use for recycled paper developed during the last decade, according to Battelle, has been the Garden State Paper Company mills in New Jersey, Indiana and California which produce recycled newsprint. Coupled with lack of new product possibilities for secondary fibers, the paper industry is facing stronger competition from the plastics industry. For example, plastic throw-away milk containers appear to be replacing the familiar paper cartons which in turn replaced the returnable glass container.

Technological Problems

The technology for producing recycled paper is not yet as sophisticated as the technology for producing virgin paper. Thus, the Battelle/NASMI study on opportunities for increased recycling recommended that the secondary fiber industry improve techniques in order to become more competitive with virgin pulp.[89] For example, fibers are reduced by approximately 10 percent in the repulping process which in turn reduces the bursting strength of a container.[90] (On the

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89. Ibid.
90. Harris, C., op. cit., p. 54.

other hand, recycled fibers are generally more stable and more resistant to shrinkage, a characteristic which is particularly desirable in envelope production where water-based glues are applied to the paper.) Largely due to impurities in the original waste paper, recycled paper may have visible spots and may be subject to variations in shades of white and two-sidedness of color. These variations create considerable problems for the graphic arts industry, limiting at present the potential for recycled paper in that market. Recycled paper also cannot presently meet the rigid "optical character recognition" (OCR) specifications necessary for papers which are "read" by electronic devices in the computer industry. Specialty papers, including onion skin and high rag content papers, have yet to be produced successfully from repulped fibers.[91] In addition, knowledge is lacking as to the number of times paper may be recycled.

Increasing Contaminants

The advent of new coatings, laminations, non-soluble inks, adhesives, etc., over the past 20 to 30 years has increased contamination of waste paper considerably.[92] These contaminants unfortunately tend to be used most in higher quality packaging and therefore contaminate the more desirable grades of paper stock. Consumer enthusiasm for

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91. Bank of America Report, op. cit., p. 19.
92. Battelle/NASMI Study , op. cit., Vol. VIII, Table 2.

attractive packaging coupled with manufacturers' desire to use packages for advertising purposes tends to promote both contamination of the paper stock and over-packaging itself.

Convenience items such as window envelopes, pressure-sensitive glues and carbonless papers also pose contamination problems, with the latter being particularly serious. Carbonless paper contains potentially hazardous polychlorinated biphenols (PCB's); if this paper is reused in the manufacture of packaging materials it is possible for the PCB's to migrate into the contents of the package.[93] Obviously a potentially serious situation exists if the package is used for food intended for human or animal consumption.

Two of Battelle's recommendations regarding contaminants are of special interest:[94]

1) encourage development of inks, coatings, adhesives, etc., which are easily removed during the fiber cleaning stages and

2) consider legislation which would penalize users or producers of the contaminating materials.

Sources of Waste Paper Relative to the Location of Paper Mills

Approximately 75 percent of the nation's present pulp and paper mill capacity has been constructed since World War II, and is "located away from metropolitan areas, the source of pulp wood."[95] (It is important to note that in Minnesota no

93. Harris, C., op. cit, p. 54.
94. Battelle/NASMI Study, op. cit., Vol. VIII, Table 2.
95. Quimby, op. cit., p. 16.

new mills have been built since 1917.) It is clear that as a raw material, waste paper cannot compete economically with virgin material in a rural setting particularly due to transportation costs. In addition, taxes are generally lower for the wood pulp mill located in rural areas. To encourage the recycling of waste paper, the state should, through tax and other policies, encourage the development of re-pulping facilities in or near metropolitan areas.

Leaves

With the imposition of the statewide burning ban, leaves have become a significant contribution to the solid waste stream. Their disposal in landfill creates an added solid waste burden, and represents a loss of potentially valuable soil conditioning material.

It is recommended that residents compost their leaves wherever possible and that excess leaves be composted by cities or counties, rather than introduced into landfills.

In order to reduce fuel consumption for transportation of leaves to "compost centers," it is also recommended that city or county trucks be used for collection purposes. A well-publicized leaf pickup by the city or county in late fall is suggested.

Hennepin County's Department of Public Works has established a leaf recycling program[96] which received 20,000 cubic yards of leaves in 1972 from municipalities and private citizens.[97] The finished compost will be given away and distributed on public lands (e.g., parks, highway borders). Both the City of Minneapolis and St. Louis Park's public works departments contributed their fall leaf pickups to the Hennepin County Center.

Trees

Municipal tree cuttings also represent a potentially recoverable resource. A market exists for chipped wood in the roofing felt industry and chipped wood can be used along the border of roadways to protect exposed soil against erosion. Wood chips can also be used in some paper mill operations, particularly if it is debarked. Thus, the establishment of centers for receiving waste wood together with a portable chipping operation could help to alleviate this portion of the solid waste problem. Again, Hennepin County has begun a tree recycling operation by setting up a tree receiving center in the Flying Cloud sanitary landfill in Eden Prairie, and purchasing a $91,000 tree chipper which can handle trees up to 22 inches in diameter.[98]

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96. Under the direction of J. Helgevold, Environmental Specialist, Department of Public Works Environmental Division.
97. Telephone conversation with David Winter, Hennepin County Department of Public Works, December 20, 1972.
98. Ibid.

Plastic Packaging

Consumption Patterns

The plastics represent a competitive threat to all other packaging materials, and the growth rate of this industry has been phenomenal. According to Midwest Research Institute's report of 1969, plastic usage was expected to double by 1976.[99]

Plastics have been used in packaging since the 1950's, but volume usage did not develop until about 1960 with the advent of low cost production of polyethylene, the most popular of the packaging plastics. In 1966, 1.8 billion pounds were manufactured for packaging applications, compared with about 333 million pounds in 1958.[100] This represents an increase of 550 percent in eight years., (See Table 13.) Plastic bottles are rapidly replacing the glass bottle for a number of end uses (Table 14).

On a weight basis, plastics still represented only 2.4 percent of total packaging in 1966. However, in dollar terms, plastic packaging in 1966 represented just under 10 percent of all packaging sales.[101]

The growth in blow-molded plastic bottles nationally and in Minnesota is summarized in Figure 16 following and Tables C-1 and C-2 in Appendix C.

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99. Darnay and Franklin, The Role of Packaging in Solid Waste Management, op. cit., p. 11.
100. Excluding cellophane here because it is made from wood pulp rather than fossil fuels. If cellophane is included, the 1966 figure would be 2.2 billion pounds and the 1958 figure -- 736 pounds.
101. Darnay and Franklin, The Role of Packaging in Solid Waste Management, op. cit., p. 68.

TABLE 13 - CONSUMPTION OF PLASTICS BY END USE: 1958-1976

In millions of pounds

End Use	1958	1959	1960	1961	1962	1963	1964	1965	1966	1970	1973	1976
Rigid and semi-rigid:												
Bottles	23	32	65	125	175	195	227	270	304	730	1,150	1,700
Tubes	--	--	--	--	(a)	3	3	10	15	30	35	40
Formed and molded	61	73	120	140	175	213	288	375	478	800	1,000	1,400
Closures	22	22	22	53	58	65	66	72	85	120	160	210
TOTAL	106	127	207	318	408	456	584	727	882	1,680	2,345	3,350
Film:												
Cellophane[b]	403	436	439	423	410	405	410	405	395	360	340	320
Polyethylene film	175	247	280	340	380	440	500	615	730	1,280	1,610	2,030
Other plastic film	52	54	57	65	84	104	116	133	192	300	400	560
TOTAL	630	737	776	828	874	949	1,026	1,153	1,317	1,940	2,350	2,910
Plastics total	736	864	983	1,146	1,282	1,405	1,610	1,880	2,199	3,620	4,695	6,260

a. Not available

b. The figures cited include cellophane, actually not a plastic material in the conventional usage of the term. If cellophane is excluded, 1966 plastics production would be 1.8 billion pounds, up from 333 million pounds, or an increase of 550 percent in eight years.

Source: Darnay, Arsen and Franklin, William E., The Role of Packaging in Solid Waste Management, Midwest Research Institute, Kansas City, Mo., under Contract No. PH 86-67-114 (SW-5c) for U.S. Department of Health, Education and Welfare, Bureau of Solid Waste Management, 1969, Table 42, p. 68.

TABLE 14 - COMPARISON OF MANUFACTURERS' SHIPMENTS OF GLASS CONTAINERS[a] AND BLOW-MOLDED PLASTIC BOTTLES, FOR SELECTED PERIODS

(millions of units)

End Use by Type		1965 Quantity	1965 % Total	1969 Quantity	1969 % Total
Chemical, Household, Industrial:					
Glass		991	36.0	642	20.0
Plastic[b]		1,798	64.0	2,526	80.0
	TOTAL	2,798	100.0	3,168	100.0
Toiletries, Cosmetics:					
Glass		2,194	79.0	1,817	56.0
Plastic		579	21.0	1,402	44.0
	TOTAL	2,773	100.0	3,219	100.0
Medicinal, Health					
Glass		3,393	93.0	3,355	89.0
Plastic		265	7.0	398	11.0
	TOTAL	3,658	100.0	3,753	100.0
Food, Beverage					
Glass[c]		21,635	99.5	30,216	98.0
Plastic		90	0.5	666	2.0
	TOTAL	21,725	100.0	30,882	100.0
Grand Total					
Glass		28,213	91.0	36,031	88.0
Plastic		2,732	9.0	4,992	12.0
	TOTAL	30,945	100.0	41,023	100.0

a. Domestic glass containers shipments only.
b. Includes plastic end-use categories - household chemicals, industrial chemicals and specialties, and automotive and marine.
c. Includes glass end-use categories - food, dairy products, beverage, beer, liquor, and wine.

Source: Bureau of the Census, U.S. Department of Commerce, Bureau of Domestic Commerce, *Containers and Packaging*, October, 1970, p. 9.

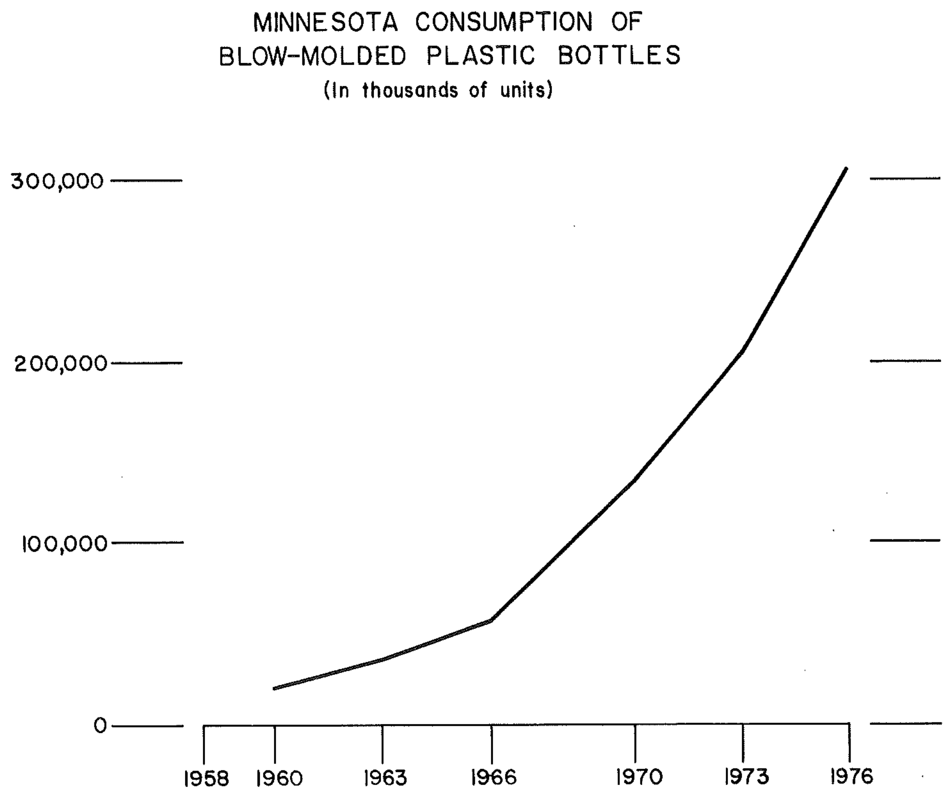

Figure 16

All major varieties of plastics are derived from a single petroleum raw material, ethylene. Ethylene is the base for a multitude of intermediate substances and end products, including explosives, detergents, DDT, certain perfumes, and the aspirin tablet. Three of the four major plastics, polyethylene, polyvinyl chloride, and polystyrene are derived from ethylene. Polypropylene, the fourth is obtained from a process which produces ethane. (See Figure 17).

PACKAGING PLASTICS COMMONLY DERIVED FROM ETEYLENE

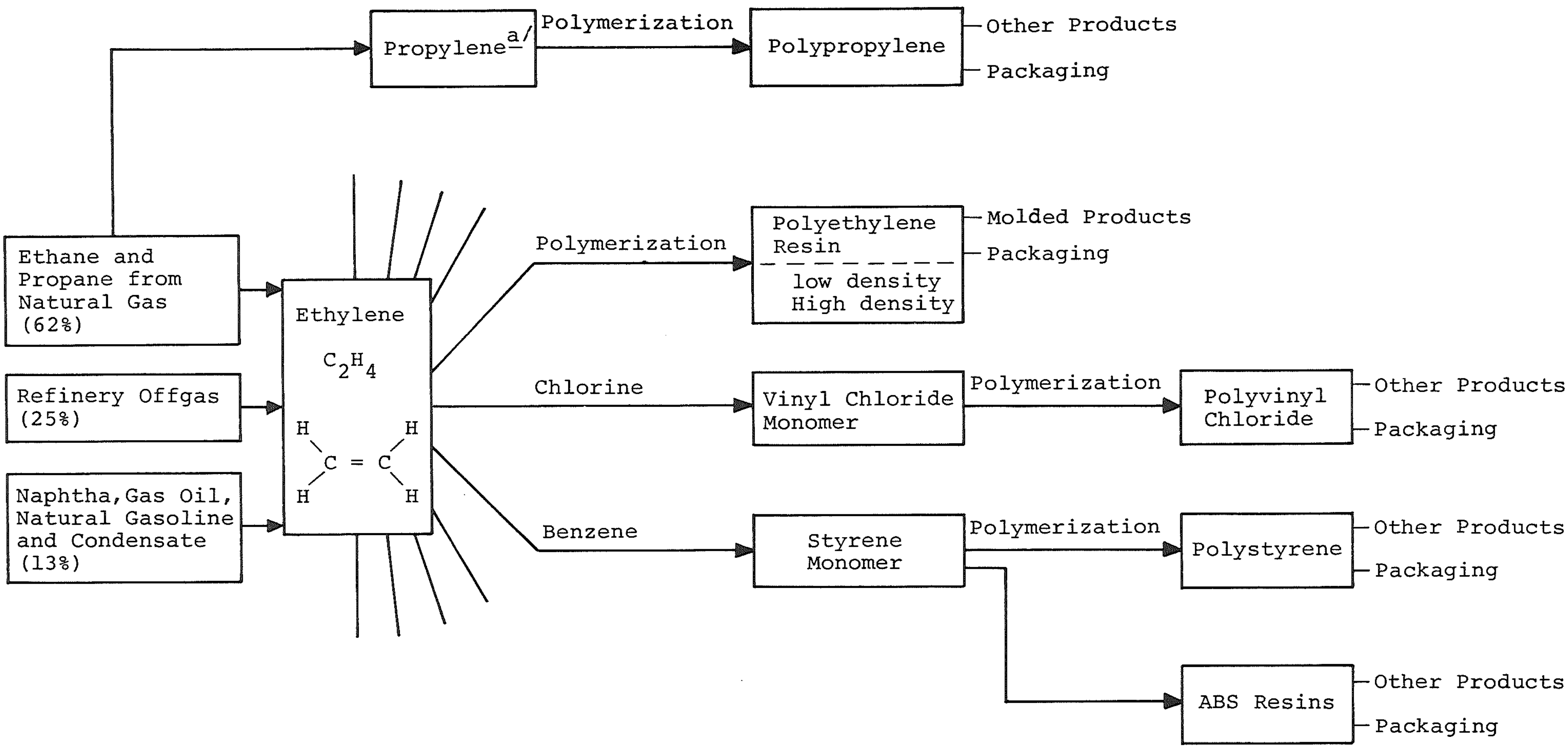

Figure 17

a. Most propylene comes from gasoline manufacturing operations.

Source: Darnay and Franklin, The Role of Packaging in Solid Waste Management, op. cit. (Footnote 58), Figure 20, p. 69.

Potential Environmental Impact of Plastic Packaging

Because virtually all plastic is derived from petroleum (see Appendix C, Figure 1, p. C-9), single use of plastic packaging material represents a disturbing misuse of a nonrenewable resource, which, as noted earlier, is becoming more difficult to obtain domestically.

In light of current growth trends for plastic packaging, non-returnable[102] use of all plastic should be discouraged, including overwrapping of foods and consumer goods with plastic film, and the use of the one-way plastic bottle. Use of plastic one-way milk, beer, soft drink and liquor bottles should be prohibited in Minnesota.

In addition to the loss of nonrenewable resource, most plastics contain, or are composed of, organic chemicals which resist decay by microorganisms, and therefore tend to accumulate in the biosphere. In some cases, the chemicals contained in the plastics may actually interfere with biochemical processes in living systems.

Of particular interest are polychlorinated biphenyls (PCB's), polyvinyl chloride plastics (PVC's), and trace metals contained in plastic packaging material. Plasticizers such as polychlorinated biphenyls, which are used to make packaging material

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102. "Remelt" recycling, or incineration of plastics to generate power, is much less desirable than reuse from an energy conservation standpoint. In addition, remelt recycling is currently hampered by the great variation in properties and chemical compositions of plastic materials.

flexible, may migrate out of the plastic into food or air because they do not combine with the polymer resin in the plastic.[103] PCB's are not destroyed by incineration but instead vaporize to the atmosphere.[104] Further, their behavior in living systems appears to be similar to that of DDT.

Polyvinyl chloride plastics and plastics containing trace metals, such as cadmium or lead, become air contaminant problems when they are incinerated. The combustion of polyvinyl chloride yields hydrochloric acid which can be damaging to both incinerators and urban air quality.

In addition, the gas phosgene may originate from the incineration of chlorinated hydrocarbons such as PVC.[105]

Polyvinyl chloride also contains PCB's and the plasticizer DEHP, which has been associated with a congestive lung disease known as shock-lung, believed to be the result of DEHP migration into blood stored in PVC bags and tubing in hospitals.[106]

Some specific plastic packaging materials are considered below.

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103. Shea, Kevin P., "The New Car Smell," Environment, Vol. 13, No. 8, October 1971, pp. 2-9.
104. Gustafson, Carl G., "PCB's - Prevalent and Persistant," Environmental Science and Technology, October 1970, pp. 814-19.
105. Kaiser, E. R. and Carotti, A. A., Municipal Incineration of Refuse with 2% and 4% Additions of Four Plastics, a report to the Society of Plastics Industries, Inc., June 30, 1971, p. 24.
106. Jaeger, R. J. and Rubin, R. J., "Plasticizers From Plastic Devices: Extraction, Metabolism, and Accumulation by Biological Systems," Science, 170 (3956), 1970, p. 460-61.

Polyvinyl Chloride Bottles

To date the increase in plastics in the food and beverage markets has not been as great as in other areas. However, over the last two years, the IRS has permitted test marketing of liquor sold in polyvinyl chloride bottles (PVC), and the potential exists for the use of these bottles in place of glass for much of the liquor sold in the U.S.[107] In 1970, total domestic liquor consumption amounted to 312,140,902 gallons. Table 15 shows the estimated weight of PVC, which would be introduced in the waste stream nationally, assuming 25, 50 and 100 percent replacement of existing liquor bottles with half-gallon PVC bottles of 130 grams each.

TABLE 15 - 1970 LIQUOR BOTTLE DATA

Additional Pounds Of PVC

	U.S.
at 100% replacement of glass by PVC	179.2 million pounds
at 50% replacement	89.6 million pounds
at 25% replacement	44.8 million pounds

Source: Harris, Carolyn and Lavori, Nora, Comments on the Internal Revenue Source Draft Environmental Impact Statement Regarding The Use Of PVC Bottles, May 1972, Table III, p. 7.

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107. Harris, Carolyn and Lavori, Nora, Comments on the Internal Revenue Source Draft Environmental Impact Statement Regarding The Use of PVC Liquor Bottles, May 1972, p. 5. According to Harris, telephone conversation 12/20/72, a trial IRS Impact Statement has been delayed until a study of the environmental impact of polyvinyl chloride bottles has been completed by Boyd Riley, an independent consultant to the IRS.

The Bureau of Domestic Commerce estimates growth in the value of shipments of distilled liquor at six percent per year between 1970 and 1980.[108] This represents a doubling time of only slightly more than a decade. According to this estimate, total gallons of liquor bottled in the U.S. would rise from 312,140,902 gallons in 1970 to 559,042,740 gallons by 1980. At 100 percent replacement with PVC bottles (130 grams each), there would be 372.46 million pounds or 186,000 tons of PVC liquor bottles added to the total U.S. solid waste stream in 1980.[109] The Environmental Protection Agency estimates that PVC's are about .45 percent of solid waste. By 1980 this figure could be as high as 1.7 percent with the addition of PVC liquor bottles or .75 percent without their contribution.[110]

The incineration of PVC containers is especially troublesome. Approximately 57 percent of PVC is composed of chlorine.[111] Thus, the burning of 100 pounds of PVC creates 57 pounds of gaseous HCl. Polyvinyl chloride is a major source of HCl (40 - 50 percent) in incinerator effluent emissions.[112] Considering the small amount of PVC by weight in the solid waste stream, this quantity of HCl can be regarded as a very significant contribution.

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108. U.S. Bureau of Census, Department of Domestic Commerce, U.S. Industrial Outlook, 1971, p. 109.
109. Harris and Lavori, *op. cit.*, p. 10.
110. *Ibid.*, p. 11.
111. U.S. Department of Health, Education and Welfare, National Air Pollution Control Administration Study, Preliminary Air Pollution Survey of Hydrochloric Acid, hereafter referred to as NAPCA Survey, October, 1969, p. 27.
112. Affidavit by Elmer Kaiser in Society of Plastics Industry vs. New York City, p. 11.

