I
Summary

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INTRODUCTION

The shortages in many critical metals and other materials that the United States has experienced in recent years, along with its increasing dependence on foreign sour-cm of supply for those materials, has intensified interest in the prospects for making less wasteful and more efficient use of materials. This report explores the kinds and amounts of waste that occur in this Nation's use of eight critical metals and the technical options for reducing that waste. The eight metals studied are: iron, copper, aluminum, manganese. chromium, nickel. tungsten, and platinum. In their 1evels of import dependence and in other respects, these metals are a representative sample of commercially important metals.

Metals are wasted, or lost, in two different ways: 1) amounts of metal are not productively used at various points along the materials cycle, from mining of ore to product disposal, and 2) excess amounts of metal are used in the materials cycle for product manufacture. The study identifies, for each of the eight metals, the levels at which each kind of waste occurs at major points of the materials cycle. In general, the study finds that the greatest waste occurs in product use and disposal rather than in metal extraction and processing or product manufacturing.

Of the many options available to reduce losses and reduce the use of excess metal, the study concluded that product remanufacturing, reuse, and repair (collectively known as product recycling) offer the greatest leverage for saving materials and energy. Product recycling already exists in several areas, such as auto parts, furniture, typewriters, and aircraft. But additional incentives are needed to encourage development of the aftermarket industry necessary for widespread recycling.

Perhaps of even more interest at this time, however, are options to improve materials availability during critical situations, such as import embargos or disruption of transportation facilities or supply shortages. Options considered include the establishment of a governmental contingency planning function, a public data system, a private sector contingency market for essential metals, and research and development on metal substitution.

* * * * *

This study was requested by the Committee on Commerce, Science, and Transportation of the U.S. Senate. The request was prompted by the following three factors:

First, the 1973 OPEC oil embargo demonstrated the risks of U.S. dependence on foreign energy resources and focused attention on the possibility of similar problems with mineral resources for which the United States is also heavily import-dependent. Second, in 1973-74, the increased demand for materials due to economic recovery from the 1969-70 recession led to supply shortages for a wide range of metals, thus generating concern among U.S. industrial consumers about the reliability of future supplies.[1] Third, U.S. per capita consumption of minerals has grown to more than four times the world average, prompting renewed attention on how to reduce consumption through conservation.

The study focused only on metals. Other materials might well have been considered, such as chemicals, wood, and plastics. But at the time this study was initiated, metals were shortest in supply. The eight specific metals selected for detailed analysis are listed in figure 1. The three major criteria used in selecting these metals were: level of import dependence, degree of importance to American industry, and the nature of use (e.g., volume, price, product applications). As a group, the eight constitute a reasonable cross section of commercially important metals. Most are substantially imported, as indicated in figure 1. However, while the group of eight is representative, other metals, such as tin and cobalt, constitute important omissions.

This report does not include detailed discussion of conservation options for recovery of metals from municipal solid waste, the subject of another OTA

[1] See app. C for a detailed discussion.

report—*Materials and Energy From Municipal Waste*, July 1979, OTA-M-93, Nor does this report give detailed consideration to the full range of impacts of conservation options.

Figure 1 .—Metals Selected for Study

Metal	Net import reliance[a]	Typical use
Iron	29%	Base metals used in major components of many manufactured products
Copper	19%	
Aluminum	93%	
Manganese	99%	Used primarily as alloying elements in other basic metals
Chromium	92%	
Nickel	77%	Used both as basic metals and alloying elements
Tungsten	50%	
Platinum[b]	91%	Precious metal used in small amounts in specialized products

[a]Net import reliance = imports minus exports plus adjustments for government and industry stock changes 1978 data from U S Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries 1979* pp 4-5
b Refers to the platinum group metals, which Includes platinum palladium rhodium ruthenium, iridium and osmium
SOURCE OTA based on data from U S Bureau of Mines

TECHNICAL OPTIONS FOR REDUCING WASTE

Technical Options for Reducing Losses From the Materials Cycle

Losses from the materials cycle represent a major potential for waste. A typical materials cycle is shown in figure 2, which illustrates the total flow of a metal beginning with its extraction from the ground and processing of the ore to its manufacture, use. and disposal in the form of products. Losses can occur at each step in the cycle and particularly in the disposal stage where ultimately the product must be either stored, recycled, or discarded.