There is substantial evidence that the HCl acid/gas which is produced from PVC is highly corrosive to incinerator metal parts[113] and especially to any sensitive air pollution control devices present. The gas also respresents a potential threat to human health, and animal and plant populations.

It should be noted that residential gas incinerators wastes with gas incinerators in homes and apartments are still very much used in Minnesota, so that the PVC problem cannot be dismissed on the grounds that all PVC plastic now finds its way to landfill.

At present, there are no U. S. standards for either source emissions or ambient air levels of HCl. England and Canada, however, limit the emission of HCl from stacks and chimneys to 290 ppm HCl by volume.[114] Hydrochloric acid emissions from base refuse have been estimated using data from a study conducted for the Society of Plastic Industries by E. R. Kaiser. Assuming no additional PVC from liquor bottles or other sources, emissions are on the order of 460 ppm[115] or exceed by 150 percent the English and Canadian emission standards. An ambient air standard of .5 ppm HCl over a 30 minute period has been established

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113. Miller, Paul D. and Krause, Horatio, "Factors Influencing the Corrosion of Boiler Steels in Municipal Incinerators," Corrosion, Vol. 27, No. 1., January, 1971, pp. 31-45.
114. Fulmer, E. and Testin, R., Battelle Memorial Institute, The Role of Plastics in Solid Waste, for the Society of Plastics Industry, Inc., 1966, p. 30.
115. According to Kaiser, the chlorides were over 90% HCl. Kaiser and Carotti, op. cit., p. 30.

by West Germany with a maximum allowable standard of 1.0 ppm.[116] Russia has established .009 ppm as their maximum allowable 24 hour average and .03 ppm for a single exposure. Czechoslavakia has a 24 hour allowable mean of 0.02 ppm and 0.07 ppm for a single exposure.[117] Studies conducted for the plastics industry by Kaiser and Crider indicate that ground level HCl concentrations from incinerator solid waste yield maximum emissions of .045 ppm or 5 times the Russian standard and twice the Czechoslavakian standard.[118]

The addition of PVC liquor bottles, and the continuing rapid growth on other PVC packaging would further accentuate this problem.

In addition to the HCl problem, PVC bottles may be composed of .01 to .10 percent lead, which can result in emissions on the order of 200 micrograms per cubic meter when these containers are incinerated. Phosgene may be still another incineration byproduct.

If the projected growth in PVC bottles and other uses of polyvinyl chloride plastic were to actually occur, and if incineration remains a solid waste management technique in Minnesota, all of the above air contaminants will increase substantially. For this reason, and because of the current interest in incineration to generate power, <u>it is recommended that use of PVC bottles be restricted</u>.

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116. NAPCA, *op. cit.*, p. 12.
117. *Ibid.*, p. 12-13.
118. Crider, L. B., *Maximum Ground Level Concentration of HCl Due to Increased Loadings of PVC in Municipal Refuse*, B. F. Goodrich Chemical Co., Development Center, Ohio, in Appendix, IRS Draft Impact Statement, February 1972, p. 5. and Kaiser, *op. cit.*

Floating Plastics

Foamed polystyrene and other floating plastics pose an additional hazard. Because they cannot be biologically degraded, these plastics threaten to become floating "sand" on the surface of lakes and seas unless confined to sanitary landfill. Currently large quantities of floating plastics may be escaping to our waterways via the loss of "styrofoam" cups at riverside picnics and through such items as the plastic filters of discarded cigarettes which are not removed in sewage treatment. Steps should be taken to restrict uses of floating plastics that might result in contamination of water bodies.

Plastic Shotgun Shells

A particularly visible item in Minnesota forests, whose use should be discontinued, is the plastic shotgun shell casing. Both casing and wad do not degrade, and the wad may, in some cases, be a floating plastic.

Aluminum Containers

In 1968, aluminum packaging consumed an estimated 10.7 percent of U.S. demand for aluminum metal with the aluminum can alone consuming 4.87 percent.[119]

Aluminum companies entered the can market in the middle to late fifties with the all-aluminum beer can.[120] By 1965 aluminum containers represented 3.6 percent of the metal container market, by base box units, and by 1970 they represented 10.2 percent.[121] In 1968, the consumption of aluminum for metal cans alone was roughly ten times the aluminum used in shipbuilding and repair, ten times the aluminum used by the railroad industry, and 1.24 times the aluminum used by the aircraft industry.[122] At that time, national consumption of aluminum for metal cans was .21 million tons. By 1971, this figure had risen to .39 million tons or 2.8 times the amount of aluminum consumed by the aircraft industry in 1968.

Since the production of aluminum (see Chapter 3, p. 55) requires large quantities of energy relative to steel, it would appear that an unnecessary loss of energy occurs through the use of aluminum for one-way packaging.

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119. See Tables C-3 and C-4 in Appendix C.
$\frac{0.46}{4.31} = 10.67\%$ $\frac{0.209}{4.31} = 4.87\%$
120. Hannon, *op. cit.*, p. 4.
121. See Table C-5 in Appendix C.
122. See Tables C-3 and C-4 in Appendix C, *op. cit.*

Because of the high energy requirement and the pollution effects associated with aluminum smelting and refining, aluminum should not be used in making food or beverage containers, but be restricted to use in products where lightness and extension of product lifetime increase overall energy efficiency. It is further recommended that the state of Minnesota prohibit the sale and manufacture of all-aluminum containers in the state, excluding frozen food packaging until some acceptable alternative is found.

Cans and Glass Bottles Other Than Containers For Beer and Soft Drinks

Estimated consumption of non-beverage cans and bottles, for the nation and for Minnesota are given in Appendix C, Tables C-6 and C-7. Figures 18 and 19 shows estimated growth.

The slow growth in this category for both glass and metal containers is partially due to the rapid growth of plastic containers in the non-food categories. The impact on the environment and material resources resulting from the use of glass bottles and metal cans could be reduced by standardizing the size, shape, and composition of all containers to facilitate recycling or reuse. A state plan should be developed for the gradual introduction of standardized containers in these categories.

MINNESOTA CONSUMPTION OF GLASS CONTAINERS
OTHER THAN BEER AND SOFT DRINK

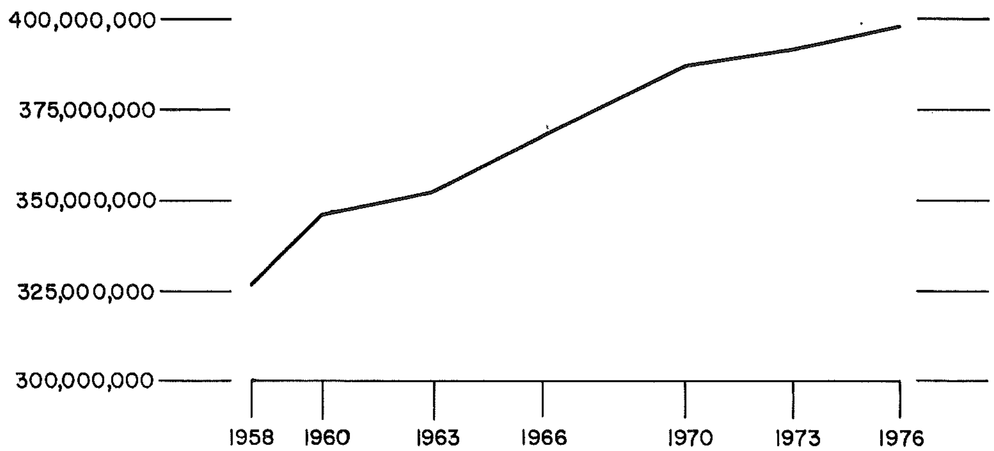

Figure 18

MINNESOTA CONSUMPTION OF METAL CANS
OTHER THAN BEER AND SOFT DRINK

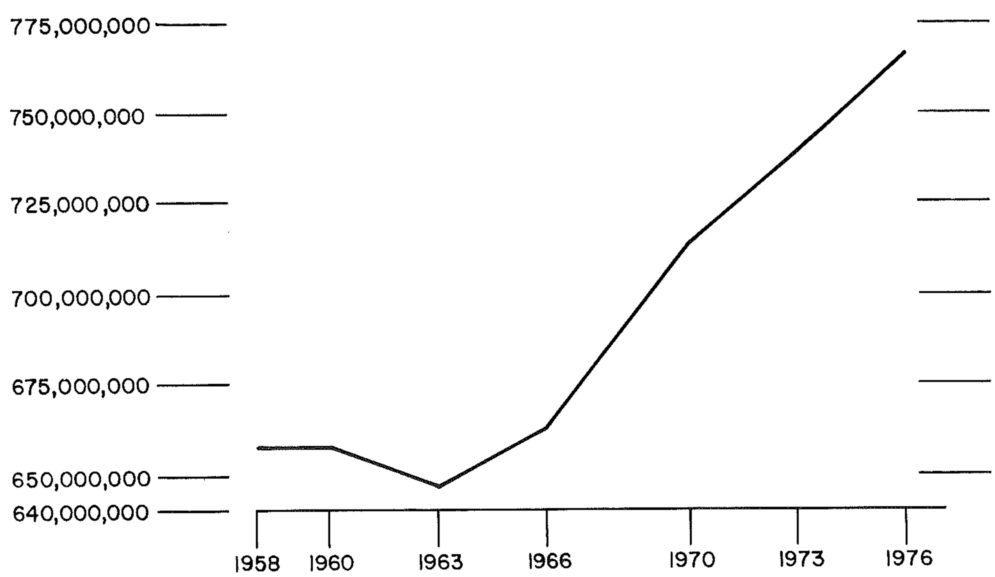

Figure 19

Source: Based on national figures from Tables C-6 and C-7 in the Appendix.

In addition, Minnesota industries (e.g., the milk industry) should be encouraged to use returnable containers for that portion of their market sold in Minnesota, since transportation distance for return of containers would be relatively short.

Frozen Food and Beverage Containers

At this time, little is known about the solid waste produced and energy consumed in this category. It is recommended that the resource costs resulting from this form of packaging be examined in detail.

The Aerosol Can

The aerosol can represents the worst in packaging from both an environmental and resource standpoint. Delivering a small volume of product per unit weight of metal to consumer, this package also involves heavy energy expenditures for the production of the gas propellant which drives the aerosol spray.

Because the containers have a tendency to explode under exposure to heat or pressure, they are damaging to both incinerators and recycling equipment. They have also been responsible for a large number of injuries.

As pointed out by Ralf Hotchkiss and Mark Gulak of the Center for Concerned Engineering:[123]

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123. Hotchkiss, Ralf and Mark Gulak, The Aerosol Bomb: A Common Sense Engineering Analysis, Center for Concerned Engineering, December 3, 1972, p. 1.

TODAY'S HEALTH/OCT. 1970

"Over fifty injuries were reported in the surveys performed for the National Commission on Product Safety in 1969. More recently, between May, 1971 and October, 1972, 76 injury cases have been reported directly from hospital emergency rooms to the National Electronic Injury Surveillance System (NEISS), a data collection and analysis division of the Bureau of Product Safety. In addition, another 84 cases have been referred to NEISS from previous sources. These figures, significant in themselves, grossly understate the problem."

At least nine deaths and six cases of partial and total blindness were reported in the referred data.[124]

Many of the injuries involve serious facial burns to children. According to Hotchkiss and Gulak:

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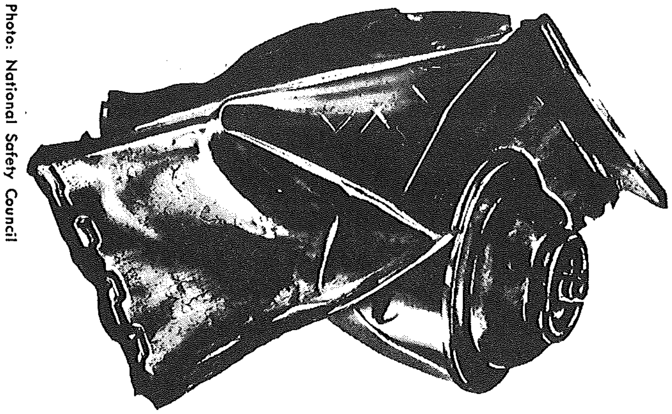
124. Ibid, p. 2.

"The available data shows that over half of the aerosol injury victims are children under 15 years old - children who are either not old enough to read the labeling or not mature enough to understand the extent of danger."[125]



An aerosol container when thrown into an open fire may explode with enough force to turn the container inside out.

In addition to the explosive hazard, aerosol sprays may be damaging to both eyes, lungs, and respiratory tract. An article in the July 26, 1965 issue of the Journal of the American Medical Association links a disorder called pulmonary granulomatosis to freon -- the gas most commonly used as an aerosol propellant, released normally when the can is nearly empty.[126]

According to the U. S. Food and Drug Administration, deliberate misuse of aerosols -- sniffing the propellant gases -- has killed more than 50 young people ranging from age 11 to 22.[127]

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125. Ibid, p. 6.
126. Written by Drs. Michael Nevins, George Stechel, Stanley Fishman, George Schwartz and Arthur Allen.
127. Rosenthal, A. and Kaufman, I., Caution: Today's Health, October, 1970, p. 38.

Figure 20 and Tables C-8, C-9 and C-10 summarize the growth in aerosol cans, and number of cans by commodity.

NUMBER OF AEROSOL CANS
CONSUMED IN MINNESOTA
(In thousands of units)

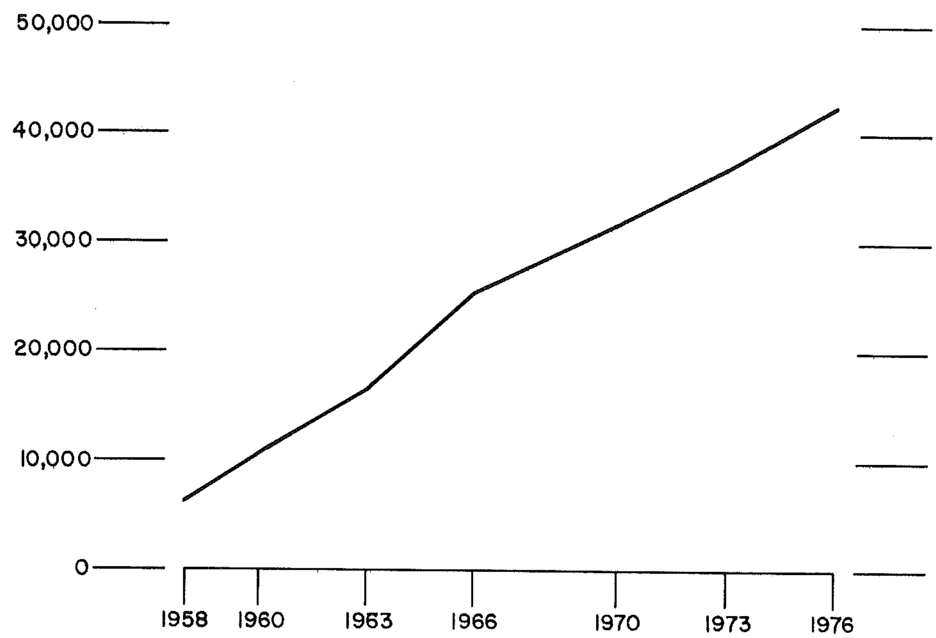

Figure 20

Because the aerosol can represents a highly energy consumptive package, a health hazard, an explosive hazard, and a package that cannot be recycled, it is recommended that its use be severely restricted.

However, heavy restriction of aerosol cans may stimulate growth in plastic aerosol containers which are equally undesirable from an energy standpoint. Therefore, it is further recommended that the use of all propellant driven aerosols be restricted.

Beverage Containers

Consumption Patterns

The no-deposit, no-return beverage container is a relatively new phenomenon. Prior to World War II, practically all beer and soft drinks were delivered to consumers in returnable containers, and it was only in the late forties and early fifties that the can industry began to consider the possibility of marketing throw-away beverage containers in competition with the standard returnable bottle.[128] As late as 1958, 98 percent of the packaged soft drink sales and 58 percent of packaged beer sales were in returnable glass bottles.[129]

At that time, the returnable was averaging about forty refills per bottle.[130] The growth potential was obvious to the can industry, for some forty cans were required to replace one returnable bottle. While the bottlers and beverage makers remained indifferent to the can industry's efforts to penetrate the beer and soft drink container market, the can industry did find support from the beverage wholesalers and retailers who discovered that they could now avoid the additional storage space and labor costs required in handling returnables.

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128. Hannon, op. cit., p. 308.
129. Darnay and Franklin, The Role of Packaging In Solid Waste Management, op. cit., Table 26, p. 44.
130. Hannon, op. cit., p. 308.

A drive was launched by the can manufacturers and the retailers which included extensive advertising aimed at the bottler, retailer, and consumer. Beer and soft drink cans began to make steady inroads into the returnable market, despite the extra cost to the consumer for beverages sold in cans. Finally, the glass bottle industry, threatened by the success of the throw-away can campaign, developed the no-deposit, no-return bottle. Beginning in 1959, shipments of non-returnable glass bottles began to rise sharply especially for beer.[131] The returnable bottle became the victim of competition between can and bottle manufacturers. By 1970, the market proportion of soft drinks and beer in returnables had declined to 45 percent and 25 percent respectively. Table 16, Figures 21 and 22, and Table C-11 in Appendix C summarize the decline in returnable market share.

A 1970 forecast by the Corporate Planning Department of the American Can Company predicts that 82 percent of packaged soft drinks will be packaged in non-returnable containers by 1975.[132]

It should be understood that the market share for returnables is substantially larger than the actual production of returnables, since returnables make 15 to 19 trips

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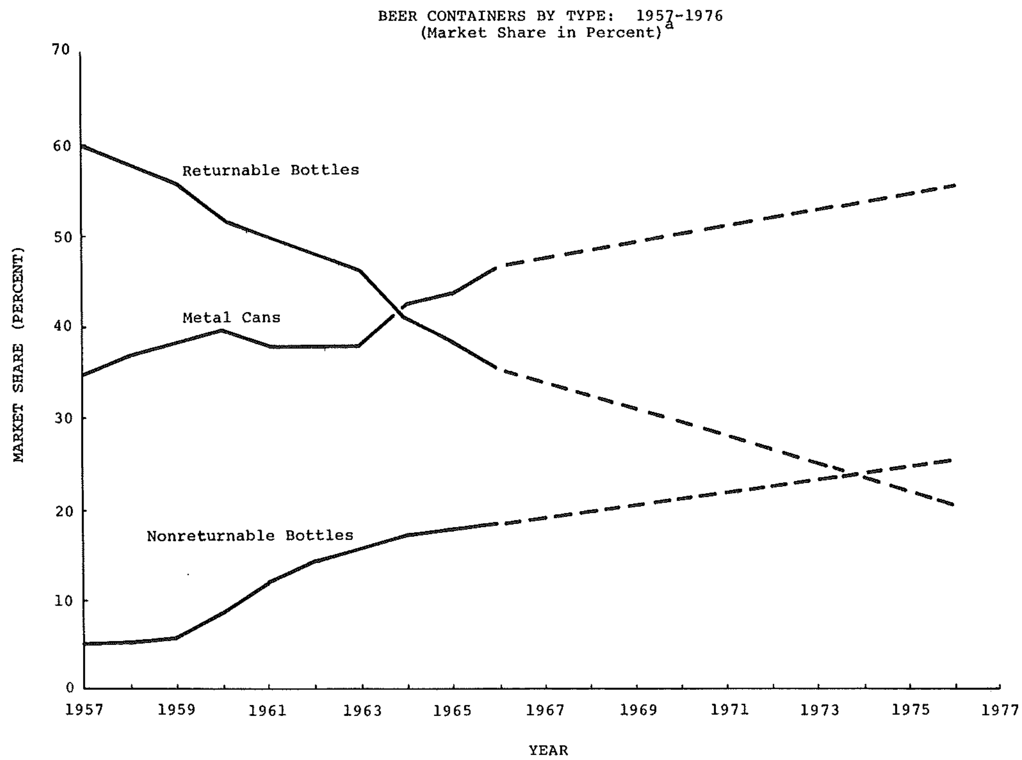
131. See Appendix C, Tables C-12 and C-13.
132. Editorial, Oregon Statesman, Sec. 1, January 16, 1970.

TABLE 16 - COMPARISON OF THE RETURNABLE BOTTLE MARKET SHARE

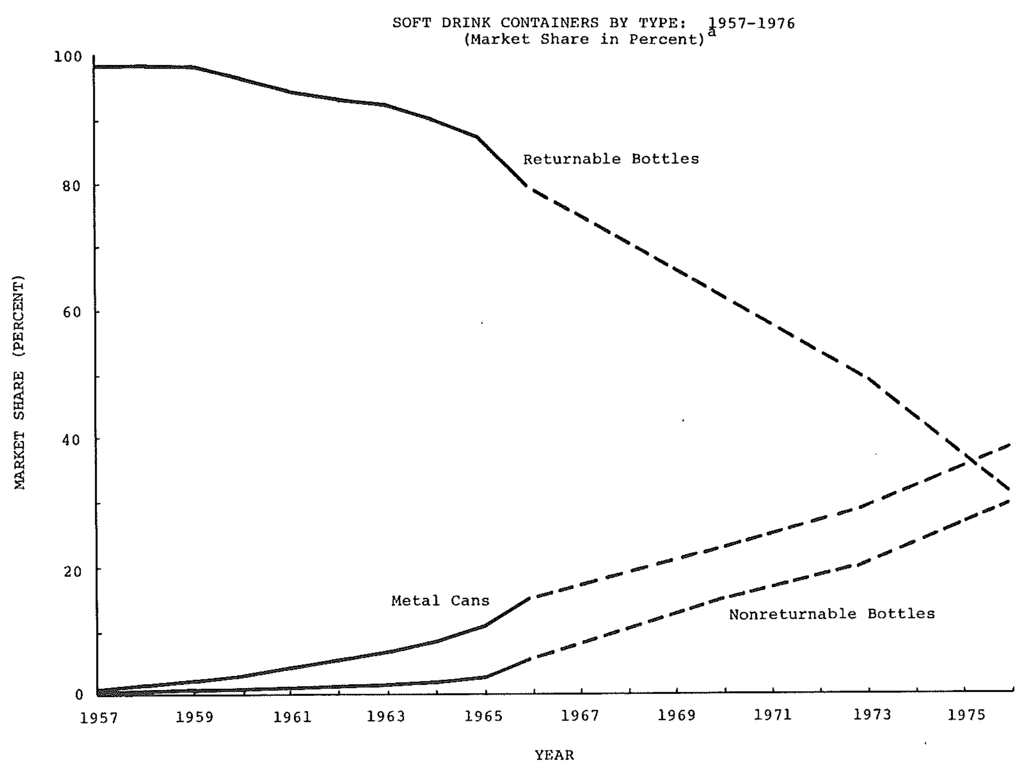
Beverage	% of Market Share By Year				
	1948[a]	1958[b]	1966[b]	1970[c]	1976[a]
Soft Drink	--	98.0	79.6	45.0	32.2
Beer	53.0	57.7	35.1	25.0	20.0

a. Bureau of the Census, U.S. Department of Commerce, Bureau of Domestic Commerce, Containers and Packaging, October, 1965, p. 5.
b. Darnay and Franklin, The Role of Packaging In Solid Waste Management, op. cit., Table 26, p. 44.
c. Bureau of the Census, U.S. Department of Commerce, Bureau of Domestic Commerce, Containers and Packaging, January, 1971, p. 6.