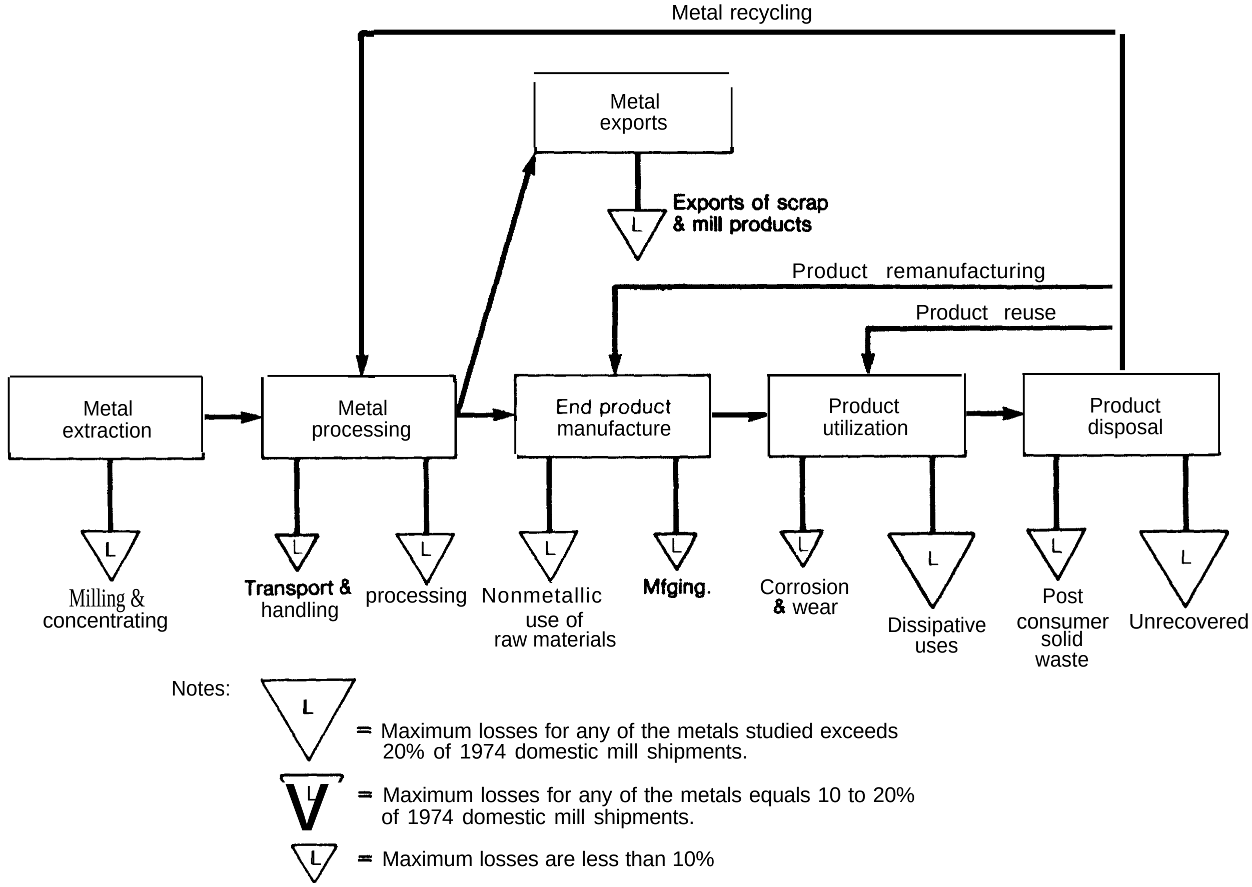
By tracing the flows of the eight metals through the materials cycle—from mining to disposal—the total losses for each metal were identified. Losses were calculated by subtracting the output at each stage of the materials cycle from the input. For example, the losses in processing aluminum were calculated by subtracting the output, mill products (7.2 million short tons) and mill scrap (5.8 million short tons), from the input. The input in this case is the sum of imported ingot and alloy elements, bauxite and alumina, and recycled scrap for a total of 13.4 million short tons. The difference is 0.4 million short tons, which represents the loss of aluminum during processing. All losses were verified through discussion with the appropriate industry. Almost 100 percent of every metal was accounted for.[2]

Figure 3 gives estimates of losses expressed as a percentage of domestic shipments of mill products of the metal (e. g., steel shipped by steel mills). In other words, these loss figures are expressed as a percentage of the amount of mtetal flowing at one place in the cycle, shipments of mill products, which is the traditional industry measure of productive output.

Excluding platinum and manganese, the total losses of the selected metals range from 55 to 78 percent. These losses occur over the life of the products containing the metal, which may range from 1 to 50 years. In reality, losses during mining, processing, and manufacturing occur during the

[2]For a complete discussion of how losses were quantified, see ch III.

Figure 2.—Typical Materials Cycle



The triangles are intended to give only an approximate indication of the relative level of losses. Generalizations are difficult due to the wide variability of losses for individual metals. See figure 3 for metal-specific data.

SOURCE. OTA, based in parrt on data from Working Papers One and Two.

first year. Losses during use and disposal stretch over - the lifetime of the product, from 1 year for cans and 15 years for refrigerators to 50 or more years for buildings.