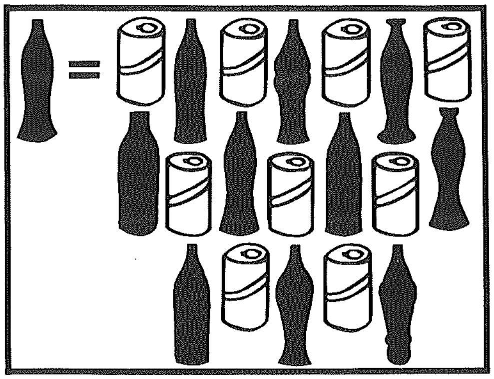
a/ Based on total fillings.

Figure 21



a/ Based on total fillings.

Figure 22



A RETURNABLE BOTTLE MAKES 19 TRIPS IN ITS LIFETIME

Source: EPA summary of <u>The Role of Packaging in Solid Waste Management 1966 - 1976</u>.

on a national average.[133] For example, when we examine actual production of returnable and non-returnable beverage containers, we find that while returnable beverage bottles are projected to represent only 6.2 percent of soft drink container production in 1973, they are still expected to make up 50 percent of the soft drink market share. Tables C-12, C-13 and C-14 in Appendix C summarize the actual shift in soft drink and beer container production. Note that the actual number of returnables sold has not substantially changed since 1960. (See Figure 23). Rather, it is the rapid growth in non-returnable beverage container production that has caused the dramatic shift in relative percents of returnable vs. non-returnables.

As the non-returnable beverage container became more and more prevalent, the "refill" rate for returnables began to fall (see Figure 24) so that the national average today is 15 returns for soft drinks and 19 returns for beer.

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133. Hannon, <u>op. cit.</u>, p. 327, Darnay and Franklin, <u>The Role of Packaging In Solid Waste Management</u>, op. cit., p. 40 and Figure 24.

ESTIMATED CONSUMPTION OF BEVERAGE CONTAINERS IN MINNESOTA

In Thousands of Units

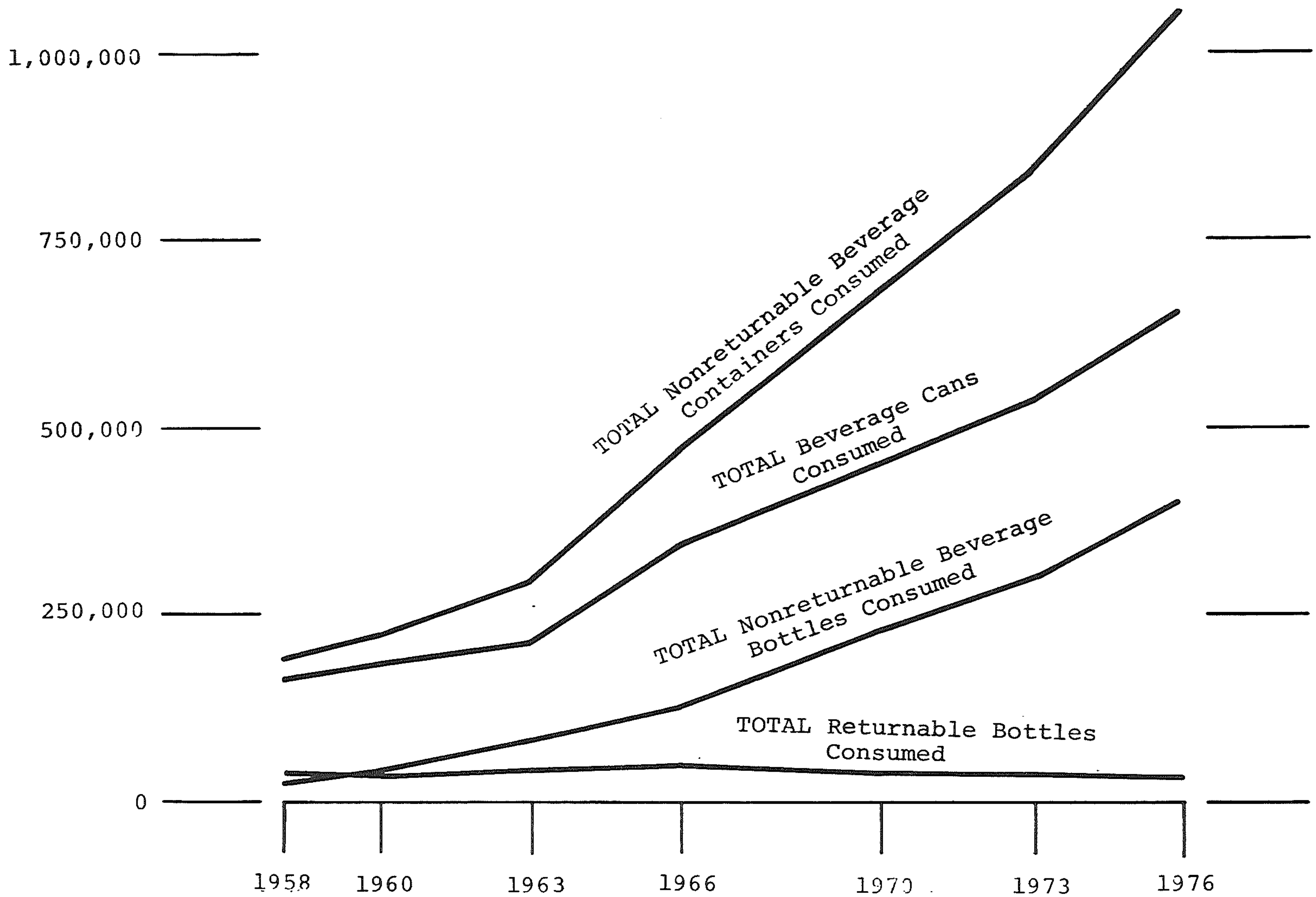

Figure 23

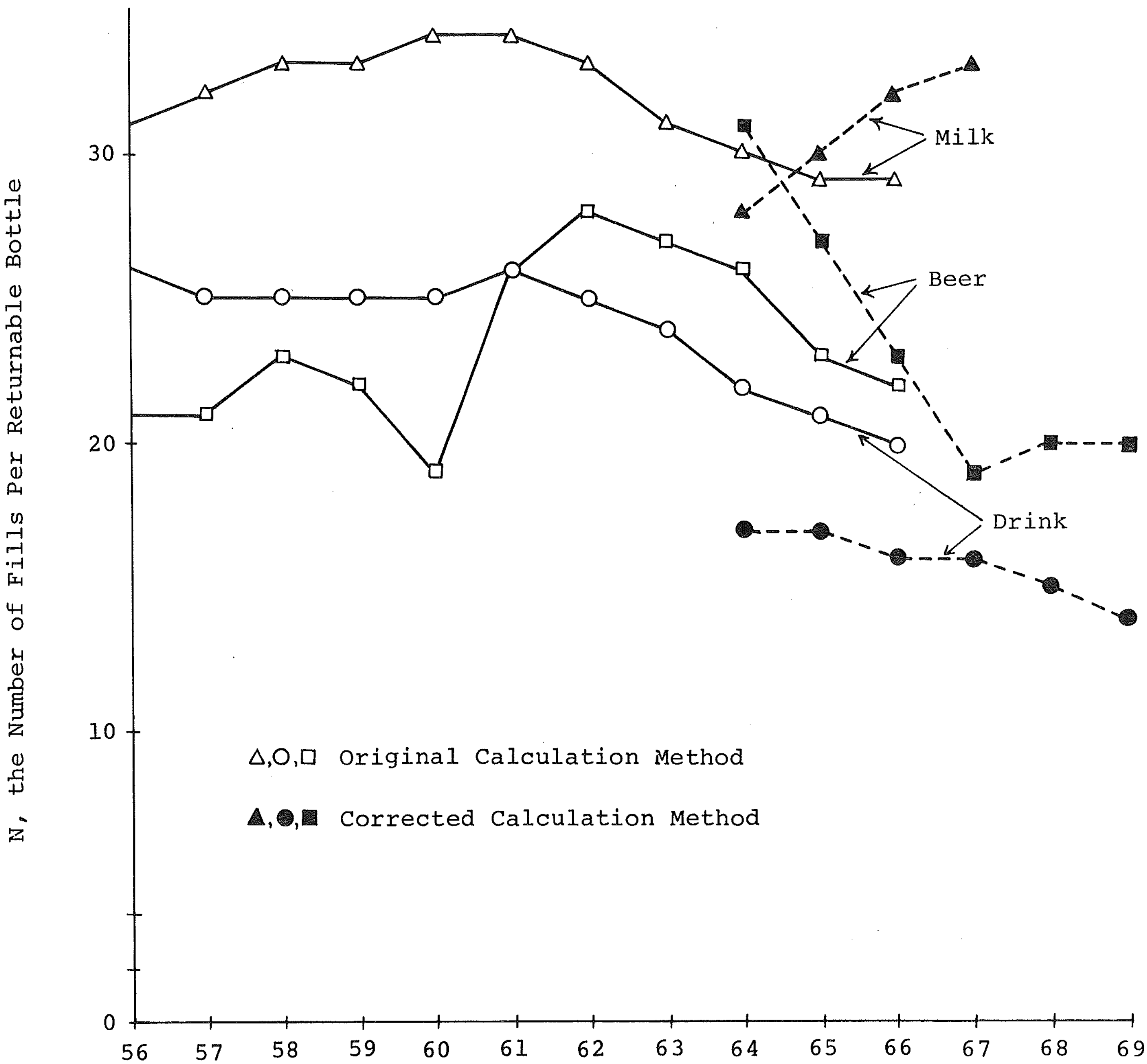

Figure 24

The Change in the Number of Fills Per Returnable Container
As Determined by Two Calculation Methods

Source: Glass Container Manufacturers Institute, Yearbook

Relationship of Non-returnable Beverage Containers To Total Glass Container and Metal Can Production

The metal and glass container industries have become heavily dependent on the production of non-returnable beverage containers. For example, Table C-15 in Appendix C shows that while non-returnable glass beverage bottles represented only 7.1 percent of total glass container production in 1958, by 1966 the figure stood at 23.8 percent. By 1973 the figure is expected to be 41.3 percent, and by 1976 non-returnable beverage bottles are projected to be 48.3 percent of total production.

The same is true for metal beverage containers. As shown in Appendix C, Table C-16, beverage cans were only 20.2 percent of total metal can production in 1958, but by 1966 this figure had climbed to 34.1 percent. By 1973, they are projected to be 40.7 percent and in 1976 the figure is expected to reach 46.0 percent.

Estimated Consumption of Beverage Containers in Minnesota

Per capita non-returnable beverage container consumption in Minnesota has risen from roughly 58.4 units in 1958 to 215.3 units projected for 1973. The most dramatic growth has been in non-returnable bottle consumption, from 8.2 units in 1958 to 77.1 units projected for 1973. Consumption of returnable bottles on the other hand has remained relatively the same, dropping from 9.3 units in 1958 to 8.7 units projected for

1973. Estimated growth per capita consumption and consumption in Minnesota is summarized in Tables C-17 and C-18 in Appendix C, and Figure 23.

Benefits Associated with Restrictions of Non-Returnable Beverage Containers

In addition to reducing energy consumption in the beverage industry by 55 percent, other benefits from a ban or deposit on non-returnable beverage containers would include a saving in minerals consumed, a reduction in solid waste generated, monetary savings for Minnesota consumers, and a reduction in litter.

Energy Savings

The Office of Emergency Preparedness' study, The Potential for Energy Conservation has stated that "reuse, especially of refillable containers can bring about major energy savings."[134]

In Minnesota the use of all returnable beverage containers in 1971 would have saved roughly the equivalent of 22,920,000 gallons of oil per year, or 6.02 gallons per person per year. This is on the order of four times the energy to be saved by recycling 25,000 automobiles (see page 64). Assuming 40 percent of this resource energy is natural gas, a ban on non-returnables would save 966,800,000 cubic feet of natural gas. This may become important in view of the increasing scarcity of domestic natural gas supplies. If action to restrict non-returnable beverage containers were to occur on the federal

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134. Office of Emergency Preparedness, *op. cit.*, p. 27.

level, perhaps by following the example of Oregon, Minnesota and other states, the savings would be on the order of 9.9 percent of Minnesota's total yearly energy consumption.

This would be the equivalent of 50 percent of the energy used to generate electricity in Minnesota, which in 1970 would have been roughly equal to 4.4 plants the size of the Alan S. King or Monticello facilities (550 MW). It would also be roughly equal to the savings that would result from pyrolyzing one-half of the total U. S. residential, commercial, and industrial wastes (see page 44).

The basis for both state and national figures on energy consumption and potential energy savings are explained in Appendix C, pp. C-29 to C-41.

Mineral Conservation

The reduction in glass consumed for beverage containers under an all-returnable system would be significant primarily because of reduced impacts from mining and energy consumption, since silica for glass will remain in abundant supply.

Aluminum used for beverage containers in Minnesota is lower than for most states because no plants within the state produce all-aluminum beverage containers.

The savings in steel however, would be substantial. The estimated saving in Minnesota would be on the order of 23,600 tons, roughly equivalent to 18,800 recycled automobiles. An all-returnable system nationally would save approximately 1,886,000 tons of steel. By comparison, shipbuilding in 1968 required 1,500,000 tons per year; air craft -- 600,000 tons; rail and rail transport -- 4,500,000 tons; and all home appliances and equipment -- 6,100,000 tons. The potential savings in steel, glass, and aluminum are summarized in Appendix C, Tables C-19 through C-22. Note that a national all-returnable system would reduce total steel consumption by two percent and aluminum consumption by 5.6 percent.[135]

Reduction in Solid Waste

Non-returnable beverage containers are a significant portion of total municipal solid waste. While HEW in 1968 estimated that non-returnables comprised 1.3 percent of total municipal waste,[136] EPA now estimates that non-returnable beverage containers account for roughly 3.7 percent of the total. Total bottles and cans represent roughly 9.8 percent.[137]

A ban or deposit on non-returnable beverage containers would reduce the estimated number of beverage units entering landfills in Minnesota in 1973 by 89.7 percent from 874,000,000 units to roughly 90,000,000 units.[138]

Total pounds of solid waste generated from beverage containers in Minnesota would be reduced from roughly 273,842,000

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135. Telephone conversation with Alex Cole, Research Economist, Research Triangle Institute, North Carolina, December 15, 1972.
136. Maille, Jeff, The National Economic Impact of a Ban on Nonrefillable Beverage Containers, Midwest Research Institute Report, June 30, 1971, Fig. 18, p. 57
137. See letter from Patrick E. Lynch, Deputy Chief, Solid Waste Management Branch, EPA, Region V, November 9, 1972, Appendix C, pp. C-35 to C-37.
138. See Appendix C, Table C-23 and Estimated Solid Waste Reduction Through All-Returnable Beverage Container System in 1973 in Minnesota, p. C-39.

pounds to 89,977,000 pounds or by roughly 67.1 percent (3.04 times less),[139] simply because fewer beverage containers would need to be manufactured and eventually disposed of. This would mean an equivalent reduction in solid waste of 12,258 packer truckloads per year assuming 15 cubic yard packers and 1000 pounds per cubic yard.[140] In fact, the reduction would probably be much more significant since a substantial deposit would ensure that most unusable returnables would be returned to the bottler, withdrawn from production, and used as cullet in manufacture of new bottles. Also the assumption here is that returnables will make only 15 trips. If return trippage proved to be higher, the number of bottles entering landfill would be further reduced.

The reduction resulting from a ban can be compared with the operation of the Metropolitan Recycling Center[141] assuming that the center averages 117,658 pounds of bottles and cans per week (the highest weekly total in April, 1972). If the Metropolitan Recycling Center handled only beverage containers, the equivalent of 30 centers would be required to reduce solid waste by an amount equal to the solid waste reduction resulting from a ban.

However, only a portion of the cans and bottles handled by the Metropolitan Recycling Center are beverage containers.

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139. Assuming the national average of 15 returns for soft drink returnables.
140. See Appendix C, p. C-39.
141. See Appendix C, p. C-39 and 40.

Assuming only 30 percent of the containers handled are for beverages, approximately 100 Metropolitan Recycling Centers would be required to have an impact on solid waste reduction as significant as a non-returnable beverage container ban.

Using the above assumptions, the Metropolitan Recycling Center in April of 1972 was recycling roughly 0.7 percent of all beverage containers and 1.0 percent of all bottles and cans.[142]

It should be pointed out that the imposition of a ban would still leave 423,735,000 pounds per year[143] of bottles and cans to be disposed of, which if totally recycled would require 69 Metro Recycling Centers.

Reduction in Solid Waste Disposal Costs

The reduction in solid waste costs resulting from a ban on non-returnable beverage containers would be somewhere between $1.8 and $2.3 million assuming 15 trips per returnable. The lower figure assumes no returnables will be recycled as cullet; the higher figure that all returnables will eventually become cullet. With no restriction on non-returnables, disposal costs for one-way beverage containers are projected to be on the order of $4.1 million by 1980. (See Appendix C, pp. C-41 and 42.)

Reduction in Litter

Reduction in litter should not be confused with resource conservation. An effective litter control program in the State of Minnesota, while desirable, is not nearly so imperative as

142. See Appendix C, pp. C-40 and 41.
143. See Appendix C, p. C-41.

more rational use of mineral and energy resources. However, by switching to an all-returnable system for Minnesota, a substantial reduction in beverage container litter would also occur.

The only national survey of roadside litter was conducted in 1968 by Research Triangle Institute for the Highway Research Board, National Research Council, and submitted to Keep America Beautiful, Inc. -- a non-profit organization supported by container manufacturers and the beverage industry, among others.

According to Tayler Bingham and Paul Mulligan, authors of a 1972 Research Triangle Institute study of the beverage container for the U.S. Environmental Protection Agency, the national survey shows:

> "The littered beer and soft drink containers are a substantial portion of litter. On a national basis this portion is probably at least 20 percent of the items littered and 30 percent of the items collected -- the difference being due to the containers' lack of degradability."[144] Bingham and Mulligan conclude further:
>
> "Because of the growth expected in beverage consumption and the continued trend to the more litter-prone, non-refillable container, it appears that without government intervention, both the number of containers littered and their share of total litter will be substantially greater in the future."[145]

The results of the national survey are confusing to the layman. From Table 17 and Table C-24 in Appendix C,

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144. Bingham, T. H. and Mulligan, P. F., The Beverage Container Problem, Research Triangle Institute, Prepared for Office of Research and Monitoring, U.S. Environmental Protection Agency, EPA-R2-72-059, September 1972, p. 34.
145. Ibid.

TABLE 17 - DISTRIBUTION OF THE BEVERAGE CONTAINER ELEMENT OF ROADSIDE LITTER (PERCENT OF TOTAL ITEMS FOUND IN LITTER)

Type of beverage container	First pickup	Second pickup
Cans		
Beer	21.7	11.8
Soft drink	4.4	3.1
Bottles		
Refillable		
Beer	0.4	0.4
Soft drink	1.6	1.6
Nonrefillable		
Beer	2.7	2.3
Soft drink	0.8	0.5
Total	31.6	19.7

Source: Bingham and Mulligan, *op. cit.*, (footnote 144) p. 30. Research Triangle Institute, *National Study of the Composition of Roadside Litter*, 1969, Table A-01.

it would appear that while beverage cans and non-refillable beer bottles represent a substantial portion of roadside litter, returnable soft drink bottles are littered somewhat more frequently than non-returnables. While these figures are useful, Bingham and Mulligan point out that it is important to compare the number of littered containers to the number of fillings to gain a more accurate indication of the actual contribution each type of container makes to litter. Their findings are presented in Table 18.

Note that 6.5 percent of all beverage cans filled are eventually littered, 1.2 percent of all non-returnable soft drink bottles, only 0.8 percent of all returnable soft drink bottles, and 0.4 percent of all returnable beer bottles. They conclude:

> "...a comparison of the soft drink littering rates does indicate that the refillable bottle is littered at a rate somewhat below that for the non-refillable bottle and significantly below the rate for soft drinks in cans."[146]

Bingham and Mulligan also find that with the projected growth in beverage consumption and the continued shift to the non-refillable container, beverage containers will comprise 25 percent of all littered items in 1976 compared to 20 percent in 1969, assuming litter continues to increase four percent annually.[147]

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146. <u>Ibid</u>, p. 32.
147. <u>Ibid</u>, p. 33.

TABLE 18 - ANNUAL RATE OF
LITTERING OF BEVERAGE CONTAINERS, 1969

Type of beverage container	Proportion of fillings littered (percent)
Cans	6.5
Beer	7.9
Soft drink	4.2
Bottles	1.4
Refillable	0.7
Beer	0.4
Soft drink	0.8
Nonrefillable	3.8
Beer	4.7
Soft drink	1.2
Total, all types	3.0[a]

a. Estimated number of littered containers divided by total fillings.

Source: Bingham and Mulligan, *op. cit.*, (footnote 144), p. 32, Research Triangle Institute, *National Study of the Composition of Roadside Litter*, 1969.

The unit basis of measuring litter may result in a serious underestimation of the visibility of some littered items.[148] For example, a 1971 survey of litter in Oregon by the Oregon State Highway Division found that by volume, cans totaled 40 percent of litter collected, bottles equalled 22 percent, and remaining litter amounted to 38 percent of the total. On the other hand, the 1968 National Highway Survey, based on a count of number items littered, showed total cans at 21.23 percent, total bottles and jars at 6.65 percent, beverage cans at 19.60 percent, and beverage bottles at 5.61 percent of total litter. These surveys are summarized in Table 19.

As to the claim that returnables with mandatory deposits would be littered as much as non-returnables, Bingham and Mulligan state:

> "The littering of beverage containers should virtually cease with a mandatory high deposit (10 cents). Most containers littered would probably be quickly scavenged."[149]

Reduction in Cost of Litter Collection and Disposal

It is estimated that if 20 percent of litter by weight were non-returnable beverage containers, cost of litter collection and disposal could be reduced by $805,000 in Minnesota through imposition of a ban on non-returnable beverage containers. On the other hand, if 40 percent of litter by weight consists of non-returnable beverage containers in Minnesota, the reduction in litter collection

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148. For example, on a volume basis, 140 cigarette butts are equivalent to one 12 oz. can.
149. Bingham and Mulligan, p. 56.

TABLE 19 - SELECTED SURVEYS: PERCENTAGE OF BOTTLES AND CANS IN LITTER

	National Survey of Roadside Litter, 1968 by unit count[a]		Oregon State Highway Division, 1971 by volume count[b]
	Minnesota	Oregon	
Cans			
Beer	20.07	16.14	
Soft drink	4.52	3.46	
Other	1.92	1.64	
Total	26.51	21.23	40%
Bottles			
Beer	0.82	1.47	
Nonrefillable beer	4.53	3.12	
Returnable soft drink	1.30	0.52	
Nonrefillable soft drink	.14	0.50	
Other	2.82	1.04	
Total	9.59	6.65	22%

a. Finkner, A. L., National Study of the Composition of Roadside Litter, Prepared by the Statistics Research Division, Research Triangle Institute, for the Highway Research Board, National Research Council, and submitted to keep America Beautiful, Inc., pp. B-14 and B-24.

b. News Release, Oregon State Highway Division, Public Information Office, Salem, Oregon, January 4, 1972.

and disposal costs would be on the order $1.61 million. (See Appendix C, p. C-44 for the derivation of these figures.)

Total Savings to Minnesota Citizens

A ban or deposit on throw-away beverage bottles and cans should create considerable consumer savings for Minnesotans approaching $18 million per year in 1970.[150] Total savings to Minnesota citizens is summarized below.

	millions
reduction in solid waste disposal cost in 1970	$2
reduction litter collection costs assuming 40 percent by volume are non-returnables in 1969	1.6
consumer savings for Minnesota in 1970	18
Total savings	$21.6

These savings are likely to be spent elsewhere in the state economy creating new jobs and tax revenues.

This $21.6 million does not reflect the true savings to society of using non-returnable containers, since it does not include the savings in terms of resource conservation or environmental impact.

The Costs of Ban on Non-returnable Beverage Containers

The potential negative impacts of a ban on returnables must be weighed against the positive effects considered above.

In particular the impact on investment, labor, personal income, beverage prices, tax revenue, and the environment. and the loss of convenience to consumers resulting from the

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150. Folk, Hugh, Employment Effects of a Ban on Non-returnable Beverage Containers in Minnesota. Prepared under contract with the Minnesota Pollution Control Agency. January 10, 1973, pp. 12-19.

use of one-way containers must be examined.

Drop in Beverage Consumption

The impact on demand for beverages resulting from shift to all returnable containers is difficult to predict because little is actually known about consumer preference for throw-away packaging. Hugh Folk concludes that any drop in sales would be negligible,[151] and Bingham and Mulligan believe that the reduction in consumption would be on the order of four percent.[152] The Research Triangle Institute study concludes:

> "Assuming no effect on the rates of growth projected for beverage consumption, these losses in consumption would be a temporary interruption in the sales growth of beer and soft drinks and would be made up in about one year."[153]

Loss of Equipment, Investment, Tax Revenue and Personal Income

It is estimated that a major loss in production would occur in both the can and bottle industry with the imposition of a ban on non-returnable beverage containers, although it is likely to be less severe in the bottle industry because glass container manufacturers will receive the market currently held by beverage cans.

Much of the equipment used to manufacture and fill nonrefillable bottles and cans would become obsolete. In

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151. Folk, Hugh, op.cit. pp 4-5
152. Bingham and Mulligan, op. cit., p. 53
153. Ibid, p. 54.

Table 20, Bingham and Mulligan summarize both nationwide writeoffs and new investment for 1969, assuming a four percent drop in beverage consumption.

With regard to tax revenues, Bingham and Mulligan state:

> "Policies which reduce beverage consumption will reduce tax revenues. There are three possible sources of losses in tax revenue: beer excise and beverage sales tax, income taxes, and equipment writeoffs. None of these possible revenue losses, however, represent real losses to society since they are reallocations of resources, not reductions in resource utilization."[154]

Using data from the 1971 Midwest Research Institute study entitled The National Economic Impact of a Ban on Nonrefillable Beverage Containers, Bingham and Mulligan estimate that with a national shift to an all-returnable system, there would be a reduction in beer excise tax revenues of $51.3 million, and they note that if the investment writeoff were spread over five years, the tax loss nationally would be $271 million annually.[155] According to Bingham and Mulligan, the loss in personal income nationally would be on the order of $114.0 in 1969.[156] However, they point out that these income losses would be transitory to the extent that displaced workers would be able to find employment elsewhere.[157] Also Hugh Folk points out that money saved by consumers from an all-returnable system would likely be spent for other goods and services.[158] This pre-

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154. Ibid., p. 44.
155. Ibid., p. 61.
156. Ibid., p. 62
157. Ibid., p. 44.
158. Folk, op. cit., p. 29

TABLE 20 - INVESTMENT IMPACTS ESTIMATED WITH A MANDATORY HIGH DEPOSIT (10 CENTS) ON BEVERAGE CONTAINERS[a]

(millions)

	Total writeoff	New investment[b]
Soft drinks	$ 181	$ 345
Malt liquor	169	501
Wholesale beer distribution	-0-	298
Retailing	-0-	24
Glass container[c]	161	-0-
Metal can	550	-0-
Metals	300	-0-
Total	$1,361	$1,168

a. Bingham and Mulligan, op. cit. (footnote 144), p. 60
b. These figures are four percent lower than the amounts estimated if consumption had remained constant. MRI assumed an 8 percent decline in consumption.
c. Trippage of 15; MRI assumed a trippage of 8.
Source: Maillie, Jeff, The National Economic Impact of a Ban on Nonrefillable Beverage Containers, Midwest Research Institute, Kansas City, 1971, pp. 23,83, 75,76,78, and Research Triangle Institute.

sumably would create a multiplier effect that would result in increased personal income in other sectors of the economy.

Making a crude estimate of the impact in Minnesota gives:[159]

total writeoff	\$25.5 million
total new investment	\$21.9 million
total reduction in beer excise tax	\$ .96 million
total loss in personal income	\$ 2.14 million

All these "one-time" costs might be compared with the annual savings to Minnesota citizens over a twenty year period of (20)(\$21.6 million) or \$432 million plus the benefits to the economy of spending this \$432 million on other goods and services.

Impact on Labor

The displacement of the labor force would be the least desirable effect resulting from a ban on non-returnable beverage containers. Every action which would reduce over-consumption or waste in society, threatens to unemploy sectors of the labor force. If no retraining, or alternative employment is available, the result could be tragic for the men involved. It is recommended that the state of Minnesota come to grips with the very serious problem of expanding employment opportunities in sectors of the economy which do not result in wasteful consumption of resources.

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159. Using the ratio of Minnesota population/U.S. population in 1970.

Hugh Folk, a Professor of Economics and Labor and Industrial Relations at the University of Illinois, Urbana-Champaign has examined the employment effects of a ban on non-returnable beverage containers in Minnesota.[160] His findings are summarized below:[161]

Reductions in employment	
Metal cans	433
Glass containers	301
Indirect effects from metal cans	806
Indirect effects from glass containers	118
Total reductions	1,658
Increases in employment	
Retail trade	671
Beer distribution	483
Soft-drink distribution	348
Beer bottling	498
Soft-drink bottling	327
Total increases	2,327
Net increase in employment	669

Folk states further:

> "These estimates are not complete, but they include most of the major effects. One specific omission is a reduction in solid waste handling and litter collection which might run to 200 or 300 jobs. In addition to these measured effects in the directly concerned industries,

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160. Folk, *op. cit.*
161. *Ibid*, p. 26.

> consumers can be expected to spend the $18 million consumer savings. If they spend some of this on more beverages, the glass reductions will be smaller and the increases in employment in beverage production and distribution will be larger. If the $18 million in consumer savings is spent on other commodities and services, it should have direct and indirect employment effects of perhaps 1,200 jobs. This suggests that the total direct and indirect employment effects resulting from a ban on one-way containers could amount to an increase in employment of about 1,500 to 2,000 jobs."[162]

He concludes:

> "The occurrence of employment reductions concentrated in particular industries does not constitute a strong argument against legislation which is desirable on other grounds. The employment in the container industries is in a very real sense a substitute for employment in the beverage production and distribution industries which once was engaged in operating the returnable system. Changes in the industrial distribution of employment are the normal consequence of economic growth and change. Changes such as those which will occur with the adoption of a ban on one-way containers can be readily absorbed in the economy as long as it remains vigorous and expanding.[163]

Folk's figures are supported somewhat by Bingham and Mulligan's analysis. Nationally, they anticipate a large addition to employment (60,800) in the beverage and distribution industries and large reduction (60,500) in the beverage container industries.[164] The only other study, by the Mid-west Research Institute, examined only the loss of employment

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162. Ibid, pp. 26-28.
163. Ibid, p. 30.
164. Bingham and Mulligan, p. 58, assuming a 4% drop in consumption. If consumption were to remain the same, Bingham and Mulligan conclude that employment would increase by 14,700 jobs nationwide. (Table F-15, p. 189).

from the affected industries and not the potential employment gains elsewhere.[165]

It should also be noted that both the beer and soft drink industries should increase in employment under the ban. In fact, Bingham and Mulligan state:

> "The interesting implication of the employment requirements of the soft drink industry is that current containerization trends towards non-refillables are resulting in a lower rate of employment growth in the soft drink industries than would be the case if all containers were refillable bottles."[166]

Declining employment in the brewing industry[167] may also be attributed to the increased use of non-returnable containers.

Loss of Convenience to Consumers

The non-returnable beverage container has a special convenience for low income families, despite its higher cost, since it does not have to be "walked back to the store." It is also the preferred package of many travelers. Nevertheless, convenience is apparently not important to most consumers. A poll conducted for the Minneapolis Star in the spring of 1972 indicated that nine out of ten Twin City area residents are willing to pay a deposit on canned and bottled beverages to encourage returning them.[168]

For consumers who attempt to recycle non-returnables, this form of package actually represents an inconvenience

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165. Maillie, op. cit.
166. Bingham and Mulligan, op. cit., p. 174
167. Burch, Charles G., "While the Big Brewers Quaff, the Little Ones Thirst," Fortune, November, 1972, p. 103
168. Minneapolis Star, "Metro Poll", June 20, 1972, p. 108

over returnables, because of the elaborate preparations the resident must make before the containers may be considered for recycling.

Conclusion

Although the labor displacement effects are considered to be serious, the costs of continued use of non-returnable beverage containers outweigh the potential employment benefits of their continued production. It is therefore recommended that non-returnable containers be banned with a long enough date before enactment to allow most of the labor displacement effects to be absorbed by the normal turnover rates for the can and glass manufacturing industries.

Abandoned Motor Vehicles

The 1970 MPCA report[169] on abandoned automobiles states:

> "In 1969, automobiles and truck registration in Minnesota was 2,088,961.[170] Automobiles accounted for 81 percent of the total or 1,694,936 vehicles, approximately one vehicle for every 2.2 people in the state. During the past ten years, the increase in automobile registration has outpaced population growth by 350 percent and it is estimated that auto registration in 1980 will exceed 2,300,000 vehicles. Vehicle scrappage is expected to be 208,400 units in 1970 and 280,500 units in 1980."

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169. Disposal and Reuse of Abandoned and Retired Automobiles, A Report to the Minnesota Pollution Control Agency, Solid Waste Division, Henningson, Durham and Richardson, Inc., Omaha, Nebraska, October 1970, p. I-1.
170. 1971 registration of motorized vehicles was 2,330,000, Minnesota Department of Public Safety, December 27, 1972.

Thus, the equivalent of more than 10 percent of all vehicles registered in Minnesota are scrapped each year. Over 70 percent of the automobiles registered in Minnesota in 1969 were located within a 100 mile radius of Minneapolis-St. Paul. Also, eight of the 16 scrap processors operating in 1969 were located in the Twin City area.[171]

The 1970 MPCA report estimated that of the 260,500 tons of scrap available from abandoned motor vehicles in Minnesota in 1969, 200,000-250,000 tons were being processed annually in Minnesota by existing privately financed scrap industries. A portion of scrap moved out of state to scrap processors in western Wisconsin, Chicago and Winnipeg but it was estimated that 10 percent[172] of all the available scrap was not recycled, and was therefore added to the existing accumulation of old hulks. In 1970, this addition would have amounted to roughly 20,000 units.

In response to this growing problem, the 1971 Minnesota State Legislature enacted a $1.00 tax on the transfer of title of any motor vehicle weighing over 1,000 pounds.[173]

The funds generated from the tax went directly into the general revenue fund, from which $800,000 was allocated in fiscal 1970 for the abandoned motor vehicles program of the MPCA solid waste division.

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171. Disposal and Reuse of Abandoned and Retired Automobiles, op. cit., p. V-3.
172. U.S. Department of Commerce, Motor Vehicle Abandonment in U.S. Urban Areas, March, 1967, p. 3.
173. Chapter 168B-1971, Minnesota Statutes.

In fiscal 1972, an estimated $152,000 of this money was used, primarily to conduct inventories of abandoned motor vehicles and to establish collection sites. Fifty-seven counties conducted inventories during this period.[174]

In fiscal 1973, it is anticipated that the second allotment of $800,000 will be completely used for the collection, reduction, and transportation of 25,000 abandoned vehicles. Using 1.25 tons[175] as the estimated average weight per vehicle, the recycling of 25,000 vehicles represents a mineral saving of 31,250 tons of steel as compared to the 23,660 tons that would be saved from a ban on non-returnable beverage containers. Applying Stephen Berry's estimated energy saving of $27(10^6)$ Btu/automobile recycled, the energy saving resulting from this program would be roughly $0.675(10^{12})$ Btu or roughly 28 percent of the energy that would be saved through a ban on non-returnable beverage containers.[176]

Since adequate markets exist for the abandoned vehicles once they reach the processor, the State of Minnesota abandoned vehicle program will result in major savings of both mineral and energy resources and its success should provide a model for legislation in other areas where incentives for reuse and recycling of materials are long overdue.

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174. Office memo from Floyd F. Forsberg, Director, Division of Solid Waste to Grant J. Merritt, Executive Director, MPCA, November 8, 1972.

175. Disposal and Reuse of Abandoned and Retired Automobiles, op. cit., p. V-3.

176. $2.4169(10^{12})$ Btu saved in Minnesota from a ban on non-returnable beverage containers $\frac{0.675}{2.4169}=27.9$ percent

It should be made clear, however, that a public education program to extend the average life of passenger cars from 5.6 years[177] to 11.4 years would result in even more significant resource savings on the order of 118,438 tons of steel and $11.626(10^{12})$ Btu.[178] Table 21 compares these savings to those for auto recycling, and a ban on non-returnable beverage containers.

TABLE 21 - POTENTIAL SAVINGS FROM ALTERNATIVE RESOURCE CONSERVATION MEASURES

	metal in tons	energy in (10^6) Btu
ban on non-returnable beverage containers	23,660	2.4169
recycling 25,000 autos/year	31,250	0.675
doubling the lifetime of Minnesota automobiles from 5.7 to 11.4 years	118,438	11.626

177. _1971 Automobile Facts and Figures_, Automobile Manufacturers, Association, Inc., 1971, p. 22.

178. This assumes auto lifetime could be extended with no significant loss in miles/gallon or significant increase in repairs.

CHAPTER 5

RECOMMENDATIONS

We can no longer afford to assume that mountains of trash are the inevitable result of a high standard of living. Neither can we any longer avoid the subtle inter-relationships between solid waste and energy and resource consumption. We must take a fresh look at solid waste and its implications, and begin to deal with it from a broader perspective.

As President Nixon put it,

> "One way to meet the problems of solid waste is simply to surrender to it: to continue pouring more and more public money into collection and disposal of whatever happens to be privately produced and discarded. This is the old way; it amounts to a public subsidy of waste pollution."
>
> -- President Richard M. Nixon
> The President's Message on the Environment
> February 10, 1970

It is no longer sufficient for the state to deal with solid waste by simply regulating its collection, transportation and disposal. It is imperative that the state begin to deal with materials use <u>before</u> solid waste is created. The most important recommendation of this report is that <u>a program is needed to encourage the use of materials in a manner which minimizes environmental impact, resource loss, and economic cost to the people of the state</u>.

The program should be given the authority, staff and funds to:

- Conduct further studies of environmental, resource and economic impacts of components in the solid waste stream.

- Encourage extension of product life-time and less wasteful use of materials having undesirable environmental or resource impacts.

- Examine and develop mechanisms which will encourage markets for recycled materials.

- Develop recommendations for redesign and standardization of materials to facilitate their recyclability.

- Assist in the development of a recycling industry in the state which is capable of meeting the above criteria.

It is vital that a portion of these funds be provided for a public information program on materials use and resource conservation.

We would also urge the Legislature to take several additional immediate steps to alleviate both undesirable materials use and solid waste generation:

- Restrictions on soft drink and beer containers which would create an all returnable beverage container system with a minimum five cent deposit. While an outright ban on throw-aways is preferred, a mandatory five cent deposit or a five cent tax per container should have the same effect.

- A ban on all-aluminum container sale and manufacture within the state, excluding frozen food packaging until an acceptable alternative is found.

- A one cent tax on single-use plastic containers and a twenty-five cent tax on aerosol cans to discourage use and to generate revenues for the state materials use program.

- A prohibition on retail sales of throw-away plastic milk, beverage, and liquor containers.

- Restrictions on the use of plastics having detrimental environmental impacts such as floating plastics, PVC plastics, and plastic shotgun shells.

It is further recommended that there be no major state funding for programs involving incineration or pyrolysis of solid waste to generate power. Similarly there should be no state funding of volunteer recycling programs.

In addition to these legislative recommendations, the state should immediately examine internal operations to identify:

- unnecessary materials consumption and waste generation,
- policies which discriminate against secondary materials,
- purchase and use of materials and products which are difficult to recycle, and
- potentials for salvaging waste.

An example of unnecessary materials consumption and waste generation is evident in the state's motor vehicle licensing program. License plates are, according to statute, issued for three year periods in the case of passenger vehicles and one or two years in the case of other vehicles. While the Loaned Executive Advisory Program (LEAP) recently recommended that license plates be issued for five year periods, it would seem that product lifetime in this case could be extended much further. A single license plate assigned for the life of the vehicle should be explored. Such an extension of product lifetime would reduce resource consumption and waste generation while also providing significant savings to the state and taxpayers. All state agencies and departments should examine operations to identify similar situations and take corrective action.

Policies and programs throughout state government should be examined to identify and correct discrimination against secondary materials. For example, intra-state freight rates and taxation policies may favor virgin over recycled materials. Procurement specifications may discriminate against secondary materials by requiring virgin content. Whenever it is feasible to use secondary materials, specifications should be revised with careful attention being paid to the definition of the required recycled content. Recycled paper and recycled oil for state automobiles are two examples of where the state might assist in the development of markets for secondary materials.

Whenever possible state agencies and departments should not purchase or use products and materials which are difficult to recycle. For example, to enhance opportunities for recycling paper, open window envelopes should be favored over glassine or cellophane window envelopes. State printing operations should use bindings which are easily separated from the paper rather than the non-soluble hot melt bindings. Procurement personnel should make special note of the paper contaminants mentioned earlier in this report to ensure that the state's paper needs are met by products which avoid such contamination.

The state should also examine potentials for increased salvaging of waste products. The Department of Administration, for example, already reclaims used computer tab cards for sale to a local waste paper user. Approximately sixteen to twenty tons per year are reclaimed and sold for a salvage value of forty to forty-five dollars per ton. The Minnesota Pollution Control Agency and the Department of Health have been jointly experimenting for the past year with desk separation of mixed ledger papers. Materials salvaged are donated to the University of Minnesota recycling program where various grades of paper are presently being salvaged. It is recommended that the Department of Administration conduct a study of opportunities for increased recycling of the state's paper and other wastes.

APPENDIX A

Excerpt from Darnay, Arsen and Franklin, William E., Salvage Markets For Materials In Solid Wastes, Project No. (SW-29c), Midwest Research Institute, Kansas City, Mo., Contract No. CPE 69-3, for U.S. EPA, 1972, p. 90.

THE PROBLEM OF COMPREHENSIVE ECONOMIC ACCOUNTING

When is it "cheaper" to use secondary materials? The answer would be easy to give if the total costs, tangible and intangible, costs of producing, distributing, using, and disposing of materials were known.

Today, financial accounting practices, industrial reporting practices and census survey practices do not permit the tracing of a material all the way from a mine to the terminal disposal point, showing at each step in the process, the energy consumed and the energy effluents produced, the water consumed and the quality of the liquid effluent, the solid waste generated, the manpower inputs required, and the like -- both in production and transportation steps. These are measurable external cost elements but they are not available today.

Such data are not readily available because they were not heretofore needed. Meaningful environmental analysis, however, requires data on the total environmental impact of a product or material.

To compare the solid waste generation associated with a steel can, for instance, versus a glass bottle, it is not enough to know what each one weighs and how much space each occupies. One also needs to know the quantity of mine tailings generated in mining raw materials, unusable residues generated in raw materials conversion, quantities of unsalable fabrication wastes generated, and the like. Solid waste generation is only one of the many dimensions of external costs.