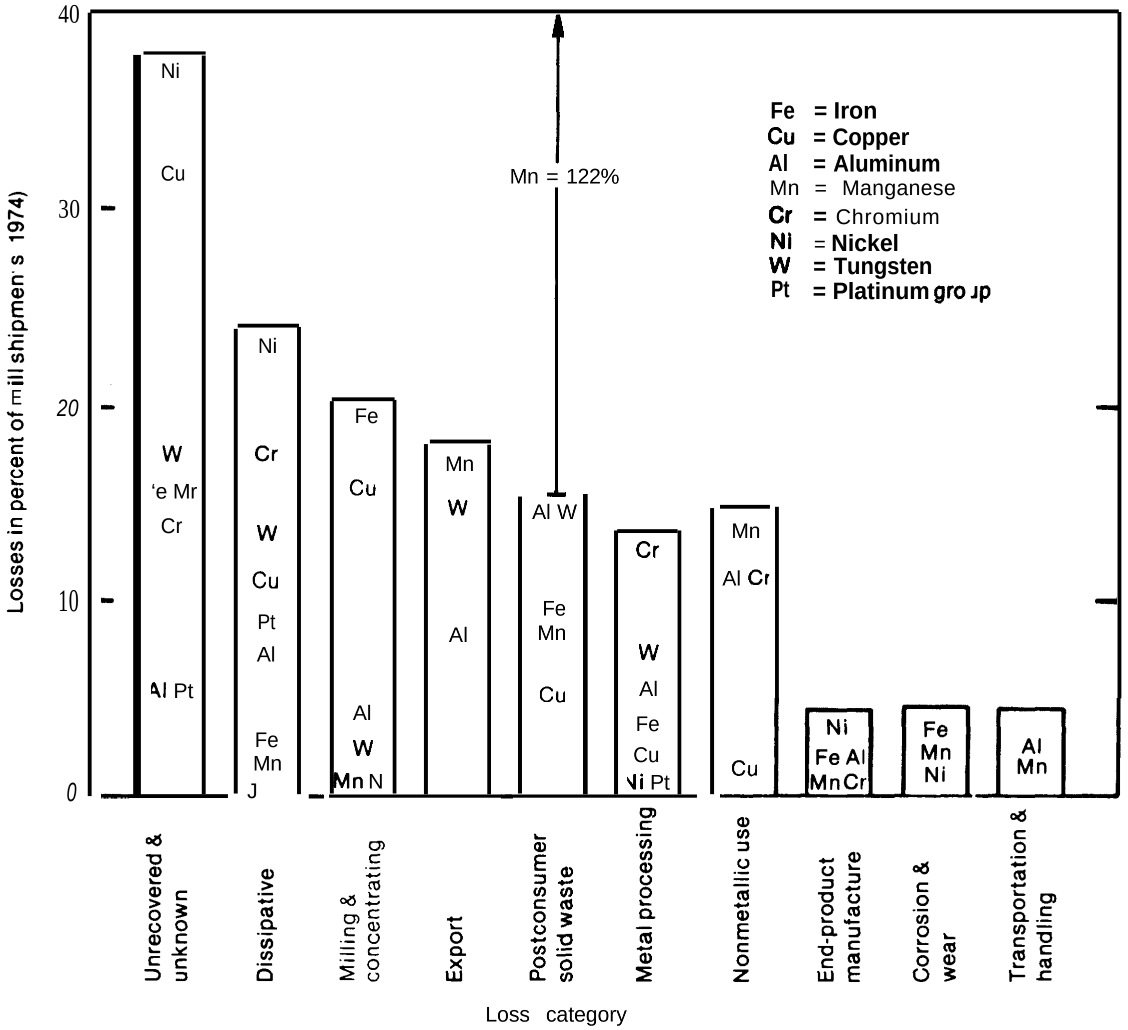
The loss of platinum is only 15 percent, due to the very high recycling rate for this precious metal. on the other hand, the loss of manganese exceeds 1()() percent, due to the primary use of this metal in steel production. More manganese is lost in the steel making process (e.g., as slags) than is contained in the steel products actually shipped.

For each metal the total loss is a sum of a large number of smaller losses that occur at every stage of the materials cycle. This dispersal of losses is a major harrier to effective overall waste reduction. However, some stages of the materials cycle experience greater loss than others, as illustrated in figure 3. The four largest loss categories are:

- Unrecovered metals in obsolete products . . . . 5-37% lost
- Dissipative uses of metals as alloys, powders, pigments (e.g., catalysts, paints, fertilizers) . . . . .4-23 % lost
- Milling and concentrating losses prior to metal smelting . . . . Nil-19X lost
- Metal losses through export of scrap and mill products . . . . 0-17 % lost

The technical conservation options with the greatest leverage in reducing each category of loss are shown in figure 4. The most highly leveraged

Figure 3.—Estimated Metal Losses for Each Loss Category, Expressed as a Percentage of Domestic Mill Shipments (1974)



NOTE See chapter III, tables 20 and 21 for data on which figure 3 is based
SOURCE OTA based on data from Working papers One and Two

options are metal recycling, product remanufacturing and reuse, R&D on substitute materials and processes, and R&D on metal recovery from low-grade ores.

Metal recycling and product remanufacturing have multiple leverage because, in addition to the direct reduction in losses of unrecovered metals in obsolete products, these options lead to an additional savings in future years. For example, if through product recycling an additional 10 percent of obsolete office equipment in a given year is remanufactured, 10 percent less metal will be required for next year's production run (assuming constant demand). This will eliminate the losses (e.g., milling and concentrating that would have been associated with producing that amount of metal.

Technical Options for Reducing Excess Metal in the Materials Cycle

Losses from the materials cycle, as discussed above, represent one of two major classes of waste. The second class of waste is the use of excess metal in the materials cycle. The different types of excess metal usage are shown in figure 5.

Figure 4. —Technical Options for Reducing Losses in the Materials Cycle

Loss category	Range of losses*	Technical conservation option
Unrecovered metals	5-37%	Metal recycling Product remanufacturing and reuse
Dissipative uses	4-23%	R&D on substitute materials and/or processes
Milling & concentrating	Nil-19%	R&D on metal recovery from low-grade ores, e.g. fine particle technology
Exports of scrap & mill products	o-17%	Export controls
Postconsumer solid waste	5-1470	Product recycling
Metal processing	0.5-1 2% (Mn=122%)	Capital replacement Alternative desulfurization process (for Manganese)
Nonmetallic uses of raw materials	Nom-11%	R&D on substitute metals & processes
End-product manufacture	Nil-3%	Improved management controls
Corrosion and wear	Nil-3%	R&D on improved corrosion and wear resistant treatments
Transportation & handling	Nil-3%	Improved management controls

• Range of losses for the eight metals in percent of 1974 domestic mill shipments. See figure 3 and tables 20 and 21 in chapter III for metal-specific data.
Nom = small but undetermined amount of losses.
Nil = amount of losses close to zero.

SOURCE OTA based in part on data from Working Papers One and Two

The seven major products listed in figure 6 were selected as case examples in order to evaluate 25 options for reducing excess metals These products were selected as typical of five major U.S. industries that collectively account for about 60 percent of total metal consumption in the United States.[4] As a group, these products use the selected metals in amounts typical of many metal products. Analysis of additional products was conducted where necessary. For example, office equipment, pipelines, and television sets were included in the analysis of product recycling.