To develop meaningful public policy to advance recycling, the first step is to acquire such data for at least major material groupings (including secondary materials) and product categories within each. Some of the types of data needed are the following.

1) Materials compositions of major product classes, including proportions of materials in blends (cotton-synthetic textiles).

2) Detailed transportation data on materials and products, on a comparable basis for air, water, rail, and truck modes, by type of fuel consumed in each mode, ton-miles of movement, and similar data.

3) Solid wastes generated in production of materials and products, by type of material, showing portions sold, reused internally, and disposed of.

4) Fuel consumption, by type of fuel and conversion system, stationary and mobile, in all major mining, harvesting, processing, and fabrications operations.

5) Gaseous effluents generated in various types of transportation and production operations, related to output tonnage.

6) Water use in transportation and production operations, related to output tonnage, including data on intake, discharge, and consumption and on water impurities in influent and effluent waters.

7) More detailed "materials consumed" data by industry classification, in comparable units of measure (pounds or tons, instead of square inches of glass, number of chickens, board feet of lumber, yards of clothing, etc.) with detailed indication of types of waste materials consumed.

8) Detailed data on processing losses "not accounted for" in gaseous, water, and solid waste effluents.

9) Detailed cost breakdowns in transportation and production, insofar as these are not available, showing costs of manpower, materials, energy, water, etc. -- especially on captive production operations such as primary aluminum smelting, pig iron production, wood pulping, and the like.

Data collection should be by actual survey, should result in national averages and ratios related or relatable to specific materials by weight, and should be comparable for all production sectors, whatever their outputs. Data collection should be continuous and should be institutionalized in the appropriate Federal agencies -- Commerce, Interior, and Agriculture. The Environmental Protection Agency and its Solid Wastes Management Office provides a focus and has the need for such data, while the National Materials Policy Act of 1970 provides legislative sanction.

Once such data are available and are analyzed in combination with information on exports and imports of materials, natural resource inventory data, population and production forecasts, national defense materials and energy requirement forecasts, and other measurable factors, an important step has been taken to determine the relative costs of using secondary versus virgin materials.

This still leaves the problem of establishing priorities for different types of values. For instance, what is more desirable, to import fossil fuels at the expense of foreign trade balance and domestic production and employment while conserving the national resource or to maintain a favorable trade balance and domestic production at the expense of depleting the domestic stockpile? These are questions that must necessarily be resolved by the political process.

APPENDIX B

References to TABLE 5

1. Stanford Research Institute, Executive Office of the President, Patterns of Energy Consumption in the United States, Report for the Office of Science and Technology, Menlo Park, January, 1972.

On page 152 the following table appears:

Energy Required for One Ton of Material

Material	Millions of Btu to Produce a ton of Product
Magnesium	92.6
Aluminum	60.8
Zinc	45.9
Manganese	45.8
Tin	20.0
Steel	26.0
Copper	27.8
Glass	17.5
Ferro alloys	17.3
Lead	11.2
Paper	27.0
Nickel	6.4
Lime	5.6

The source quoted for this table is A Study of Process Energy Requirements for U. S. Industries - AGA. Stanford Research Institute.

However, this data appears to be less reliable than other information contained in the report.

Summary of Energy Requirements in (10^6) Btu/ton

page 99 - gross energy required to produce a ton raw steel
in 1960 - 30.0
in 1968 - 26.0

page 108 - In the ferrous foundry industry, energy consumption data is highly fragmented. For example, Rehder (1966), states that the amount of coke required to melt 2,000 pounds of cast iron in a refractory-lined, cold blast cupola varies from 2.9 (10^6) Btu/ton to 4.5 (10^6) Btu/ton or a difference of 55% over the lower figure. Thus, it is hazardous to choose a single industry estimate representing an average within such a wide range.

Page 109 - Lownie (1967) makes the following estimates for (10^6) Btu/ton necessary to preheat, melt and superheat one ton of cast iron.

	Cupola	Electric Induction	Electric Arc
Theoretical	1.10	1.10	1.10
Actual			
Preheat and melt	1.60	1.59	1.28
Superheat	2.04	0.24	0.57
Total	3.64	1.83	1.85

Although as shown here, energy input to the electric furnace is roughly half that of the cupola, if the energy required to generate the electrical power is counted, the electric induction furnace in effect consumes 5.49 (10^6) Btu/ton, or 1.5 times as much as the 3.64 (10^6) Btu consumed by the cupola.

page 111 - energy required for copper smelting and refining
40.1

page 112 - energy consumption for refined lead
31.3

page 113 - zinc smelting and refining by distillation methods
31.4

refining by electrolytic process
51.8

pages 114-115 - aluminum smelting electrical requirement 46.7
fuel to melt aluminum ingot 4.7
other process power and fuel consumed 3.6

total power and fuel consumed 55.0

Carbonaceous material such as petroleum coke, coal tar pitch, and carbon blocks for anodes, pot linings, and so forth probably add another $20(10^6)$ Btu/ton.

Total for aluminum manufacture: ~ 75

$8.5(10^6)$ Btu represents the approximate figure for aluminum recycle.

page 125 - paper manufacture 11,670 Btu/lb.
or 23.3

page 135 - fuel energy required to produce finished glass for plate, sheet and hollow glassware
14.0 - 18.0

2. Bravard, J. C., Flora, II, H. B. and Portal, Charles, Oak Ridge National Laboratory, ORNL-NSF-EP-24, Energy Expenditures Associated with the Production and Recycle of Metals, November, 1972, pp. 1-2.

	Energy Requirement in (10^6) Btu/ton
For aluminum from bauxite presently	175.4
with future lower grade ore	203.5
for aluminum recycle	4.4 - 6.8
for iron from high grade hematite	14.6

for iron from magnetic taconites	15.9
for iron recycle	5.7
for copper from 1% sulfide ore	46.2
for copper from .3% sulfide ore	84.5
for recycle of 98% pure copper scrap	2.2
for recycle of impure copper scrap	5.3

page 1 - Although the high grade hematite ores for the production of pig iron are almost completely exhaused, the present use of vast U.S. reserves of mangetic taconites increases the energy requirements only 9%.

For copper production, the quality of the mined ore is rapidly falling from 4% to less than 1%), and use of low-grade ores will involve significantly higher mining and milling energies and may increase total energy expenditures by 83%.

Potentially, 75% of the copper produced is recyclable.

3. Commoner, B., Corr, M., and Stamler, R. J., "The Causes of Pollution", Environment Magazine. April 1971, p. 13.

Total energy required to produce a pound of aluminum
29,860 Btu's
or 59.7 (10^6) Btu's/ton.

Total energy required to produce a pound of steel
4,615 Btu's
or 9.2 (10^6) Btu's/ton.

Aluminum manufacture requires roughly 6.5 times the energy required to produce the same weight of steel.

4. Hirst, Eric., summary in Atomic Energy Clearinghouse, Vol. 18, No. 20, "Electric Utility Advertising and the Environment," May 15, 1972, p. 10.

"For steel, aluminum, copper and paper the energy required to produce goods from recycled scrap is considerably less than the energy required to make products from raw ores. The energy required to produce finished steel from scrap is only 7-15% of that required to make steel from raw ores. For aluminum, the figure is less than 5%, for copper about 5% and for paper 60-70%. For glass, recycling does not reduce energy consumption. However, returnable bottles require only 25% as much energy per gallon of beverage as do throw-away bottles."

"These energy savings apply to the primary fuels, i.e., coal, oil and natural gas. However, it is reasonable to assume that similar savings apply to the electric energy component since electricity is used for every step in the processes described above."

5. Hirst, Eric, Intra-Laboratory Memorandum Received from H. Flora, Intra-Laboratory Correspondence, Oak Ridge National Laboratory, July 26, 1972.

TO: H. B. Flora

FROM: Eric Hirst

SUBJECT: Energy Costs of Solid Waste Separation Methods

Estimates of the energy required per ton of solid waste for separation preparatory to recycling are fragmentary and vary widely. Perhaps this is so because there is not yet much experience with such systems. Based on the data I have gathered, I estimate an upper limit on the energy cost for recycling solid waste as:

50 - 75 kwhr-electric/ton of solid waste input.

$0.17(10^6)$ Btu/ton - $0.26(10^6)$ Btu/ton

This estimate does not include the energy required for: transportation of solid waste to separation site; transportation of separated components to factories for reprocessing; operation of special sorting equipment; non-electric energy uses of which there is probably very little.

Below are estimates for various separation processes:

1. Black Clawson: 150 kwhr/ton of waste or $0.51(10^6)$ Btu/ton
2. Franklin Institute: 13 kwhr/ton of waste
3. Junked cars: 25-60 kwhr/ton of automobile
4. Incineration: 10-20 kwhr/ton of waste

   (incineration can yield ~10 million Btu/ton of waste, equivalent to roughly 950 kwhr/ton of waste.)

   Bureau of Mines Incinerator Residue: 7 kwhr/ton of residue

   Total: 12-22 kwhr/ton of solid waste
   40-75 kwhr/ton of incinerator residue*

5. Average, U. S. EPA: 20-40 kwhr/ton of waste**

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* Assumes a 70% weight reduction by incineration.
** "Recovery and Utilization of Municipal Solid Waste," Rep. SW-10c, 1971.

6. Hunt, Robert G., letter of June 14, 1972.

"Each step in the manufacturing cycle is included from raw materials acquisition to final disposal."

"In the data included here only the process energy used by the actual manufacturing operations was considered. That used for space heating of buildings and other miscellaneous categories was excluded whenever possible. Energy values of the materials in the finished product were not considered directly since virgin raw materials was a separate category and this energy is recoverable after the product it used. Electric energy was included in terms of the fossil fuel energy required to generate electricity, 1.15×10^4 Btu per kilowatt hour."

TABLE B-1 - ENERGY REQUIREMENTS FOR THE MANUFACTURE OF ONE TON OF PAPER OR PAPERBOARD PRODUCTS
(10^6 Btu)

	Raw Materials Acquisition	Transportation to Pulp Mill	Pulp Manufacture	Paper or Paperboard Forming	Transportation of Paper or Paperboard	Transportation of Finished Product	Total
Virgin							
Bleached kraft paper or paperboard	1.6	0.2	25	14	0.5	0.4	42
Unbleached kraft paper or paperboard	1.6	0.2	16	14	0.5	0.4	33
Unbleached groundwood paper	1.0	0.2	11	14	0.5	0.4	27
Recycled							
Repulped paper and paperboard (no deinking)	--	0.4	6	14	0.3	0.4	21
Deinked and bleached paper and paperboard	--	0.4	9	14	0.3	0.4	24

TABLE B-2 - ENERGY REQUIREMENTS FOR THE MANUFACTURE OF 1,000 POUNDS OF PLASTIC PRODUCTS (10^6 Btu)

	Raw Materials Acquisition	Raw Materials Processing	Chemical and Plastics Manufacture	Product Fabrication	Transportation (all steps)	Total
Polystyrene Foam						
100% Virgin	0.3	7.4	21.2	9.4	1.2	
100% Recycled	--	--	--	10.4	1.5	

TABLE B-3 - ENERGY REQUIREMENTS FOR THE MANUFACTURE OF ONE TON OF GLASS (10^6 Btu)

100% virgin:	no purchased cullet	16.2
100% scrap :	if wet separation used for glass recovery	16.7
	if Bureau of Mines incinerator residue system is used	15.2

TABLE B-4 - ENERGY REQUIREMENTS FOR THE MANUFACTURE OF ONE TON OF STEEL (10^6 Btu)

100% virgin	23
100% scrap	6

7. Baile, Richard C., "Wasted Solids as an Energy Resource," paper before 138th meeting of the AAAS, December 29, 1971, Table 1.

Energy in Municipal Solid Waste Components

paper	7,970 Btu/lb.	or	15.9(10^6) Btu/ton
leather, plastics, rubber	10,000 - 11,500 Btu/lb.	or	20 - 23 (10^6) Btu/ton

8. Bell, J. M., "Characteristic of Municipal Refuse," National Conference on Solid Waste Research Proceedings, December, 1963, Table 3. (Additional information, Table B-4 on following page.)

Btu's in Municipal Refuse

paper, mixed	7,572 Btu/lb.	or	15.1(10^6) Btu/ton
plastics	14,368 Btu/lb.	or	28.7(10^6) Btu/ton
rubber	11,330 Btu/lb.	or	22.7(10^6) Btu/ton

9. Hannon, Bruce, Hearings Before the Subcommittee on the Environment on S 1377 and S 3058, "System Energy and Recycling: A Study of the Beverage Industry," Serial No. 92-60, March 6, 10, 13, 1972, pp. 302-350.

page 319 - .002625 tons glass/gallon for throwaway bottles

page 321 - Raw Material Acquisition for glass

1,979,000 Btu's/ton

page 335 - Energy Requirements for 100% New Glass Container in Btu's/gallon

material acquisition 100% new	5,195
transportation of raw materials	650
container manufacture	40,624
	46,469

46,469 Btu's/gallon is equivalent to $\frac{46,469}{.002625}$ Btu's/ton

or 17.7(10^6) Btu/ton for glass bottle manufacture.

TABLE B-5 - COMPOSITION AND ANALYSIS OF AN AVERAGE MUNICIPAL REFUSE[a]

Item	Total Refuse %	Approximate Analysis[b] "As Received" Basis, Weight %				Ultimate Analysis, Dry Basis, Weight%								Btu per lb.	
		Moist-ure	Volatile Matter	Fixed Carbon	Non-Comb.[c]	Carbon	Total Hydro-gen	Avail-able Hydrogen	Oxygen	Nitro-gen	Sulfur	Non Comb.[c]	Ratio C:(H)	Dry Basis	Dry Ash-Free Basis
Rubbish, 64%															
Paper, Mixed	42.0	10.24	75.94	8.44	5.38	43.41	5.82	(0.28)	44.32	0.25	0.20	6.00	155	7,572	8,055
Wood and Bark	2.4	20.00	67.89	11.31	0.80	50.46	5.97	(0.672)	42.37	0.15	0.05	1.00	75	8,613	8,700
Grass	4.0	65.00	--	--	2.37	43.33	6.04	(0.83)	41.68	2.15	0.05	6.75	52	7,693	8,250
Brush	1.5	40.00	--	--	5.00	42.52	5.90	(0.75)	41.20	2.00	0.05	8.33	56.7	7,900	8,600
Greens	1.5	62.00	26.74	6.32	4.94	40.31	5.64	(0.77)	39.00	2.00	0.05	13.00	52.4	7,077	8,135
Leaves Ripe	5.0	50.00	--	--	4.10	40.50	5.95	(0.31)	45.10	0.20	0.05	8.20	131	7,069	7,700
Leather	0.3	10.00	68.46	12.44	9.10	60.00	8.00	(6.56)	11.50	10.00	0.40	10.10	9.1	8,850	9,850
Rubber	0.6	1.20	83.98	4.94	9.88	77.65	10.35	(10.35)	--	--	2.0	10.00	7.5	11,330	12,600
Plastics	0.7	2.00	--	--	10.00	60.00	7.20	(4.40)	22.60	--	--	10.20	13.6	14,368	16,000
Oils, Paints	0.8	0.00	--	--	16.30	66.85	9.65	(9.00)	5.20	2.00	--	16.30	7.43	13,400	16,000
Linoleum	0.1	2.10	64.50	6.60	26.80	48.06	5.34	(3.00)	18.70	0.10	0.40	27.40	16	8,310	11,450
Rags	0.6	10.00	84.34	3.46	2.20	55.00	6.60	(2.70)	31.20	4.62	0.13	2.45	20.4	7,652	7,844
Sweepings, Street	3.0	20.00	54.00	6.00	20.00	34.70	4.76	(0.36)	35.20	0.14	0.20	25.00	96	6,000	8,000
Dirt, Household	1.0	3.20	20.54	6.26	70.00	20.62	2.57	(2.07)	4.00	0.50	0.01	72.30	10	3,790	13,650
Unclassi-fied	0.5	4.00	--	--	60.00	16.60	2.45	(0.166)	18.35	0.05	0.05	62.50	100	3,000	8,000
Food Wastes, 12%															
Garbage	10.0	72.00	20.26	3.26	4.48	44.99	6.43	(2.845)	28.76	3.30	0.52	16.00	15.8	8,484	10,100
Fats	2.0	0.00	--	--	0.00	76.70	12.10	(10.70)	11.20	0.0	0.0	0.0	7.2	16,700	16,700
Noncombus-tibles, 24%															
Metallics	8.0	3.00	0.5	0.5	96.0	0.76	0.04	(0.02)	0.2	--	--	99.0	51	124	12,000
Glass and Cera-mics	6.0	2.00	0.4	0.4	97.2	0.56	0.03	(0.02)	0.11	--	--	99.3	34	65	8,000
Ashes	10.0	10.00	2.68	24.12	63.2	28.0	0.5	(0.40)	0.8	--	0.5	70.2	70	4,172	14,000
	100.0														

Source: a. Bell, John M. "Characteristics of Municipal Refuse," National Conference on Solid Waste Research Proceedings, December 1963

b. Based on ASTM methods of analysis of coal and coke, as adapted for refuse.

c. Noncombustibles - ash, metal, glass, and ceramics.

page 333 - Energy Requirements for Glass Recycle Btu's/ton

separation	1,941,000
sorting	523,000
	2,464,000

Transportation Energy for Virgin Raw Materials

$\frac{649.3}{.002625}$ Btu's/ton

or $.247(10^6)$ Btu's/ton

given transportation energy for moving cullet to the glass manufacture as 30% of the transportation energy for virgin glass materials, the transportation energy component is:

$\frac{649.3(.30)}{.002625} = .074(10^6)$ Btu/ton for recycled glass transportation

$.074(10^6)$ Btu/ton
$2.464(10^6)$ Btu/ton

$2.538(10^6)$ Btu/ton for transportation, separation, and sorting of recycled glass.

Total Energy Requirement for Glass Manufacture Using 100% Recycled Glass - (10^6) Btu's/ton

17.7	energy requirement for manufacture from virgin materials
- 1.979	acquisition of virgin raw materials
- .247	transportation of virgin raw materials
+ 2.538	transportation, separation, and sorting of recycled glass
18.012	total requirement for glass bottle manufacture from recycled glass.

page 331 Hannon is assuming the use of a separation and sorting system similar to the Franklin, Ohio Hydrosposal system which is highly energy intensive.

Franklin, Ohio Hydrasposal, Fiberclaim System

separation	1,941,000 Btu/ton
sorting	523,000 Btu/ton

page 337 Btu/pound of Virgin Steel

mining	1,300
transportation	470
manufacturing	23,000
	24,770

or $49.5(10^6)$ Btu/ton

page 337 Btu/pound of Virgin Aluminum

10,000 Btu/.119 pound = 84,033.61 Btu/pound

or 168.1 Btu/ton

page 338 Recycled paper consumes only 63% of the energy needed for an equivalent amount of virgin paper. (Letter to Bruce Hannon, Garden State Paper Company, Inc., Garfield New Jersey, December 2, 1971.)

10. Makhijani, A. B. and Lichtenberg, A. J., Environment, "Energy and Well-Being," June, 1972, pp. 14-16.

From Table 1, p. 14 - Energy Consumption in Basic Materials Processing

Material	Energy/Unit Produced (kwh/ton)	Energy/Unit Produced (10^6) Btu/ton
steel	11,700	39.9
aluminum (rolled)	66,000	225.3
copper (rolled or hard drawn)	20,000	68.3
glass (plate finished)	6,700	22.9
plastics	2,400	8.2
paper	5,900	20.1

From Table 2, pp. 15-16 - Breakdown of U.S. Energy Consumption, 1968

Finished Product	Energy/Unit Produced (kwh/ton)	Energy/Unit Produced (10^6) Btu/ton)
Household and Commercial Durables		
steel	20,000	68.3
aluminum	75,000	256.0
Steel Cans & Packaging	20,000	68.3
Aluminum Cans & Packaging	82,800	282.6
Miscellaneous Aluminum	70,000	238.9
Glass		
containers	4/lb.	27.3
miscellaneous	4/lb.	27.3
Plastics		
packaging & containers	3,500	11.9
miscellaneous	3,500	11.9
Paper (average, including paper board)	6,400	21.8

11. Forbes Magazine, "Another Lost Frontier?", August 15, 1972, p. 29.

"Last year it took the industry 64 billion kilowatt hours to produce just under 4 million tons of aluminum. . ."

This is $\frac{64(10^9)}{4(10^6)}$ = 16,000 kwh/ton

or $54.6(10^6)$ Btu/ton.

12. Berry, R. Stephen, Bulletin of the Atomic Scientists, "Recycling, Thermodynamics and Environmental Thrift," May, 1972, page 12.

"Producing the automobiles 0.1 metric ton of aluminum requires about 1,640 kwh."

This is $\underline{56.0(10^6)\text{ Btu/ton}}$.

13. Silverman, A. J., personal communication, September 22, 1972.

Energy required for Anaconda copper operation including mining, milling, smelting, and refining:

Total Anaconda production: $243(10^6)$ lbs/year
or: $1.215(10^5)$ tons/year of Cu

requires: $1,200(10^6)$ kwh
(in electrical equivalent)

Total Anaconda production: 1 ton/year

requires: $\frac{12(10^8)}{1.215(10^5)}$ kwh (in electrical equivalent)

or: $$\frac{(3413)(12)(10^8)}{(1.215)(10^5)} = 33.7(10^6)\text{ Btu/ton}$$

14. Harris, Carolyn, The Environment and Packaging: An Economic and Legislative Analysis Environmental Protection Administration of the City of New York, March, 1972, pp. 48-49.

"Recycling aluminum also saves energy since only about 800 kilowatt hours are needed to recycle a ton of aluminum cans from can scrap, whereas 16,000 kilowatt hours per ton would be needed to make aluminum from virgin ore " (This represents:

$2.7(10^6)$ Btu/ton to recycle aluminum

and $54.6(10^6)$ Btu/ton to manufacture aluminum from virgin ore.)