Estimated metal savings for the case examples were then generalized to a whole range of products that contained the metals under evaluation. Thus, if 10 percent of the steel used in automobiles could be saved by a stress-optimized design, that percentage was applied to the amount of steel used in all transportation products.

Figure 7 shows the percent of 1974 domestic mill shipments of each metal that could be saved by each conservation option listed.

These numbers are engineering judgments of the overall conservation potential for the listed options. The numbers are interdependent in that implementation of one option will reduce the savings possible with another option. Also, the percentages shown indicate the savings that are technically possible. Economic and other factors may severely limit the actual savings.

[3]For the complete list of options evaluated, see table 24, ch V

[4]See table 33, ch. VI

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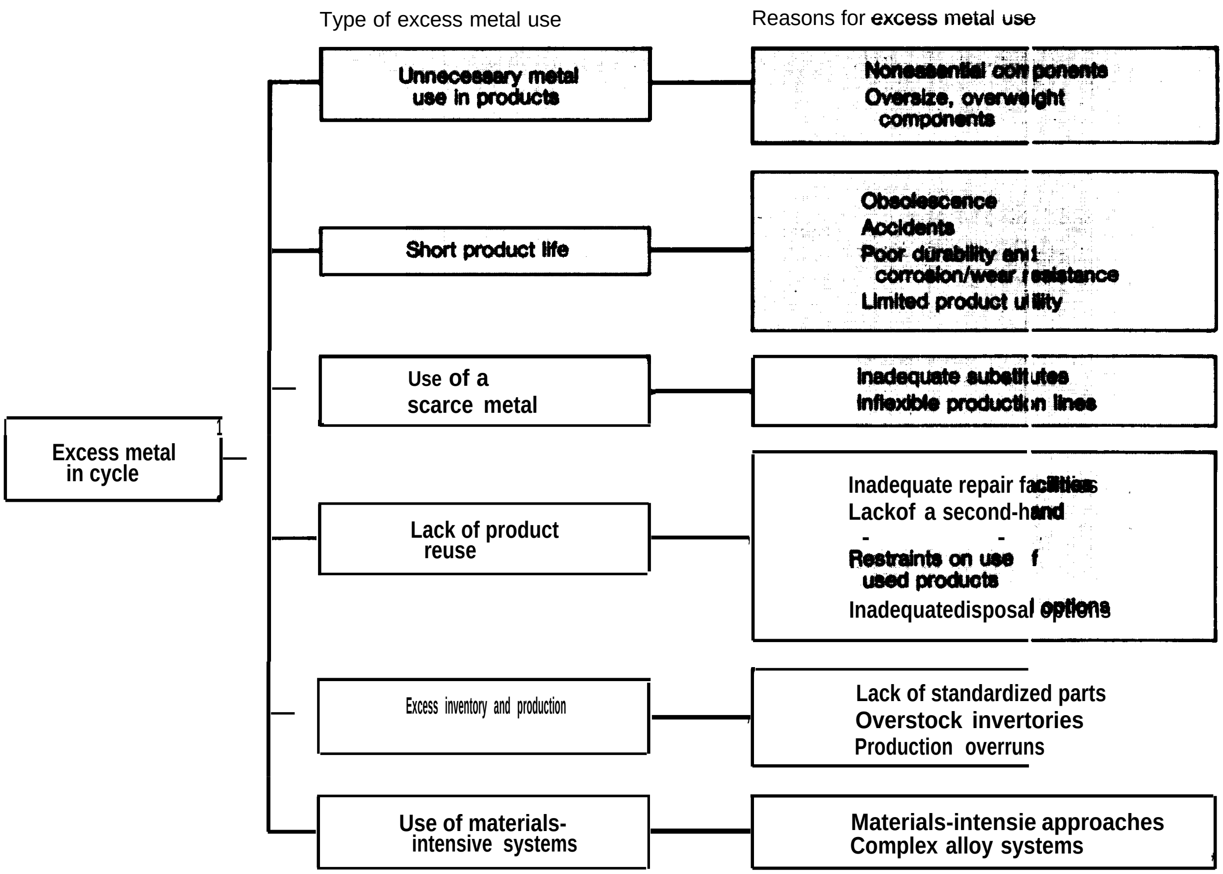
Figure 5.—Classes of Excess Metal in the Materials Cycle



SOURCE OTA

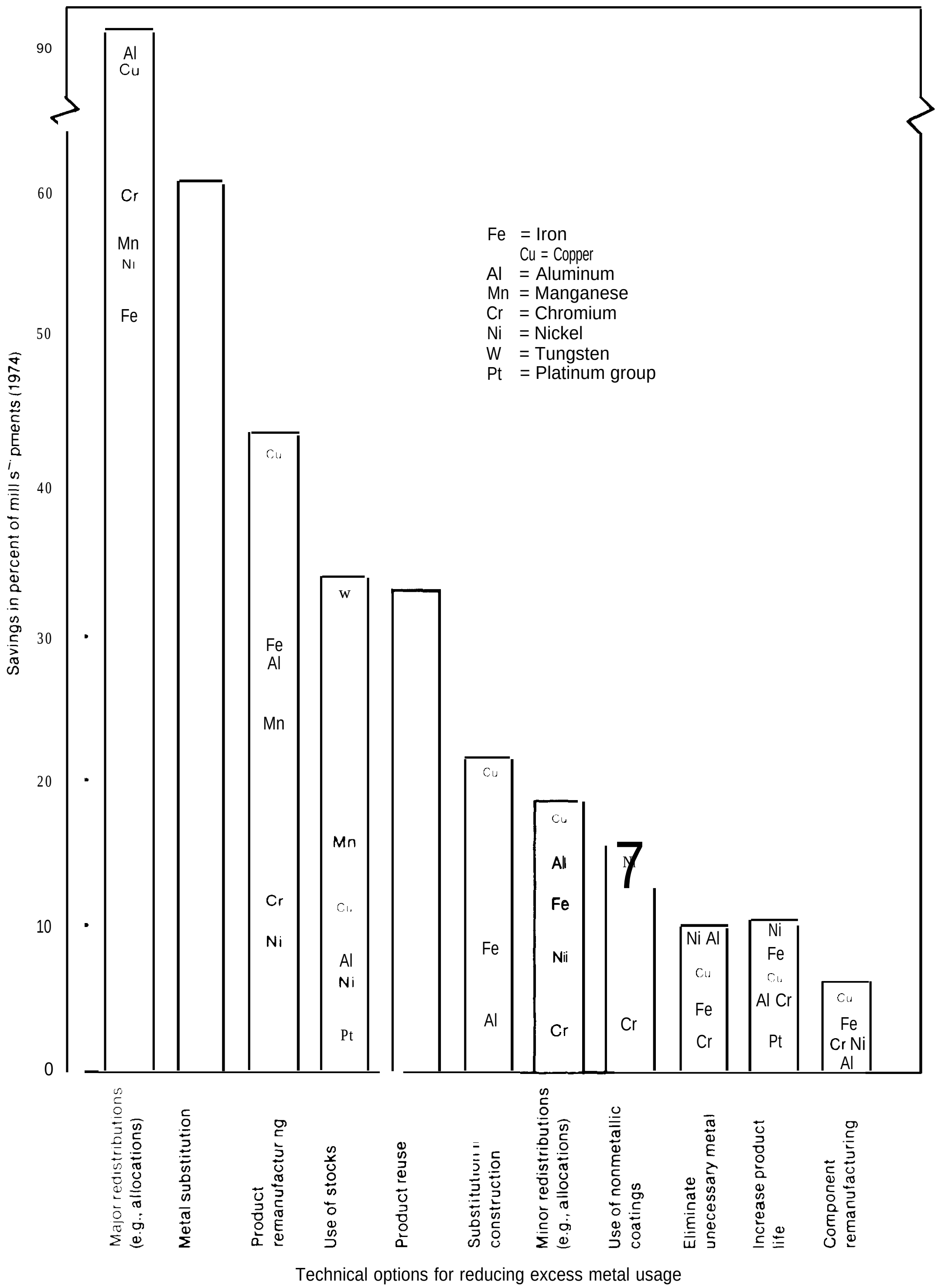
Figure 6.—Products Selected for Study

Product	Industry
Automobile	Transportation
Refrigerator	Appliances
Building	Construction
Bridge	
Lathe	Machinery
Tractor	
Can	Fabricated metal products

Three additional categories have been added to figure 7 for comparison purposes: major redistributions, minor redistributions, and use of stocks. The major redistributions option is based on experience with use of allocations during World War 11. The use of stocks option is based on the amount of metal that went into stocks during 1974. Although 1974 may not be a typical year, these numbers give some basis for comparison. (See pages 10 and 11 for an explanation of these categories).

Metal substitution, product remanufacturing and reuse, and savings through some sort of redistribution or allocation system, offer the largest potential for reduction of excess metal usage.

Figure 7.— Potential Savings From Technical Options by Reducing Excess Metal Usage, Expressed as a Percentage of Domestic **Mill Shipments (1974)**



NOTE See ch VI table 36 for data on which figure 7 is based
SOURCE: OTA based on data from Working Paper Three

SUMMARY OF TECHNICAL OPTIONS FOR REDUCING LOSSES AND REDUCING EXCESS METAL

A summary of the technical conservation options is presented in figure 8, which includes options for reducing losses (designated by 'L') as well as options for reducing excess metal ('E'). The percentages shown give the range of potential savings for the eight metals studied, rounded off to the nearest 5 percent. These percentages are nonaddictive, since many of the options are mutually exclusive, such as product recycling and metal recycling. The purpose of figure 8 is to show which options offer the most potential for conservation of metals.

The percentages shown in figure 8 represent the maximum technical potential for conservation. The actual amounts may be considerably less due to various barriers to implementation and undesirable impacts and costs. Only options with 10 percent or more potential metal savings for at least one metal have been included.

The conservation options are, of course, metal specific as indicated by the wide range of percentages. A metal like platinum, which costs over *$2,000* per pound, offers only limited additional opportunities for conservation. Metals used primarily for alloys (such as manganese and chromium) require different options than do the basic structural metals (iron, copper, aluminum). However, in this summary, the options are discussed only in general terms.[5]

Each of the technical conservation options presented in figure 8 is discussed below.

Major redistributions.—A review of the World War 11 experience (see appendix B) showed that from 50 to 90 percent of several of the metals studied were diverted from their then current use. During wartime, when flexibility became absolutely necessary, major metal savings in the *civilian* sector were accomplished with a very tight allocation system that drastically reduced the domestic products that could be manufactured and consumed. Production was diverted to war products, so severe economic consequences were averted. This would not necessarily be the case in peacetime. The World War 11 experience indicates the upper limit for conservation in the civilian sector under crisis conditions.

Metal substitution.–Con:iderable potential flexibility enters into materials use via the substitution option. However, several major impediments must be overcome. First, a successful substitution can often take years to implement. Second, many products are manufactured with a highly specialized production process that is costly to change. If the substitution option is to be acceptable, greater flexibility must be built into the production process so that alternative metals can be used. Third, every substitution involves a risk that will add to the product cost. Strong financial incentives will be required to overcome these barriers.