University of Montana
Missoula, Montana 59801
(406) 243-0211

September 22, 1972

Mr. Wes Fischer
Special Services Division
Minnesota Air Pollution Control Office
Minneapolis, Minnesota

Dear Wes:

The following is an analysis of the energy requirement and cost for running an integrated (mining, milling, smelting and refining) copper business the size of Anaconda in Montana. I've had to estimate some numbers but I think the data is very good and will give you the handle you need.

The Anaconda Co., Butte (mining), Anaconda (smelting), Great Falls (electrolytic refining), Montana - 1970.

Production - 243×10^6 # of Cu.
Value - $\$122 \times 10^6$
Estimated average unit cost - ~ 40¢/# (this may be slightly low, for Anaconda has highest average cost in the industry.)
Cost of Energy (~ $\$12 \times 10^6$)
Units of Energy consumed (in KW.HR.) ~ 1200×10^6
Energy cost to Anaconda ~ 1¢/KW.
(The above two items could be as high as $1300\text{-}1400 \times 10^6$ KW.HR. and cost could be as low as 0.7¢/KW.)
Energy /# of Copper production ~ 4.5 to 4.9 KW.HR./#
Energy cost is between 8% to 12% of total production costs (power supplied by Montana Power Company).

This is not an electric furnace operation.

Company uses reverberatory, converter furnace system. Energy requirement for a new, electric furnace system could be substantially higher.

Call me if you need more detailed information.

Sincerely,

Arnold J. Silverman
Geology Department

15. Hickman, Howard J., Lewis, R., and Salomonson, J., A Study of the Environmental Impact of Polystyrene vs. Paper Pulp Egg Cartons and Meat Trays, The Center for Studies of the Physical Environment, University of Minnesota, March, 1972, Data Summary.

	Egg Cartons		Meat Trays	
	molded pulp	foamed polystyrene	molded pulp	foamed polystyrene
pages ii and iii - energy for manufacture	895 Btu/ctn.	2159 Btu/ctn.	758 Btu/tray	1051 Btu/tray
weights, tray cartons	.11 lb.	.044 lb.	.056 lb.	.021 lb.
	$16.27(10^6)$ Btu/ton	$98.14(10^6)$ Btu/ton	$27.1(10^6)$ Btu/ton	$100.1(10^6)$ Btu/ton

page E1 - Hickman gives total energy requirements of a paper mill, including heating and lighting in (10^6) Btu/ton for Hoerner-Waldorf's mill in St. Paul, Minnesota. This plant produces primarily boxboard from waste paper.

electrical requirement	6.04
steam requirement	15.30
	21.34

page F9 - Hickman gives the energy required for manufacturing polystyrene (not the final meat trays) as $34.0(10^6)$ Btu/ton.

pages H1 - H3 - Using Hickman's assumption for transportation requirements gives roughly $7.7(10^6)$ Btu/ton for total transportation of raw materials and final product.

Total energy required for 1 ton of polystyrene would be roughly:

manufacturing	34.0
transportation*	7.7
	41.7

---

* Actual transportation energy should be less than 7.7 Btu/ton as this figure includes transportation of the final product (e.g., the meat tray).

page F10 - In addition, Hickman considers the nonrenewable fossil fuel energy contained in the plastic which is given as $42.8(10^6)$ Btu/ton.

16. Franklin, William E. and Hunt, Robert G., <u>Environmental Impacts of Polystyrene Foam and Molded Pulp Meat Trays</u>, Midwest Research Institute Project No. 3354-D, April 25, 1972, pp. 88-89, Tables D-1, D-2.

Table D-1 - The energy requirement for 1,000 pounds of polystyrene foam is given as $30.1(10^6)$ Btu or $60.2(10^6)$ Btu/ton.

Table D-2 - The energy requirement for 1,000 pounds of molded pulp meat trays is given as $17(10^6)$ Btu or $34(10^6)$ Btu/ton.

If in the MRI study Hickman's estimate of $42.8(10^6)$ Btu contained in one ton of polystyrene is included, then total energy used for manufacture of polystyrene trays is:

79.0 (total Btu for 1 ton on fabricated polystyrene trays)
42.8 (energy contained in tray)
$121.8(10^6)$ Btu/ton

or $$\frac{(.021)(121.8)(10^6)}{2000} = 1278.9 \text{ Btu/polystyrene tray}$$

vs $$\frac{(.056)(34)(10^6)}{2000} = 952 \text{ Btu/paper tray}$$

where 34.0 is total energy/ton for fabricated paper trays.

If the $42.8(10^6)$ Btu is not included, then the energy used in manufacture is:

$$\frac{(.021)(79)(10^6)}{2000} = 829.5 \text{ Btu/polystyrene tray}$$

APPENDIX C

Paper

Paper and Paperboard Grades

Paper and paperboard grades are generally discussed in terms of end use -- non-packaging and packaging. There are five major grades of non-packaging paper and four major grades of non-packaging paperboard. In addition, there are six major grades of packaging paper and five major grades of packaging paperboard. There are virtually thousands of end uses for the various grades of paper. Following is a brief description of each grade with examples of end use.

Non-Packaging Paper and Paperboard[a]

Newsprint, typically composed of 75% groundwood and 25% chemical pulp, is the largest category of non-packaging paper, accounting for about one-third of total non-packaging paper and paperboard consumption.[b] Approximately 93% of all newsprint is used for newspapers, with the remainder going into comic books, handbills, sales books, and other low-grade printed items. About two-thirds of the nation's newsprint is supplied by imports, mostly from Canada, which make newsprint the only major paper grade which is supplied primarily by imports.

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a. Source for the discussion of non-packaging paper and paperboard grades is Darnay, A. and Franklin, W., The Role of Non-Packaging Paper in Solid Waste Management 1966 to 1976, U.S. Environmental Protection Agency, 1971, pp. 9-48.

b. Consumption figures used in this Appendix are for 1966.

Printing Paper is the second largest grade of non-packaging paper, accounting for approximately 21% of non-packaging paper consumption. Groundwood paper and book paper are the two basic grades of printing papers. Groundwood paper, which is somewhat similar to newsprint, contains at least 25% mechanical groundwood pulp and is used for such products as telephone books, directories, paperback books, and magazines. Book papers are made from various combinations of bleached chemical pulps and are typically used for books, commercial printing, envelopes, writing tablets and for products designed to receive printing during consumption like adding machine tapes.

Fine Papers, generally made from bleached, chemical pulp, account for approximately 10% of non-packaging paper consumption. Fine papers are primarily used for business purposes such as writing paper and stationery, index and post cards, cover stock for brochures and menus, file folders, text paper for high quality printing other than books, colored school and construction papers, and thin papers which include carbon, copy and lens papers. Rag content papers such as those used in bond, currency, ledgers and maps are also included in the fine paper grade.

Special Industrial Paper, the fourth major grade, actually accounts for a very small percentage (3.3%) of total non-packaging paper consumption. The characteristics of these papers vary considerably from tissue-like filter paper to stiff heavy abrasive paper. Typical uses include electrical insulation, shot, shell and explosive paper, artificial leather base, blotting paper and filter paper.

Sanitary Tissue accounts for the third largest consumption of non-packaging paper (10.3%), having experienced substantial growth in recent years. Absorbency and gauze-like texture tend to distinguish tissue products from other grades. Typical uses include toweling, toilet tissue, table napkin, facial tissue, and sanitary napkin stock wadding.

Special Paperboard represents about 7% of total non-packaging paper consumption and includes seven major categories with varying characteristics. Uses include match book covers, panelboard (e.g., automobile door panels, seat-backs, and glove compartments), gypsum and wall board, luggage and book covers, cardboard and machinery gaskets.

Wet Machine Board accounts for less than 1% of total non-packaging paper consumption, and is typically used for electrical-press board and various shoe components such as innersoles and heels.

Construction Board represents 9% of non-packaging paper consumption and includes insulation, accoustical tile, insulating siding and other materials used largely in building construction.

Construction Paper (a paperboard category) constituted 5.5% of non-packaging paper consumption. Over 80% of construction paper consumed in roofing papers; other uses include sheathing, vapor barrier, floor covering, automobile trunk and floor lining.

Packaging Paper and Paperboard[c]

Bag Paper is generally made from bleached or unbleached Kraft pulp. The most common bag paper product is the grocery sack made from unbleached Kraft paper. About one-eighth of bag paper is bleached, dyed and printed for use in variety and specialty sacks such as those used by department stores.

Converting Paper is generally made from unbleached Kraft pulp which is coated with a variety of materials to increase barrier properties (asphalt, wax, polyethylene, lacquer, etc.). Uses include shipping sacks, cups and other container forms.

Wrapping Paper is most often produced from unbleached Kraft pulp and, like converting paper, is often coated. Because wrapping papers are strong, they are used to wrap industrial products such as roofing shingles, lumber and steel, and food products such as meats and frozen foods. They are also sometimes used to produce paper cans, ubes and other containers.

Glassine, Greaseproof and Vegetable Paper is a smooth, high-density paper which has been treated to obtain resistance to grease, fats and oils. These papers are commonly used as food package liners and pouches for prepared mixes, powders,

c. The discussion of packaging paper and paperboard is taken from Darnay, A., and Franklin, E., "The Role of Packaging in Solid Waste Management, 1966 to 1976, SW-5c, U. S. Department of Health, Education and Welfare, 1969, p. 15-32.

etc., and may also be used for specialized applications such as the wrapping of pre-greased mechanical parts.

Shipping Sacks, generally made from Kraft pulp are extremely strong with a capacity ranging from 25 to 1,700 pounds. They are primarily used to contain powdered or granular products such as cement, carbon blacks, fertilizer and feeds.

Molded Pulp is a specialty paper produced from sawmill waste or secondary fiber such as waste newsprint. Typical uses include paper plates, meat, produce and fruit trays, egg cartons, etc.

Folding Boxboard is produced primarily from secondary fibers although there has been a trend in recent years toward use of virgin fibers. Improved finishes, coatings and other decorative techniques are used to enhance visual appeal since typical uses include cereal and other food packaging, detergent boxes, beverage cartons, backing for blisterpacks, etc. According to Midwest Research Institute, folding boxboard is in a period of intense competition with plastics and flexible packaging.

Special Food Board is produced from bleached virgin pulp and is used for rigid containers which require high moisture barrier properties and highly printable outer surfaces. Nearly half of this board has been used to produce milk cartons, however plastic throwaway milk bottles are seriously competing for the milk market. The remainder of this board is used almost exclusively to package other dairy products and frozen foods. Various contaminants such as foil laminants, polyethylene and hot-melt coatings are used to enhance the attractiveness of packages.

Can, Tube, and Drum Stock is commonly produced from Kraft pulp and combined with other materials such as wood, plastic or metal to produce various containers. A major use is the composite can which is used for refrigerated dough products, frozen citrus juice concentrates, motor oil and other products. Other uses include mailing tubes, fiber drums (such as the common 55-gallon drum) and inner cores for wax paper, aluminum foil and paper towels.[d]

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d. Other paper grades may be used for some of these products.

New General Services Administration Definitions for Reclaimed Fiber*

The General Services Administration specifications require that various percentages of reclaimed fiber be included from the following categories. For example, a hypothetical specification might require recycled content as follows: Part I-A, 10 percent; Part II-A, 10 percent; Part II-E, 3 percent.

Part I

A. Paper, paperboard, and fibrous wastes from factories, retail stores, office buildings, homes, etc., after they have passed through their end-usage as a consumer item including:

- Used corrugated boxes
- Old newspapers
- Old magazines
- Mixed waste paper
- Tabulating
- Used cordage

B. All paper, paperboard, and fibrous wastes that enter and are collected from municipal waste.

Part II

A. Dry paper and paperboard waste generated after completion of the papermaking process**including:

* Battelle/NASMI, op cit. Vol. VIII, Appendix A

** The papermaking process is defined as those manufacturing operations up to and including the cutting and trimming of the paper machine reel into smaller rolls or rough sheets.

- Envelope cuttings, bindery trimmings and other paper and paperboard waste, resulting from printing, cutting, forming, and other converting operations

- Envelope cuttings, bindery trimmings and other paper and paperboard waste, resulting from printing, cutting, forming, and other converting operations

- Bag, box, and carton manufacturing wastes

- Butt rolls mill wrappers, and rejected unused stock

B. Finished paper and paperboard from obsolete inventories of paper and paperboard manufacturers, merchants, wholesalers, dealers, printers, converters or others.

C. Fibrous by-products of harvesting, manufacturing, extractive, or wood-cutting processes, flax straw, linters, bagasse, slash and other forest residues.

D. Waste generated by the conversion of goods made from fibrous materials, i.e., waste rope from cordage manufacture, textile mill waste and cuttings.

E. Fibers recovered from waste water which otherwise would enter the waste stream.

PLASTIC PACKAGING FLOW CHART FOR 1966

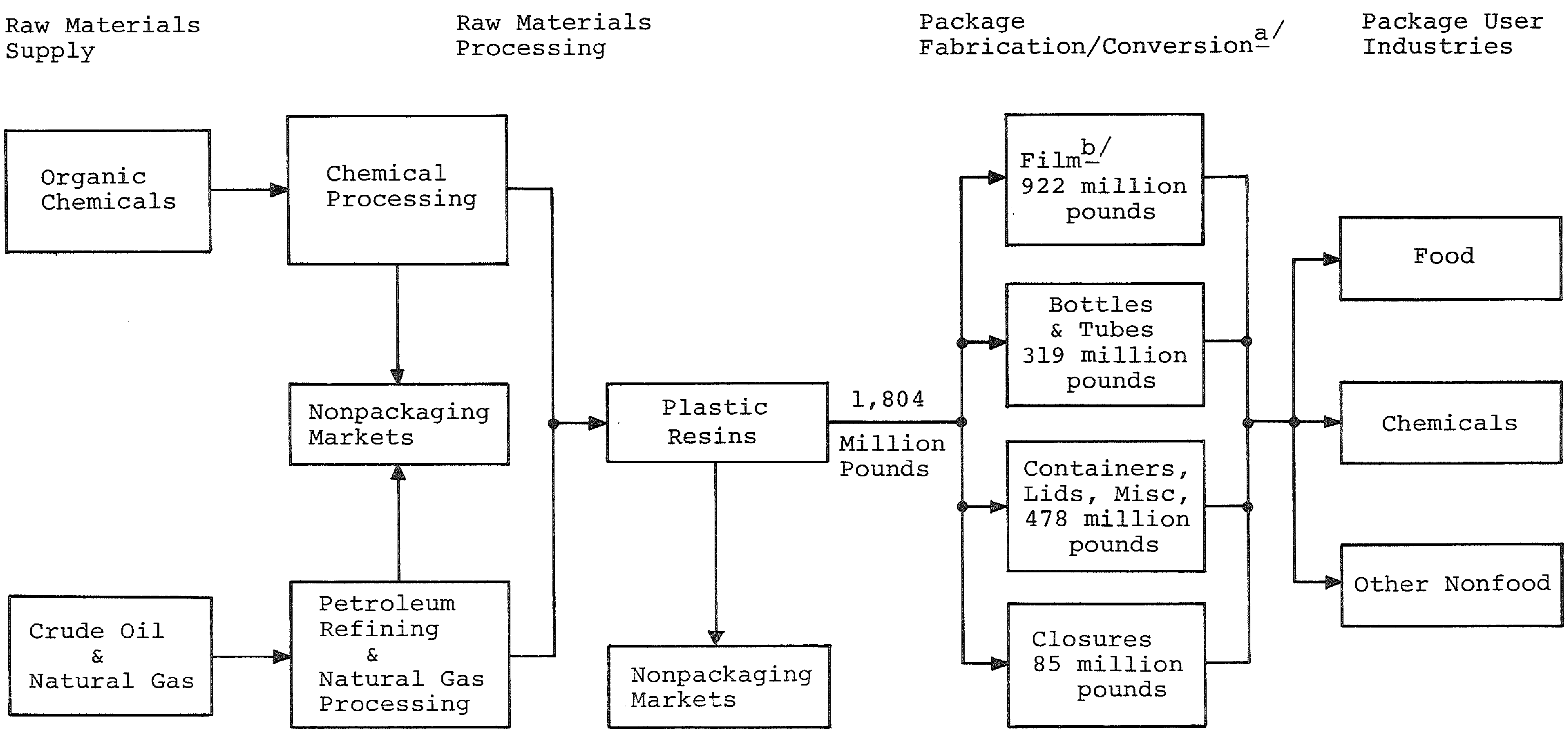

Figure i

a. Package fabricators and converters may make packages from other materials as well as plastics.
b. Excludes cellophane.

Source: Midwest Research Institute

TABLE C-1 - SHIPMENTS OF BLOW-MOLDED PLASTIC BOTTLES BY END USE AND RESIN: 1960 TO 1976
(In millions of units and millions of pounds)

Classification	1960	1961	1962	1963	1964	1965	1966	1970	1973	1976
Bottles by end use:										
Household and industrial chemicals	(a)	(a)	(a)	1,351	1,549	1,659	1,740	2,360[b]	2,680[b]	3,000[b]
Bleach				(a)	(a)	513	504			
Detergent, liquid				(a)	(a)	813	802			
Dry cleaners, other				(a)	(a)	333	434			
Industrial chemicals and specialties	(a)	(a)	(a)	58	69	106	151			
Automotive and marine	(a)	(a)	(a)	(a)	26	24	25	700	1,000	1,500
Medicinal and health	(a)	(a)	(a)	142	143	265	288	540	810	1,100
Food	(a)	(a)	(a)	22[c]	51[c]	91[c]	65[d]	700[d]	4,200[d]	1,770[d]
Milk, liquid	(a)	(a)	(a)	(a)	(a)	(a)	74	1,400	2,940	6,140
Toiletries and cosmetics	(a)	(a)	(a)	416	525	579	769	1,480	2,500	3,430
Total units:	1,100	1,700	2,100	1,989	2,364	2,723	3,112	7,180	11,130	16,940
Resin by type:										
Polyethylene	65	130	170	194	223	262	289	550	800	1,100
PVC	(a)	(a)	(a)	(a)	(a)	(a)	12	125	210	300
All other resins	(a)	(a)	(a)	(a)	(a)	(a)	3	55	140	300
Total pounds:	65	130	170	195	227	270	304	730	1,150	1,700

a. not available
b. total household and industrial chemicals
c. includes milk
d. excludes milk

Source: U.S. Department of Commerce, Bureau of the Census. Plastic Bottles. Current Industrial Reports. Series M30E(61-13)-M30E(65-13). Washington, D.C. 1962-1966. Modern Packaging Encyclopedia. William C. Simms, ed. Vol. 39, No. 4A, New York, McGraw-Hill, Inc. December 1965. 863 p. Forecasts by Midwest Research Institute.

TABLE C-2 - MINNESOTA CONSUMPTION OF BLOW-MOLDED PLASTIC BOTTLES
(In thousands of units)

	1960	1963	1966	1970	1973	1976
U.S. population	179,992[a]	188,658	195,923	203,166[b]	211,530[c]	219,239
U.S. consumption[d]	1,100,000	1,989,000	3,112,000	7,180,000	11,130,000	16,940,000
U.S. per capita consumption	6.11	10.54	15.88	35.34	52.62	77.27
Minnesota population[e]	3,414	3,531	3,617	3,805	3,903[f]	3,975
Estimated Minnesota consumption	20,861	37,217	57,438	134,469	205,376	307,148

a. U.S. Bureau of the Census, Statistical Abstract of the United States: 1970, (1960-66), p. 12.
b. U.S. Bureau of the Census, Current Population Reports, Washington, D.C., March, 1972, Series P-25, No. 477, Table 1, p. 4.
c. Ibid., (1973-76) Population Estimates Projections, November, 1971, Series P-25, No. 470, Table 1, p. 12.
d. Darnay, Arsen and Franklin, William E., The Role of Packaging in Solid Waste Management 1966 to 1976, Midwest Research Institute, Kansas City, Mo., contract No. Ph 86-67-114, for U.S. Department of Health, Education and Welfare, Bureau of Solid Waste Management, (SW-5c), Table 53, p. 85.
e. Minnesota Department of Health, Section of Vital Statistics. Minnesota Population Trends: Estimates Projection , March 1972, Table 3, p. 6.
f. Minnesota Department of Health, Section of Health Statistics, Projection 2, February 1972, computer print-out.

TABLE C-3 - TRENDS IN CONSUMPTION OF ALUMINUM FOR METAL CANS[a]

	1971[b]	1970	1969	1968	1967	1966	1965	1964	1963	1962
Base Boxes in thousands	18,281	16,235	12,369	9,816	7,839	5,912	4,467	3,942	2,356	1,792
Tonnage equivalent in thousands of tons	393	352	270	209	174	124	94	81	43	26

a. Bureau of the Census, U.S. Department of Commerce, Bureau of Domestic Commerce, Containers and Packaging, October 1971, p. 18.
b. Bureau of the Census, U.S. Department of Commerce, Bureau of Domestic Commerce, Containers and Packaging, January/April, 1972, p. 20.

TABLE C-4 - THE CONSUMPTION OF ALUMINUM FOR PACKAGING

(Compared with Other End Uses with Forecasts of Demand in the Year 2000)

End Use (million short tons)	Demand 1968	U.S. forecast base 2000	Demand in year 2000[a] Low	Demand in year 2000[a] High
Metal:				
Metal cans and containers, and packaging	.46	2.3	1.4	5.0
	(metal cans were .21 - table immediately above)			
Shipbuilding and repair	.02	.4	.4	1.0
Railroad	.02			
Aircraft and parts	.17	.8	.4	1.0
Machinery and equipment (except electrical)	.31	4.2	2.5	6.0
Fabricated metal parts (consumer durables)	.47	4.0	3.5	5.0
Electrical	.60	4.5	4.0	8.0
Motor vehicles	.67	2.7	2.7	6.0
Building and construction	1.00	4.5	4.0	6.0
Highway and street construction	.06	.4	.3	1.0
Other manufacturing and fabrication[b]	.53	2.1	2.0	3.0
Total	4.31	--	21.2	42.0
Bauxite and alumina:[c]				
Abrasives, aluminous	.08	.3	.2	.4
Chemical and allied products	.16	.7	.5	1.0
Nonclay refractories	.16	.6	.5	1.0
Total	.40	--	1.2	2.4
	4.71	--	22.4	44.4
			(Median 33.4)	

a. The total demand in the rest of the world in 2000 is forecast to be between 31.5 and 68.0 million short tons (median - 49.8).
b. Includes aluminum content of some alumina and bauxite.
c. Aluminum content of bauxite and alumina.
Source: Mineral Facts and Problems, U.S. Department of Interior, Bureau of Mines, 1970, Table 3, p. 454.