A special case is the construction industry, which uses 10 to 20 percent of metals. This industry is not tied down to a specific production process. For example, considerable dollar savings (on the order of $15 million out of a total cost of about $60 million) are found to be possible by substituting concrete, plastics, and fiberglass for iron and copper in the construction of a typical 40-story office building. Substitution is a common practice in the construction industry, particularly where local labor practices and customer preferences are favorable.

Use of nonmetallic coatings.--A substantial percentage of certain metals (cadmium 60 percent, chromium 5 percent, cobalt 18 percent, nickel 13 percent, tungsten 8 percent) is used to coat steel or alloys for corrosion and wear resistance. Use of nonmetallic coatings could save considerable metal. However, additional R&D is required to sufficiently develop such coatings.

Metal recycling.—Some industrial scrap is effectively recycled. Estimates of the potential for additional recycling of obsolete scrap (from products) range from 5 percent for platinum to 40 percent for copper.[6] Unfortunately, obsolete scrap metal has a limited market and competes with virgin ore of

[5]For the complete metal-specific discussion of options, see chs. IV, *v, and* VI.

[6]For the detailed estimates. see figure 21, ch IV,

Figure 8.—Summary of Technical Options for Reducing Losses and Reducing Excess Metal

	Option	Potential metal savings (%o of 1974 shipments)
E	Major redistributions (e.g., through allocations)	50-90
E	Metal substitution	15-60
E	Use of nonmetallic coating	5-50"
E	Product remanufacturing	10-45
L	Metal recycling	5-40
E	Product reuse	5-30
E	Use of stocks	5-30
L	Reduce dissipative uses	5-25
L	Reduce milling and concentrating losses	0-20
E	Metal substitution in construction	0-20
E	Minor redistributions (e.g., through allocations)	5-15
L	Reduce post consumer waste	5-15
L	Export controls on scrap and mill products	0-15
E	Eliminate unnecessary metal in products	5-1o
E	Increase product life	5-10

E =Promising options for reducing excess metal used in the materials cycle See figure 7 for metal specific data

L =Promising options for reducing metal losses from the materials cycle See figure 3 for metal specific data

" For cadmium

SOURCE: OTA based on data from Working Papers One, Two and Three

known quality and more stable supply as well as with industrial scrap, which has a known consistency and presents fewer collection difficulties.

Options for increasing the recycling of obsolete scrap include investment tax credits, product charges, and freight rate changes. Several of these options have been studied in another OTA assessment.[7]

Moreover, most obsolete scrap exists in the form of a product. And as a product (with workable components), the scrap usually has more value than the metal alone. Thus, to a large extent, metal recycling can be accomplished through remanufacturing and reuse of products.

Product remanufacturing and reuse.—According to a recent OTA conference on the subject,[8] this option offers major potential for conserving metal, saving the energy already invested in products, and reducing the environmental pollutants associated with the manufacturing process. One major barrier to product remanufacturing and reuse is the lack of the necessary industrial infrastructure.

Another major barrier is economic. To be economically attractive, a product must be remanufactured at a cost that will allow a resale price at a reasonable discount under the price of a new product. For many current products, this discount averages 60 percent. However, for other products there is no difference between new and reworked product pricing.

[7] Materials and Energy From Municipal Waste (Washington, D.C.: U.S. Congress Office of Technology Assessment, July 1979), OTA-M-93.

[8] Product Remanufacturing Forum, Nov. [illegible] 1978, cosponsored by the U.S. Office of Technology Assessment, U.S. National Bureau of Standards, and U.S. Department of Energy.

Product remanufacturing is not a new concept and is extensively carried out for a wide range of products and components. Automotive parts are probably the best example of what can be accomplished when the economic conditions are favorable. Products that are most likely to be remanufactured are those with higher initial costs, where appearance or styling is not a problem, and where there is an abundant supply of used products to remanufacture.

For products where remanufacturing is feasible but economically marginal, two major barriers exist. First, the concept of a "used" product runs counter to established traditions and even regulations. The second major barrier is the lack of established industries to remanufacture and resell that product. The recycling business is labor-intensive and may not have as high a rate of return as others. Therefore, if product remanufacturing is to be encouraged, some additional investment incentives may be necessary, such as low-interest loans or tax benefits for plant and equipment, and perhaps tax credits or deductions for leased products made of recycled parts and materials.

Reduce dissipative uses.—Dissipative uses involve the dispersal of metals and alloys by chemical action or physical dispersion during use. For example, aluminum pig and aluminum scrap are often used during the deoxidation of steel. The aluminum is lost as an oxide in the slag. Relatively few options are available to reduce waste here. Most technical options have significant performance penalties, or increased costs, or both. In some cases, R&D programs to find substitute materials and/or processes might be successful.

Reduce milling and concentrating losses.–Althougth relatively large quantities of metal may be lost in the milling and concentrating stages, the value of the material lost is low and the cost of further recovery is high.

One option is to increase imports of high-grade ore concentrate. But this raises serious questions about the amount of risk associated with import dependence versus the increased costs of energy and environmental controls that would be required in domestic processing of lower grade ores. Another option is to invest in a major R&D program, perhaps building on current U.S. Bureau of Mines research, directed toward increased recovery of metal values from lower grade ores.

Minor redistribution (through, e.g., allocations, export controls, use of stocks).—During emergency situations, these options could reduce metal usage with relatively minor effort, for example, allocations that encourage the use of proven substitutes in industries where changes in production equipment would not be necessary. The exact percentage saved would depend on the timing and specific metal, but could be as high as 30 percent.

Reduce postconsumer waste.—Options for reducing postconsumer waste are discussed in another OTA report, *Materials and Energy From Municipal Waste,* July 1979, OTA-M-93. However, once metals enter the municipal solid waste (MSW) stream, their recovery is generally more difficult and at present is limited to aluminum cans and ferrous metals (along with paper and glass). Options such as product recycling may offer significant energy conservation and environmental quality benefits when compared to sources separation and centralized recovery from the MSW stream.