TABLE C-5 - ANNUAL SHIPMENTS FOR STEEL AND ALUMINUM CONTAINERS

Base Boxes[a]	1970	% Total	1965	% Total	% Growth 1970/1965
Steel (1,000 base boxes)	143,064	89.8%	116,583	96.5%	22.7%
Aluminum (1,000 base boxes)	16,235	10.2%	4,467	3.6%	263.4%
Total:	159,299	100%	121,050	100%	31.6%
Tonnage Equivalent					
Steel (1,000)[b]	5,655	94.1%	4,858	98.1%	16.3%
Aluminum (1,000)	352	5.9%	94	1.9%	274.5%
Total:	6,007	100%	4,952	100%	21.3%

a. a base box = area of 31,360 square inches
b. derived by the use of the factor 25.3 base boxes per short ton of steel for 1970, 24.0 for 1965.
Source: Bureau of the Census, U. S. Department of Commerce.

TABLE C-6 - PER CAPITA CONSUMPTION OF GLASS CONTAINERS OTHER THAN BEER AND SOFT DRINK

	1958	1960	1963	1966	1970	1973	1976
U.S. population (in thousands)[a]	174,149	179,992	188,658	195,923	203,166	211,530	219,239
Glass containers other than beer and soft drink (in millions)[b]	17,169	18,242	18,816	19,886	20,620	21,250	21,950
Per capita consumption	98.59	101.35	99.74	101.50	101.49	100.46	100.12
Minnesota population[c] (in thousands)	3,313	3,414	3,531	3,617	3,805	3,903	3,975
Minnesota consumption of glass containers other than beer or soft drink	326,628,670	346,008,900	352,181,940	367,125,500	386,169,450	392,095,380	397,977,000

a. U.S. Bureau of the Census, op. cit., (Table C-5, notes a-d).
b. Darnay and Franklin, The Role of Packaging in Solid Waste Management, op. cit., Table 23, p. 37.
c. Minnesota Department of Health, Section of Vital Statistics, op. cit., (Table C-5, notes f and g).

TABLE C-7 - PER CAPITA CONSUMPTION OF METAL CANS OTHER THAN BEER AND SOFT DRINK

	1958	1960	1963	1966	1970	1973	1976
U.S. population[a] (in thousands)	174,149	179,992	188,658	195,923	203,166	211,530	219,239
Total metal cans other than beer and soft drink (in millions)[b]	34,544	34,673	34,521	35,877	38,110	40,070	42,270
Per capita consumption	198.36	192.64	182.98	183.12	187.58	189.43	192.80
Minnesota Population[c] (in thousands)	3,313	3,414	3,531	3,617	3,805	3,903	3,975
Minnesota Consumption of metal cans	657,166,680	657,672,960	646,102,380	662,345,040	713,741,900	739,345,290	766,380,000

a. U.S. Bureau of the Census, op. cit., (Table C-5, notes a-d).
b. Darnay and Franklin, The Role of Packaging in Solid Waste Management, op. cit., Table 30, p. 51.
c. Minnesota Department of Health, Section of Vital Statistics, op. cit., (Table C-5, notes f and g).

TABLE C-8 - NONFOOD AEROSOL CONTAINERS CONSUMED BY SIZE: 1955 to 1966

(In thousands of units)

Year	Glass and plastic containers (all sizes)	Metal Containers		Reported Total	Complete Total[a]
		Over 6 oz.	6 oz. and less		
1951				34,184	
1952				96,619	
1953				131,515	
1954				169,362	
1955	10,412	119,720	104,985	235,117	240,000
1956	15,093	151,035	127,062	293,190	320,000
1957	21,279	167,871	150,341	339,491	390,000
1958	11,262	171,121	159,001	341,384	470,000
1959	25,260	286,098	186,930	498,288	575,000
1960	42,902	364,810	199,280	606,992	670,000
1961	34,942	445,238	196,082	676,262	796,000
1962	44,237	541,917	196,042	782,196	1,019,000
1963	37,658	702,644	175,684	915,986	1,135,000
1964	57,373	789,512	206,681	1,053,566	1,293,000
1965	77,762	977,611	304,743	1,360,116	1,711,200
1966	73,015	1,083,310	287,578	1,443,903	1,800,000
1967				1,708,798	2,090,798
1968				1,769,267	2,290,267
1969				1,834,301	2,462,301
1970				1,948,871	2,622,871

a. Adjusted to include estimated nonreported total.

Note: The unit total for metal does not correspond with that under metal cans because the reporting and data gathering approaches differ somewhat between the Can Manufacturers Institute and CSMA.

Source: 1951-1954 Containers & Packaging, U.S. Department of Commerce; Autumn 1960, Table 24, p. 25.
1955-1966 The Role of Packaging in Solid Waste Management, Midwest Research Institute, U.S. Department of Health, Education, and Welfare, 1969, Table 31, p. 56.
1967-1970 Containers & Packaging, U.S. Department of Commerce, July 1971, Table 4, p. 8.
Chemical Specialties Manufacturers Association, Inc. Aerosol and Pressurized Products Survey, Annual reports for 1958-66, New York

TABLE C-9 - CONSUMPTION OF AEROSOL CONTAINERS BY END USE: 1953-1966

End use	1951[c]	1952	1953[d]	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964[e]	1965	1966	1967	1968	1969	1970[f]
Insect sprays:																				
Space insecticides................	15,529	32,128	38,950	30,091	38,927	34,949	25,882	22,318	38,751	37,118	36,526	28,616	19,125	24,714	23,087	21,730	16,035	21,181	20,495	22,281
Residual insecticides.............	1,790	3,711	8,286	13,088	17,048	17,297	15,727	19,982	27,160	20,350	27,067	20,781	24,471	17,111	10,823	22,555	15,567	10,969	13,619	17,832
Total..........................								42,300	65,911	67,468	63,593	49,397	43,596	79,825	83,910	91,285	91,602	92,150	100,114	105,113
Coatings and finishes:																				
Finishes..........................	2,733	6,721	10,617	9,558	9,247	22,557	36,528	30,123	52,556	67,207	76,785	88,805	112,755	120,738	124,734	128,261	164,873	196,099	172,890	143,921
Coatings..........................													11,416	19,088	11,193	10,833	14,408	12,917	20,079	18,290
Total..........................	2,733	6,721	10,617	9,558	9,247	22,557	36,528	30,123	52,556	67,207	76,785	88,805	124,171	149,826	152,927	161,094	195,281	214,016	224,969	230,211
Household products:																				
Room deodorants and disinfectants..	7,287	12,410	15,770	17,203	32,110	35,312	41,989	49,780	59,724	66,755	64,591	61,094	77,659	54,921	88,052	85,195	84,548	90,002	55,891	70,058
Cleaners..........................							11,228	3,667	18,470	17,678	25,585	23,189	40,125	70,281	61,146	78,895	80,478	74,120	87,396	118,801
Waxes and polishes................									11,843	40,204	17,032	17,604	14,961	17,740	24,491	24,652	42,095	27,606	30,950	28,188
Starches and laundry products......	219	3,100	11,246	9,192	13,023	29,493				19,796	46,351	54,408	78,182	103,938	128,687	147,652	176,567	150,258	153,580	138,252
All other household products.......							14,528	22,210	47,296	32,380	25,645	26,519	20,760	27,509	9,386	11,711	14,070	9,801	10,141	23,060
Total..........................								75,657	137,333	176,813	179,204	182,814	231,687	386,388	486,762	531,105	577,758	571,787	600,958	623,359
Personal products:																				
Shaving lather....................		16,682	24,299	42,295	45,387	42,068	50,868	45,314	72,611	68,174	82,353	79,995	84,567	104,351	92,908	106,156	122,335	125,192	122,446	119,289
Hair spray........................			15,120		53,790	79,641	94,432	92,594	79,687	111,861	140,216	225,217	253,052	270,205	423,687	391,451	427,122	434,273	452,856	469,062
Medicinals........................	3,649		831	1,134	1,455	2,275	5,799	7,130	10,036	11,777	18,038	31,301	37,782	28,618	35,027	37,424	41,050	40,583	46,377	48,948
Colognes and perfumes.............		8,767				8,769	17,881	13,563	34,077	39,021	47,465	44,222	30,926	47,643	63,917	66,300	83,597	58,579	77,417	76,243
Personal deodorants...............												37,985	33,189	76,108	157,265	171,973	209,823	301,879	316,117	386,307
Other personal products...........			3,780	40,379	14,221	7,629	5,984	20,241	23,483	12,866	16,526				32,856	18,438	34,527	36,220	48,868	66,121
Total..........................								178,842	219,894	243,699	304,598	418,720	439,517	606,925	905,660	890,742	1,000,454	1,174,726	1,288,081	1,379,970
Animal products: Veterinarian and pet products.......								3,002	4,113	4,711	7,145	6,348	7,560	6,514	8,785	8,423	9,286	10,336	8,723	11,445
Total..........................								3,002	4,113	4,711	7,145	6,348	7,560	6,514	8,785	8,423	9,286	10,336	8,723	11,445
Automotive: All types of products...											(b)	(b)	30,277	28,723	26,786	20,337	29,544	37,958	44,279	42,303
Total..........................													30,277	28,723	29,786	23,337	39,544	44,958	44,279	57,303
Industrial products: Oils, greases, etc...........														10,095	14,052	18,691	19,617	21,688	32,405	45,254
Total..........................														10,095	16,052	20,691	20,617	24,688	38,405	45,254
Food products: All types...........														21,543	49,773	34,558	67,536	45,926	51,352	36,346
Total..........................														71,543	89,773	69,558	100,536	85,926	88,352	90,346
Miscellaneous......................	2,977	13,100	2,616	6,422	11,576	13,200	18,645	11,460	18,013	28,927	33,472	35,787	35,643	4,826	21,568	18,588	48,165	27,128	18,159	21,614
Total for all categories too revealing to be released..........									466	18,166	11,465	327	3,535	20,445	1,666	20,006	7,555	36,522	50,261	58,256
Total..........................								11,460	18,479	47,093	44,937	36,114	39,178	25,271	27,234	38,594	55,720	71,650	68,420	79,870
Reported Total..................	34,184	96,619	131,515	169,362	236,784	293,190	339,491	341,384	498,286	606,991	676,262	782,198	915,986	1,075,109	1,409,889	1,443,829	1,708,798	1,769,267	1,834,301	1,948,871
Grand total, adjusted...........								513,000	625,000	730,000	856,000	1,083,000	1,202,000	1,365,110	1,800,889	1,834,829	2,090,798	2,290,267	2,462,301	2,622,871

a. Categories may not total due to figure having been adjusted to include nonreported data.
b. Included in miscellaneous.
c. (1951-1952), U.S. Department of Commerce, Containers & Packaging, Autumn 1960, Table 24, p. 25.
d. (1953-1957), Ibid., August, 1964, Table 12, p. 18.
e. (1964-1969), Ibid., July, 1970, Table 3, p. 5.
f. 1970, Ibid., July, 1971, Table 4, p. 8.
Source: Chemical Specialties Manufacturers Association, Inc., Aerosol and Pressurized Products Survey, Annual reports for 1958 - 1966, New York.

TABLE C-10 - NUMBER OF AEROSOL CANS CONSUMED IN MINNESOTA[e]

(In thousands of units)

	1958	1960	1963	1966	1970	1973	1976
U.S. Population	174,149[a]	179,992[b]	188,658	195,923	203,166[c]	211,530[d]	219,239
Over 6 oz.	171,121	364,810	702,644	1,083,310	1,698,290	1,994,202	2,341,675
6 oz. and less	159,001	199,280	175,684	287,578			
	330,122	564,090	878,328	1,370,888	1,698,290	1,994,202	2,341,675[e]
Per capita consumption	1.93	3.13	4.66	7.00	8.36	9.43	10.68
Minnesota population	3,313[f]	3,414	3,531	3,617	3,805	3,903	3,975[g]
Estimated Minnesota consumption	6,394	10,686	16,454	25,319	31,810	36,805	42,453

a. U.S. Bureau of the Census, Statistical Abstract of the United States: 1970, Washington, D.C., 1970, No. 2, p. 5.
b. (1960-1966) Ibid., p. 12.
c. U.S. Bureau of the Census, Current Population Reports, op. cit. (Table C-2, note b).
d. Ibid., (Table C-2, note c).
e. Extrapolated from Darnay and Franklin, The Role of Packaging in Solid Waste Management, op. cit., (Table C-2, note d) using rate of increase of 5.5%, p. 57.
f. Minnesota Department of Health, Section of Vital Statistics, op. cit., (Table C-2, note e).
g. Ibid., Table 6-A, Projection 2, p. 111. Using the projection estimate for 1975.

Beverage Containers

TABLE C-11 - SHIPMENTS OF BEER AND SOFT DRINK CONTAINERS: 1958-1970

In millions of units

Type of Container	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967[b]	1968	1969	1970	(1970)[c]	(1970)[d]	1973	1976	1966 to 1976 rate of change (percent)
Beer:																		
Market Share (percent)																		
Metal Cans.	36.8	38.2	39.5	37.8	37.8	37.9	42.3	43.4	46.7	44.7	48.8	48.4	51.5	(50.0)	(53.0)	52.3	55.1	3.9
Returnable Bottles[a] . .	57.7	55.6	51.8	50.2	48.0	46.4	40.7	38.7	35.1	36.5	32.2	31.7	28.7	(29.3)	(25.0)	25.1	20.0	-2.2
Nonreturnable Bottles .	5.5	6.2	8.7	12.0	14.2	15.7	17.0	17.9	18.2	18.8	19.0	19.9	19.8	(20.7)	(22.0)	22.6	24.9	5.5
Soft Drink:																		
Market Share (percent)																		
Metal Cans.	1.4	1.7	2.8	4.0	5.3	6.4	8.1	10.4	14.9	18.2	24.4	24.5	26.6	(22.5)	(31.0)	29.0	37.8	11.8
Returnable Bottles[a] . .	98.0	97.7	96.4	94.7	93.2	91.9	90.1	86.9	79.6	72.8	64.3	62.0	56.1	(62.5)	(45.0)	49.8	32.2	-4.8
Nonreturnable Bottles .	.6	.6	.8	1.3	1.5	1.7	1.8	2.7	5.5	9.0	11.3	13.5	17.3	(15.0)	(24.0)	21.2	30.0	21.2

a. Calculated as a percent of total fillings (not based on returnables produced any one year).
b. Darnay and Franklin, Salvage Markets, op. cit., (footnote 12, Chapter 2), Table 45, pp. 71-3.
c. Darnay and Franklin, The Role of Packaging in Solid Waste Management, op. cit., Table 26, p. 44, 1967 estimate for 1970, '73, '76.
d. U.S. Department of Commerce, Containers and Packaging, January, 1971, pp. 6-7.
Source: (1958-66) Darnay and Franklin, The Role of Packaging in Solid Waste Management, op. cit., (Table C-7, note b), Table 26, p. 44.

TABLE C-12 - NUMBER OF RETURNABLE BEER CONTAINERS PRODUCED/YEAR vs. NUMBER OF NON-RETURNABLE BEER CONTAINERS: 1958-1967[a]

In millions of units

Type of Container	1958	1960	1963	1966	1970	1973	1976
Beer							
Metal Cans	8,337	8,888	9,324	12,947	15,100	16,930	19,000
Bottles	1,627	2,377	4,239	5,608	6,760	7,800	9,060
Returnable	388	431	388	577	530	490	460
Nonreturnable	1,239	1,946	3,851	5,031	6,230	7,310	8,600
Percent returnable	23.8	18.1	9.2	10.3	7.8	6.3	5.1
Percent Nonreturnable	76.2	81.9	90.8	89.7	92.2	93.7	94.9
TOTAL Beer Containers	9,964	11,265	13,563	18,555	21,860	24,730	28,060
Percent Metal Cans	83.7	78.9	68.7	69.8	69.1	68.5	67.7
Percent Returnable Bottles	3.9	3.8	2.9	3.1	2.4	2.0	1.6
Percent Nonreturnable Bottles	12.4	17.3	28.4	27.1	28.5	29.6	30.6

a. Adapted from Darnay and Franklin, The Role of Packaging in Solid Waste Management, op. cit., (Table C-7, note b), Table 26, p. 44.

TABLE C-13 - NUMBER OF RETURNABLE SOFT DRINK CONTAINERS PRODUCED/YEAR vs.
NUMBER OF NON-RETURNABLE SOFT DRINK CONTAINERS: 1958-1967[a]

In millions of units

Type of Container	1958	1960	1963	1966	1970	1973	1976
Soft Drink							
Metal Cans	409	812	2,058	5,612	9,000	12,300	17,000
Bottles	1,432	1,656	2,332	3,902	7,600	10,400	14,700
Returnable	1,240	1,407	1,772	1,922	1,600	1,400	1,200
Nonreturnable	192	249	560	1,980	6,000	9,000	13,500
Percent Returnable	86.6	85.0	76.0	49.3	21.1	13.5	8.2
Percent Nonreturnable	13.4	15.0	24.0	50.7	78.9	86.5	91.8
TOTAL Soft Drink Containers	1,841	2,468	4,390	9,514	16,600	22,700	31,700
Percent Metal Cans	22.2	32.9	46.9	59.0	54.2	54.2	53.6
Percent Returnable Bottles	67.4	57.0	40.4	20.2	9.6	6.2	3.8
Percent Nonreturnable Bottles	10.4	10.1	12.8	20.8	36.2	39.6	42.6

a. Adapted from Darnay and Franklin, The Role of Packaging in Solid Waste Management, op. cit., (Table C-7, note b), Table 26, p. 44.

TABLE C-14 - ESTIMATED NUMBER OF RETURNABLE BEVERAGE CONTAINERS PRODUCED/YEAR vs. NUMBER OF NON-RETURNABLE BEVERAGE CONTAINERS: 1958-1967[a]

In millions of units

Type of Container	1958	1960	1963	1966	1970	1973	1976
Metal Cans							
Beer	8,337	8,888	9,324	12,947	15,100	16,930	19,000
Soft Drink	409	812	2,058	5,612	9,000	12,300	17,000
TOTAL Beverage Cans	8,746	9,700	11,382	18,559	24,100	29,230	36,000
Nonreturnable Bottles							
Beer	1,239	1,946	3,851	5,031	6,230	7,310	8,600
Soft Drink	192	249	560	1,980	6,000	9,000	13,500
TOTAL Nonreturnable Bottles	1,431	2,195	4,411	7,011	12,230	16,310	22,100
Returnable Bottles							
Beer	388	431	388	577	530	490	460
Soft Drink	1,240	1,407	1,772	1,922	1,600	1,400	1,200
TOTAL Returnable Bottles	1,628	1,838	2,160	2,499	2,130	1,890	1,660
TOTAL Nonreturnable Bottles and Cans	10,177	11,895	15,793	25,570	36,330	45,540	58,100
TOTAL Beverage Containers	11,805	13,733	17,953	28,069	38,460	47,430	59,760
Percent Returnable Bottles	13.8	13.4	12.0	8.9	5.5	4.0	2.8
Percent Nonreturnable Bottles	12.1	16.0	24.6	25.0	31.8	34.4	37.0
Percent Cans	74.1	70.6	63.4	66.1	62.7	61.6	60.2

a. Adapted from Darnay and Franklin, The Role of Packaging in Solid Waste Management, op. cit., (Table C-7, note b), Table 26, p.44.

TABLE C-15 - DISTRIBUTION OF GLASS CONTAINER SHIPMENTS BY END USE: 1958-1976

Percent of Total Units

End Use	1958[b]	1959	1960	1961	1962	1963	1964	1965	1966	1967[c]	1968	1969	1970	(1970)[d]	1973	1976
Food Total[a]	42.9	41.5	41.3	40.5	40.6	39.7	39.5	39.1	36.7	36.0	35.0	32.9	31.5	32.9	30.7	27.9
Beverage, Total	25.0	26.3	27.7	30.3	32.5	35.1	36.6	37.7	40.9	44.7	48.2	51.0	54.1	48.8	53.3	58.6
Wine	3.2	3.3	3.3	3.1	2.9	3.0	2.9	2.8	2.6	2.5	2.6	2.7	2.6	7.8	7.3	6.7
Liquor	6.7	6.9	6.4	6.4	6.2	6.2	6.1	6.0	6.0	6.0	5.4	5.6	4.8	----	----	----
Beer, Total	8.0	8.6	10.6	13.4	15.2	16.7	18.0	18.5	19.1	19.5	20.2	20.3	20.2	19.3	19.7	19.8
Beer, Returnable	1.9	2.0	1.9	1.6	1.4	1.5	1.6	1.8	2.0	1.9	1.5	1.3	0.9	1.5	1.2	1.0
Beer, Nonreturnable	6.1	6.6	8.7	11.8	13.8	15.2	16.4	16.7	17.1	17.6	18.7	19.0	19.3	17.8	18.5	18.8
Soft Drink, Total	7.1	7.5	7.4	7.4	8.2	9.2	9.6	10.4	13.2	16.7	20.0	22.4	26.5	21.7	26.3	32.1
Soft Drink, Returnable	6.1	6.5	6.3	5.7	6.3	7.0	7.2	6.8	6.5	5.8	5.5	4.5	4.3	4.6	3.5	2.6
Soft Drink, Nonreturnable	1.0	1.0	1.1	1.7	1.9	2.2	2.4	3.6	6.7	10.9	14.5	17.9	22.2	17.1	22.8	29.5
Drug and Cosmetic, Total	23.9	23.3	22.5	21.8	21.4	20.2	19.9	19.7	19.6	16.8	14.8	14.3	13.0	16.5	14.7	12.6
Medicinal and Health	14.8	14.3	13.5	13.2	13.1	12.2	12.0	12.0	11.7	9.9	9.0	9.3	8.5	10.2	9.2	8.0
Toiletry and Cosmetic	9.1	9.0	9.0	8.6	8.3	8.0	7.9	7.7	7.9	6.9	5.8	5.0	4.5	6.3	5.5	4.6
Chemical, Household, and Industrial	8.2	8.9	8.5	7.4	5.5	5.0	4.0	3.5	2.8	2.5	2.0	1.8	1.4	1.8	1.3	0.9

a. Includes dairy products.
b. (1958-66) Darnay and Franklin, Role of Packaging in Solid Waste Management, op. cit., (Table C-7, note b), Table 24, p. 40.
c. (1967-70) Darnay and Franklin, Salvage Markets, op. cit., Table 44, pp. 72-72.
d. (1970-76) Darnay and Franklin, Role of Packaging in Solid Waste Management, op. cit., (Table C-7, note b), Table 24, p. 40. 1967 estimate for 1970-76.