Eliminate unnecessary metal in products.—Strong economic incentives already exist for careful design to avoid unnecessary uses of metal, for example, material costs, shipping weights, and handling costs. A though some further elimination of excess metal is possible, the difficulties include increased manufacturing costs, increased cost of investment in engineering and equipment, decreased durability. and reduced safety.

For example, for the refrigerator, an estimated 11 lbs of steel could be saved of the 70 lbs now used in the outer shell. However, this would add $30 to the manufacturing cost for a plastic substitute and related adhesive and finishing, and would create moisture and flammability problems, among others.

Increase product life.—Technically, longer mechanical life can be designee into many products. But longer life can often be more costly and may not result in a significant increase in the actual average lifetime. Many products are retired due to obsolescence, appearance style changes, or other reasons not related to mechanical condi-

Figure 9.—Ability of Conservation Options to Meet Selected Materials Objectives

	Selected materials objectives	
	Improve materials availability during critical situations	**Reduce waste of materials and conserve energy**
Most promising technical options (from figure 8)	**Major redistribution (e.g., through allocations)** **Metal substitution** **Use of stocks** **Metal substitution in the construction industry** **Minor redistributions** **Export controls**	**Increase metal recycling** **Increase product remanufactureing** **Increase product reuse** **Reduce dissipative uses** **Reduce milling & concentrating losses** **Reduce postconsumer waste** **Eliminate unnecessary metal in products** **Increase product life**
Illustrative implementation options	**Public data base** **Contingency planning function** **Market for contingency shares certificates** **Research and development on metal substitution**	**Public data base** **Improve product aftermarket (e.g., establish a scrap inventory, encourage product leasing, provide loans to establish aftermarket businesses)**

SOURCE: OTA.

Government options were evaluated, and four appear to warrant primary consideration:

- encourage product leasing through tax deductions,
- provide loans to establish after market businesses,
- provide funding to establish a scrap inventory, and
- increase public confidence in recycled products.

Product recycling would also save energy. As shown in figure 10, metal refining and fabricating are several times above the national average in energy intensity. Therefore, recycling of metal products and components—which involves the maintenance and manufacturing stages of the materials cycle—is more energy efficient than building products from scratch with newly mined, refined, and fabricated metal parts.

Contingency planning function. One option availab]e to Congress is to centralize a materials contingency planning function in the Government. This organization would be responsible for evaluating the severity of perceived threats to materials supply, and developing contingency plans on a commodity by commodity basis. Such a function could be an extension of the scope of work now performed by various existing offices and bureaus.

Public data systems. A public data base on materials would help to improve the quality and quantity of information available to Government and to industry for better analysis and forecasting on materials supply and demand problems. It would also help identify R&D needs for solving or alleviating technical problems in the materials cycle.

These two implementation options, contingency planning and a public data tree, have been studied in detail in an earlier OTA report on *Information* tions. Up to 50 percent of all products removed from service are still in working condition, according to one recent report on the subject.[9]

Longer product life would best apply to transportation and consumer durables (appliances) which together account for 12 to 28 percent of metal usage, depending on the metal. Even if the maximum savings per product (27 percent)[10] were applied to the maximum base of 28 percent, this would result in only a 7.5-percent metal saving.

[9] W. David Corm, *Factors Affecting Product Lifetimes*, NSF/RA Report 780219, August 1978.

[10] Based on the amount of metal saved per product per year with a 50-percent increase in mechanical lifetime. See ch. VI, table 32 and related discussion.

PRELIMINARY POLICY CONSIDERATIONS

As summarized above, the primary focus of this study was the assessment of technical options for conserving metal. However, preliminary consideration was given to materials objectives and problems and a range of possible implementation options that should be taken into account in policy discussions on materials conservation.

Materials Objectives and Problems

Conservation is a response to a real or imagined threat or condition. Conservation options are implemented in attempting to accomplish some objective. The primary objectives of concern in this assessment have been reducing the volume of waste and improving materials availability. There are a number of other objectives that might be relevant to public policy, such as conserving energy, stabilizing materials markets, protecting the environment, or promoting a resource-conserving society.

Materials availability, either short term during critical situations or long term with respect to resource depletion, is a vital concern to both industry and society. Without the proper materials, many industries would be forced to close unless alternative plans were made well in advance. As shown in appendix C, materials shortages have been commonplace for many years and will undoubtedly continue in the future. Conservation is a possible response to these problems.

Energy conservation can affect the availability of materials. Since metals refining consumes about 9 percent of the energy budget and all materials consume about 20 percent, materials conservation could be a response to the need for energy conservation. More realistically, in the foreseeable future, energy conservation will probably be more important than materials conservation.

Materials conservation may be an appropriate strategy to deal with a large number of other problems that threaten materials availability, such as: chronic lack of capacity in the metals industry, import dependency for essential metals, cyclical instabilities in supply and demand for metals, and environmental restrictions on the mining and processing of metals.