Note: U.S. Department of Commerce, Containers & Packaging, January, 1972, p. 6 gives food total as 31.0% in 1970, '71 and '72.

TABLE C-16 - BEER AND SOFT DRINK CANS -- PERCENT OF TOTAL CAN PRODUCTION[a]

(Millions of Cans)

	1958	1959	1960	1961	1962	1963	1964	1965	1966	1970	1973	1976
TOTAL Beer and Soft Drink Cans	8,746	9,704	9,700	9,986	10,726	11,382	13,691	15,223	18,559	24,100	28,230	36,000
TOTAL Metal Cans	43,290	44,674	44,373	45,592	48,161	45,903	49,124	50,464	54,436	62,210	69,300	78,270
PERCENT Of Total Production	20.2	21.7	21.9	21.9	22.3	24.8	27.9	30.2	34.1	38.7	40.7	46.0

a. Adapted from Darnay and Franklin, Role of Packaging in Solid Waste Management, op. cit., (Table C-7, note b) Table 30, p. 51.

TABLE C-17 - ESTIMATED PER CAPITA BEVERAGE CONTAINER USE

	1958	1960	1963	1966	1970	1973	1976
Population[a] (in thousands)	174,149	179,992	188,658	195,923	203,166	211,530	219,239
Metal Cans (in millions of units)	8,746	9,700	11,382	18,559	24,100	29,230	36,000
Metal Can Per Capita Use	50.2	53.9	60.3	94.7	118.6	138.2	164.2
Nonreturnable Bottles (in millions of units)	1,431	2,195	4,411	7,011	12,230	16,310	22,100
Nonreturnable Bottles Per Capita Use	8.2	12.2	23.4	35.8	60.2	77.1	100.8
TOTAL Per Capita Use of Nonreturnables	58.4	66.1	83.7	130.5	178.8	215.3	265.0
Returnable Bottles (in millions of units)	1,628	1,838	2,160	2,499	2,130	1,890	1,660
Returnable Bottle Per Capita Use	9.3	10.2	11.4	12.8	10.5	8.7	7.6
TOTAL Per Capita Beverage Container Use	67.7	76.3	95.1	143.3	189.3	224.0	272.6

a. U. S. Bureau of the Census, op. cit., (Table C-2, notes a-c).

TABLE C-18 - ESTIMATED CONSUMPTION OF BEVERAGE CONTAINERS IN MINNESOTA

(in thousands of units)

	1958	1960	1963	1966	1970	1973	1976
Minnesota Population[a]	3,313	3,414	3,531	3,617	3,805	3,903	3,975
Metal Beverage Cans Per Capita	50.2	53.9	60.3	94.7	118.6	138.2	164.2
TOTAL Beverage Cans Consumed	166,313	184,015	212,919	342,530	451,273	539,395	652,695
Nonreturnable Beverage Bottles Per Capita	8.2	12.2	23.4	35.8	60.2	77.1	100.8
TOTAL Nonreturnable Beverage Bottles Consumed	27,167	41,651	82,625	129,489	229,061	300,921	400,680
TOTAL Nonreturnable Beverage Containers Consumed	193,480	225,666	295,544	472,019	680,334	840,316	1,053,375
Returnable Bottles Per Capita	9.3	10.2	11.4	12.8	10.5	8.7	7.6
TOTAL Returnable Bottles Consumed	30,479	34,823	40,253	46,298	39,952	33,956	30,210
TOTAL Beverage Containers Consumed	223,959	260,489	335,797	518,317	720,286	874,272	1,083,585

a. Minnesota Department of Health, Section of Vital Statistics, op. cit., (Table C-2, notes e & f).

Energy Savings

Total U.S. consumption in equivalent barrels of oil in 1971 was 11.899 billion barrels.[e]

Energy consumption in beverage industry was .34 percent[f] of total consumption or the equivalent of:

$$\begin{array}{r} 11.899 \\ \underline{\times\ .0034} \\ 40.46 \end{array}$$ million barrels of oil in 1971

Assuming each barrel of oil contains $(5.8)(10^6)$ Btu,[g] total Btu consumed by the beverage industry would be:

$$[(5.8)(10^6)]\ [(40.46)(10^6)] = \underline{234.67\ (10^{12})\ \text{Btu}}$$

Roughly 40 percent of total resource energy is natural gas[h] or $93.87(10^{12})$ Btu. One cubic foot of natural gas contains roughly 1,000 Btu.

Total natural gas consumed by the beverage industry would be on the order of:

93,870,000,000 cubic feet

A nationwide ban on non-returnables would reduce energy consumption in the beverage industry by 55 percent.[i] This would represent a savings in equivalent barrels of oil of:

22.25 million barrels/year

or $129.05(10^{12})$ Btu.

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e. Office of Emergency Preparedness, The Potential for Energy Conservation, October 1972, p. iv.
f. Hannon, op. cit., p. 347.
g. Office of Emergency Preparedness, op. cit., p. 1.
h. Hannon, op. cit., p. 344.
i. Ibid., p. 347.

Roughly 40 percent of this saving in resource energy would be for natural gas or:

51,620,000,000 cubic feet

From a per capita viewpoint, a nationwide ban would reduce energy consumption by the equivalent of:

$$\frac{(22.25)(10^6)(55)}{203.166(10^6)^j} = 6.02 \text{ gallons per person per year}$$

as compared to the overall per capita consumption of energy equivalent to 58.57 barrels/person/year.

In Minnesota a ban on non-returnable beverage containers would save roughly the equivalent of:

$$(6.02)(3,805,000) = 22,900,000 \text{ gallons of oil/year}$$

Assuming 40 percent of this resource energy is for natural gas, a ban on non-returnables would save:

$$\frac{(3.805)(10^6)(22.25)(10^6)(5.8)(10^6)(.40)}{(203.166)(10^6)(10^3)} =$$

966,800,000 cubic feet of natural gas

A nationwide ban on non-returnables would represent an energy saving equivalent to:

$$\frac{22.25}{222.851} = 9.98\% \text{ of Minnesota's total energy consumption per year}$$

By comparison the coal equivalent used to generate electrical power in the U.S. in 1969 was apparently 520,000,000 tons[k] or $(520.00)(10^6)(25)(10^6) = 13.00\ (\times 10^{15})$ Btu

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j. 1970 U.S. population.

k. Culberson, Oran L., <u>The Consumption of Electricity in the United States</u>, Oak Ridge National Laboratory, ORNL-NSF-EP-5, June, 1971, Table 12, p. 25.

For Minnesota this represents roughly

$$(520)(10^6)(25)(10^6)(.018728527) =$$

$$243.47(10^{12}) \text{ Btu}$$

The potential energy saving from a nationwide ban on non-returnables using Minnesota as 1.873 percent of national consumption would be equivalent to

$$\frac{129.05}{243.47} = .53$$ or 53 percent of the energy used to generate electricity in Minnesota in 1970

More local estimates of 1970 Minnesota power consumption made for the State Planning Agency by the Center for the Study of Local Government at St. John's University shows 1970 demand at $23.5(10^9)$ kwh.[l] Assuming 30 percent efficiency for electrical power generation facilities, total Btu consumed for electricity would be on the order of $267.352(10^{12})$ Btu. If this were the case, the total energy saving nationwide from an all returnable system would be equivalent to $\frac{129.05}{267.352} = .4827$ or 48.3 percent of the energy used to generate electricity in Minnesota.[m] Using 50 percent as a rough approximation, the savings resulting from nationwide all returnable system would be equivalent to the annual power generated by 4.4 plants the size of the Alan S. King or Monticello facilities (550 MW).[n]

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l. Center for the Study of Local Government, St. John's University, The Impact of Future Electrical Power Requirements on the State of Minnesota for the Minnesota State Planning Agency, January 15, 1970, Fig. 2, p. 4.

m. Using 40 percent efficiency it would be $\frac{129.05}{200.51375} = .6436$ or 64.4 percent.

n. Center for the Study of Local Government, op. cit., Figure 2, p. 4, gives total demand for electrical power in Minnesota in 1970 as 4801 Mw.

Mineral Conservation

TABLE C-19 - SUMMARY OF THE ESTIMATED MATERIALS USED TO PRODUCE BEVERAGE CONTAINERS, 1969[a]

Type of Material	Total U.S. production of material (thousand tons)	U.S. Production of beverage containers (thousand tons)	Percent of U.S. production used for beverage containers
Glass	13,150	5,908	44.9
Steel	93,900	1,886	2.0
Aluminum	4,020	226	5.6

a. Bingham, Tayler H. and Paul F. Mulligan, The Beverage Container Problem, Research Triangle Institute, Prepared for Office of Research and Monitoring, U.S. Environmental Protection Agency, September, 1972, Table 4, p. 14.

TABLE C-20 - ESTIMATED MINERAL CONSERVATION RESULTING FROM AN ALL RETURNABLE SYSTEM IN MINNESOTA, 1969

Type of Material	U.S. Production of beverage containers in tons	Minnesota share of consumption of beverage containers in tons[a]	Minnesota minerals conserved under an all returnable system in tons[b]
Glass	5,908,000	110,650	74,140
Steel	1,886,000	35,320	23,660
Aluminum	226,000	4,230	2,830[c]

a. Using ratio of Minnesota population to national population in 1970. $\frac{(3.805)(10^6)}{(203.166)(10^6)} = .0187285274$

b. Reduction in material use is estimated to be roughly 67 percent of present consumption. (See p. C-37.)

c. This figure is probably too high for Minnesota because all-aluminum beverage containers are not marketed here in any significant quantity.

TABLE C-21 - TRENDS IN CONSUMPTION OF STEEL FOR METAL CANS[a]

	1971[b]	1970	1969	1968	1967	1966	1965	1964	1963	1962
Base boxes in thousands	139,339	143,064	140,248	136,046	126,141	123,477	116,583	112,271	108,593	112,714
Tons equivalent in thousands of tons[c]	5,508	5,655	5,588	5,508	5,149	5,061	4,858	4,737	4,621	4,858

a. Bureau of the Census, U.S. Department of Commerce, Bureau of Domestic Commerce, Containers and Packaging, October, 1971, p. 18.
b. Bureau of the Census, U.S. Department of Commerce, Bureau of Domestic Commerce, Containers and Packaging, January/ April, 1972, p. 20.
c. Derived by using the factor 25.3 base boxes/short ton of steel for 1970 and 1971, and 25.1 for 1969, 24.7 for 1968, 24.5 for 1967, 24.4 for 1966, 24.0 for 1965, 23.7 for 1964, 25.5 for 1963,and 23.2 for 1962.

TABLE C-22 - THE CONSUMPTION OF IRON FOR METAL CONTAINERS

As Compared with Other End Uses with Forecasts of Demand in the Year 2000[a]

(million short tons)

End Use	Demand 1968	U.S. Forecast Base 2000	Demand in Year 2000 United States Low	Demand in Year 2000 United States High
Containers	7.9	12.0	10.0	14.0
Transportation:				
Aircraft	.6	.1	--	.2
Shipbuilding	1.5	3.5	2.3	4.6
Rail transport	4.5	14.0	8.2	17.1
Automotive	23.5	40.6	29.0	57.0
TOTAL	30.1	58.2	39.5	78.9
Construction products	32.0	59.4	37.2	68.4
Home appliances and equipment	6.1	8.2	6.9	10.4
Machinery and equipment:				
Mining	2.0	2.0	1.1	2.6
Agriculture	2.2	7.5	3.8	10.6
Industrial tools and machines	10.2	11.8	9.0	14.3
Electric machinery	7.0	10.6	7.0	21.5
TOTAL	21.4	31.9	20.9	49.0
Pipe, tubes, and equipment (oil and gas)	5.6	8.2	5.9	11.4
Other	16.9	15.8	11.7	21.5
Total iron by end use	120.0	--	132.1	253.6
Adjusted range	--	--	162.0	221.0
			(Median 192)	

a. The total demand in the rest of the world in 2000 is forecast at between 537 and 758 million short tons (median 648).

Source: Adapted from U.S. Department of Interior, Bureau of Mines, Mineral Facts and Problems, 1970, Table 6, p. 306.

Reduction in Solid Waste

Percentage of Non-Returnable Beverage Containers in Solid Waste

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
REGION V
1 NORTH WACKER DRIVE
CHICAGO, ILLINOIS 60606

November 9, 1972

Ms. Jackie Burke
Minnesota Pollution Control Agency
717 Delaware Street S.E.
Minneapolis, Minnesota 55440

Dear Ms. Burke:

We have assembled the following material in response to your request for information regarding the percentage of non-returnable beverage containers in the municipal solid waste stream.

Following is a breakdown of the percentages of bottles and cans in municipal solid waste using two different information sources. (All figures are in percent by weight of the total municipal solid waste load).

Method A:

Bottles (1)

Food	1.6%		
Beverages	2.7%		
	Returnable	0.25%	
	Non-returnable	2.45%	
		Liquor & wine	0.35%
		Beer & soft drinks	2.10%
Other:	0.7%		
Total:	5.0%		

(1) Based on a study by the Glass Container Manufacturers Institute which showed that glass containers represent about 5% of municipal solid waste (page 5, Economic Realities of Reclaiming Natural Resources in Solid Waste. Thomas D. Clark, U.S. Environmental Protection Agency, 1971). Percentage breakdown calculated using Table 44, page 71 of Salvage Markets for Materials in Solid Wastes. A. Darnay and W. E. Franklin, Midwest Research Institute, Kansas City, Missouri, U.S. Environmental Protection Agency, 1972.

Cans (2)

Food	2.3%
Beverages	1.7%
Other	0.8%
Total	4.8%

Non-returnable beverage containers (Beer & soft drinks).

Bottles:	2.1%
Cans :	1.7%
Total :	3.8%

(2) Based on a study by the Bureau of Mines which showed that cans represent about 4.8% of municipal solid waste (page 271, Proceedings of the Solid Waste Resources Conference on Design of Consumer Containers for Re-use or Disposal, May 12-13, 1971. G.F. Sachsel, corp. U.S. Environmental Protection Agency, 1972). Percentage breakdown calculated using Table 28, page 47 of The Role of Packaging in Solid Waste Management, 1966 to 1976. A. Darnay and W. E. Franklin, Midwest Research Institute, Kansas City, Missouri. U.S. Public Health Service, 1969.

Method B:

A beverage container study was done by the Research Triangle Institute, (3) to determine the quantity of non-returnable beverage containers in municipal solid waste. Their results were as follows:

Non-returnable beverage containers (Beer & soft drinks).

Bottles:	2.3%
Cans :	1.3%
Total :	3.6%

(3) An Analysis of the Beverage Containers Problem with Recommendations for Governmental Policy. Richard H. Ongerth, Research Triangle Institute. Research Triangle Park, North Carolina. U. S. Environmental Protection Agency, 1972.

Summary:

The total amount of bottles and cans in the municipal solid waste stream is about 9.8%. From the preceeding figures it can be seen that the amount of non-returnable beverage containers is approximately 3.6% to 3.8% of the total municipal solid waste load.

If you have questions regarding this information or if we can be of further assistance, please feel free to contact us.

Sincerely yours,

Patrick E. Lynch

Patrick E. Lynch
Deputy Chief
Solid Waste Management Branch

cc: Mr. Floyd J. Forsberg
Director, Division of Solid Wastes
Minnesota Pollution Control Agency

TABLE C-23 - ESTIMATED SOLID WASTE FROM BEVERAGE CONTAINERS IN MINNESOTA IN 1973

	No. of Units	Approximate Weight Container in Pounds	Total Weight in Pounds	Total Weight in Tons
Metal Cans	539,395,000	(.11)	59,333,450	29,666.7
Throw-away Beverage Bottles	300,921,000	(.6)	180,552,600	90,276.3
Returnable Bottles	33,956,000	(1)	33,956,000	16,978.0
Total Containers	874,272,000	-----	273,842,050	136,921.0

Estimated Solid Waste Reduction Through An All Returnable Beverage Container System in 1973 in Minnesota (assuming 15 returns/bottle)

current total returnables	33,956,000	units
returnables to replace non-returnables	56,021,067	units
Total beverage containers with ban on non-returnables	89,977,067	units
Total weight of beverage containers	89,977,067	pounds
	44,988.5	tons
Total Solid Waste Reduction:		
Estimated current solid waste generated from beverage containers	273,842,050	lbs.
with ban on non-returnables[o]	89,977,067	lbs.
Total Reduction	183,864,983	lbs.
	91,932.5	tons

Solid waste from beverage containers would be reduced by 67.14 percent. This would result in the reduction of solid waste by $\frac{(183,864,983)}{(15)\ (1000)} = 12,257.67$ packer truckloads, assuming 15 cubic yard packer trucks containing 1,000 lbs./cubic yard.

Comparison of Solid Waste Reduction in Minnesota from a Ban on Non-Returnable Beverage Containers vs. Recycling

Reduction in solid waste from bottles and cans by Metropolitan Recycling Center:

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o. Assumes all returnables enter the solid waste stream after 15 trips. In reality, this is not likely to be the case as many returnables will be recycled as cullet by bottlers.

assuming an average of 117,658 lbs./week[p]

or 6,118,216 lbs./year

3,059.1 tons/year

Equivalent number of Metropolitan Recycling Centers necessary to reduce solid waste by an amount equal to the reduction resulting from a ban:

$$\frac{\text{estimated reduction from ban}}{\text{estimated MRC reduction}} \quad \frac{183,864,983 \text{ lbs.}}{6,118,216 \text{ lbs.}} = $$ 30.05 Metropolitan Recycling Centers handling only beverage containers

or: for a Metropolitan Recycling Center assuming 30% of all bottles and cans are beverage containers:

$$\frac{\text{reduction from ban}}{\text{MRC reduction}} \quad \frac{183,864,983 \text{ lbs.}}{1,835,465 \text{ lbs.}} = $$ 100.2 Metropolitan Recycling Centers handling 30% beverage containers

<u>Percent of Minnesota Containers Handled by Metropolitan Recycling Center (assuming an average of 117,658 lbs./week)</u>

Total beverage containers handled by the Metropolitan Recycling Center:

$$\frac{1,835,465}{(273,842,050 - 1,835,465)} =$$

.675 percent of all containers

Containers are an estimated 9.8 percent of all solid waste.

Total Minnesota solid waste:

6,200,000,000 pounds

Solid waste reduction through a ban:

183,864,983 pounds

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p. Highest weekly total from October 16, 1971 to April 30, 1972, Wadham, Sherrill, Project Coordinator, for Metropolitan Recycling Center, a division of Occupational Training Center, Inc., "Progress Report for October 26, 1971 to April 30, 1972," Appendix H, p. 21.

MRC reduction: 6,118,216 pounds

Total bottles and cans handled by the Metropolitan Recycling Center:

$$\frac{6,118,216}{(.098)(6,200,000,000) - (6,118,216)} =$$

1.02 percent of all bottles and cans

Potential for Recycling of Containers After Imposition of a Ban on Non-Returnable Beverage Containers

Equivalent Metropolitan Recycling Centers necessary to recycle remaining containers after imposition of a ban:

$$(.098)(6,200,000,000) - (183,864,983) =$$

423,735,000 lbs./year

of bottles and cans would still be consumed which, if totally recycled, would require:

$$\frac{423,735,000}{6,118,216} = 69.26 \text{ Metropolitan Recycling Centers}$$

Reduction in Solid Waste Disposal Costs (Calculated using two different methods)

Method 1

The cost of collection, transportation, and disposal of solid waste is estimated at $20/ton.

The estimated reduction in disposal costs would be

(20)(91,932.5) = $1.84 million in 1973

assuming all returnables enter solid waste stream after 15 trips

or (20)(119,943) = $2.40 million assuming

no returnable beverage containers enter the solid waste stream.

Method 2

Total cost of solid waste disposal in Minnesota estimated at $62 million.

EPA estimate of percent of non-returnable beverage containers - 3.7 percent.

$$(62{,}000{,}000)(.37) = \$2.3 \text{ million}$$

assuming no returnable beverage containers enter the solid waste stream.

By 1980, this figure may reach

$$(111{,}000{,}000)(.37) = \$4.1 \text{ million}$$

where $62,000,000 is total cost of solid waste disposal for Minnesota in 1970 and $111,000,000 is the projected total cost of solid waste disposal for Minnesota in 1980.[q]

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q. The 1980 estimate assumes no growth in population, inflation or percentage of non-returnables.

Reduction in Litter

TABLE C-24 - DISTRIBUTION AND ESTIMATED NUMBER OF LITTERED BEVERAGE CONTAINERS, 1969

Type of beverage container	Items per mile per month--primary roads	Distribution of littered containers (percent)	Estimated number of littered containers (million)
Cans	193	75.4	1,637
Beer	153	59.8	1,218
Soft drink	40	15.6	419
Bottles	63	24.6	596
Refillable	26	10.2	256
Beer	5	2.0	45
Soft drink	21	8.2	211
Nonrefillable	37	14.4	340
Beer	30	11.7	283
Soft drink	7	2.7	57
Total, all types	256	100.0	2,233

Source: Bingham and Mulligan, op. cit., (footnote 144), p. 31. Based on data presented in: Research Triangle Institute, National Study of the Composition of Roadside Litter, 1969.

Reduction in Litter Collection Costs[r]

A Rough Estimation

Assuming that non-returnable beverage containers are 20 percent of litter, their collection required a minimum expenditure of $43 million in 1969 nationwide or

(.01873)(43) = $805,000 for the state of Minnesota

If non-returnable beverage containers are assumed to be 40 percent of litter, their share of collection costs would be $86 million nationwide or

(.01873)(86) = $1.61 million for the state of Minnesota

r. Using national estimates from Bingham and Mulligan, *op. cit.*, pp. 33-34.