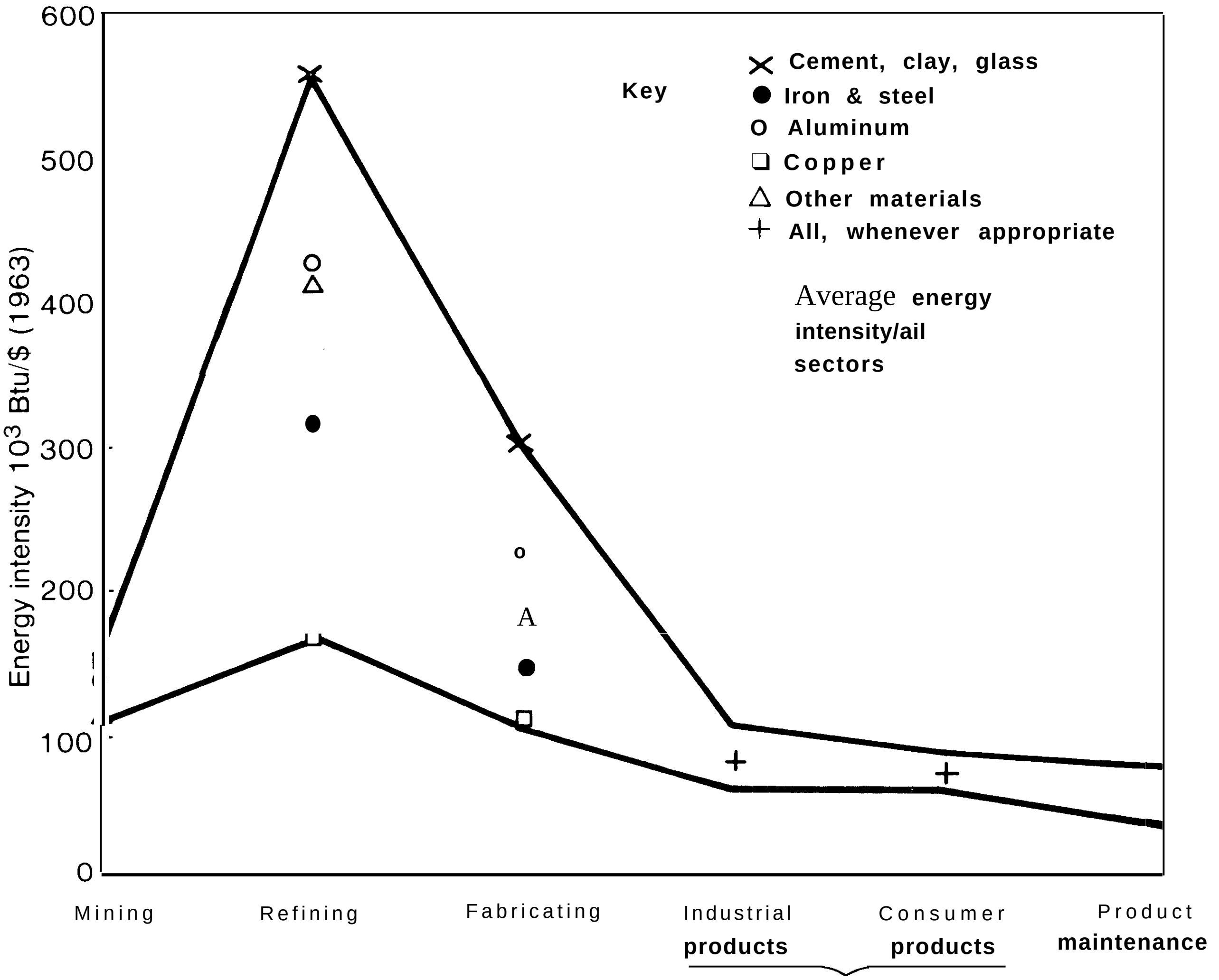
Illustrative Implementation Options

This study briefly considered several methods for implementing the more promising technical conservation options. Both technical and implementation options are listed in figure 9 as options to improve materials availability during critical situations and/or to redue waste and conserve energy. The impacts of these options were not assessed in detail.

Improve product aftermarket. Product remanufacturing, reuse, and repair (collectively known as product recycling) offer significant leverage for conserving materials and energy. Improved aftermarket (the market for recycled products) would help to reduce the mixing of scarce materials with the landfill waste stream as well as to improve the rate of recovery of the major metals—iron, steel, aluminum, and copper.

Improved product recycling to capture the residual value in products through a strengthened aftermarket would eventually have implications for the entire materials cycle. Twenty possible

Figure 10.— Energy Intensity at Each Stage of the Materials Cycle



SOURCE: OTA, based on data from Working Paper Six

Systems Capabilities Required to Support U.S. Materials Policy Decisions (December 1976). Option 3 in that report, known as the Bureau of Materials Statistics and Forecasting, encompasses these two options. Chapters VII and VIII of that report provide a detailed discussion of the impacts and issues associated with implementation of such a Bureau with contingency planning and public data base capabilities.

Market for contingency shares certificates, in this implementation option, a private sector market for contingency shares certificates would be established between materials suppliers and industrial customers of basic materials. This option would be a private allocation system.

R&D on metal substitution. Substitution promises substantial savings for specific metals. Discovering the available substitution options is in part a product of Government-sponsored R&D. Research programs to develop practical substitutes for scarce materials, with particular emphasis on products with high metal use, nonmetallic coatings for corrosion and wear resistance, and dissipative uses could be established.

Summary

The implementation options presented above avoid Government intervention in private decision processes to a large extent. Instead, they enable the private sector to more efficiently deal with their own needs while reducing the uncertainties and vulnerabilities for all parties. These means of implementation are to a great extent self-correcting. They do not require constant Government adjustment of standards or regulations in order to achieve a balance of interests. Nor do they involve excessive costs for administration, monitoring, enforcing, or recordkeeping.

This set of illustrative options is mutually reinforcing. The contingency planning and public data base support all other options. The contingency shares certificate market would moderate the extremes of materials supply and demand fluctuations. Substitution is very much the result of a private sector decision process. But through Government R&D, substitution can also be an important instrument of national materials and energy policy. Improvements in the product aftermarket will contribute to greater efficiency in materials use but could also provide an institutional mechanism to advance many other objectives such as energy conservation and environmenta protection.