Consumption of Materials in the United States, 1900–1995

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Abstract

The flows of nonfood and nonfuel materials through the economy have significant impact on our lives and the world around us. Growing populations and economies demand more goods, services, and infrastructure. Since the beginning of the 20th century, the types of materials consumed in the United States have significantly changed. In 1900, on a per-weight basis, almost half of the materials consumed were from renewable resources, such as wood, fibers, and agricultural products, the rest being derived from nonrenewable resources. By 1995, the consumption of renewable resources had declined dramatically, to only 8 percent of total consumption. During this century, the quantity of materials consumed has grown, from 161 million metric tons in 1900 to 2.8 billion metric tons by 1995, an equivalent of 10 metric tons per person per year. Of all the materials consumed during this century, more than half were consumed in the last 25 years. This paper examines the general historical shifts in materials consumption and presents an analysis of different measurements of materials use and the significance of their trends.

CONTENTS

Introduction

Food, fuel and materials are the three broad categories of commodities utilized in the economy to support the needs of society. This paper examines materials, a category that includes fibers, plastics, feedstock, metals, paper, cement, and sand and gravel. It also includes resources that supply our basic needs for producing food, clothing, shelter, transportation, and infrastructure and that maintain and improve our standard of living. Excluded are materials such as mine tailings from metal production; overburden (material overlying a mineral deposit) removed to access mineral ores; earth and stone excavated for the construction of dams, highways, and buildings (1); and the materials contained within finished products imported to or exported from the United States (2).

Materials are derived from resources that are classified as either renewable or nonrenewable. Renewable resources are those that regenerate themselves, such as agricultural, forestry, fishery, and wildlife products. If the rate they are consumed becomes so great that it drives the resource to exhaustion, however, these renewable resources can become nonrenewable. Nonrenewable resources are those that are formed over long periods of geologic time. They include metals (primary and recycled), minerals, and organic materials. In this paper, food, fuel, water, and air are not taken into account.

This paper is an overview of materials consumption in the United States from 1900 to 1995 as measured at the input-to-manufacturing stage. It includes a discussion of the changes in the preferences of consumers and industry for different materials and presents different measurements of consumption (weight and volume) as indicators of intensity of use (see below). As used in this paper, materials consumption is defined as the apparent consumption of raw materials. This equals domestic primary and secondary (recycled) production plus imports minus exports of raw material.

The data collection and analyses presented in this paper provide the following:

1. Information for materials flow analysis of the U.S. economy, from extraction through processing, manufacturing, dissipation (quantity of the material released directly to the environment, where no attempt to

recapture the material is made or where it is not practical), recycling, and ultimate disposition.

2. Information to help both the public and private sectors gain understanding about the use of materials in the economy, and about the ultimate disposition of materials into the environment.
3. An overview of shifting patterns in materials use in the United States and throughout the world. Identification of these patterns provides a framework for identifying future national and global materials requirements and for understanding the long-term issues of resource supply-and-waste management.

Trends in Consumption of Raw Materials

The U.S. government has been tracking the use of materials since the 1880's. The data gathered by the U.S. Geological Survey, the former U.S. Bureau of Mines, and other agencies provide a historical perspective on the changing patterns of materials consumption and are used to illustrate the long-term trends in materials use (3). The raw materials consumed in the United States have grown substantially since the beginning of the 20th century. These changes reflect alterations in public demand, population growth, and industrialization.

Potential impacts on the environment are related to the physical flows that take place within a finite ecosystem. In this chapter, major emphasis is placed not on monetary value but physical data, that is, weight and (or) volume measures [the purpose of the analysis may make one more relevant than the other—such as analyses involving space issues, for example, landfill disposal, where volume measurements may be more relevant than weight (4)].

Consumption Trends in the United States, 1900–1995

The consumption profiles of renewable (agriculture, wood products, and primary paper) and nonrenewable (nonrenewable organic, primary metals, industrial minerals, and construction) materials are illustrated in figure 1. Reusable, or recyclable, resources (recycled metals and paper) are also included. This illustration also reflects the consumption pattern of materials associated with major economic and military events, including the depression of the 1930's, World War I, World War II, the post-World War II boom, the energy crunch of the 1970's, and the recession of the 1980's. At the beginning of the 20th century, each person consumed per year approximately 2 t (metric tons) of materials; by 1995, that amount had increased to 10 t (metric tons), a fivefold increase.

Construction materials include crushed stone and construction sand and gravel (natural aggregates). They do not include materials such as gypsum for wallboard, copper for plumbing, wood or steel for construction frames, or asphalt for roads. Natural aggregates are a major basic raw material used by the construction, agriculture, and other industries (6). On the basis of weight, construction materials dwarf all other materials combined. They have—throughout the century—been the most dominant of all types of materials used, representing as much as three quarters (by weight) of consumed renewable and nonrenewable resources annually.

Consumption of construction materials greatly increased as a result of infrastructure growth (especially the interstate highway system) after World War II. In recent decades, construction materials have been used mainly in the widening and rebuilding of roads damaged from weather and heavier traffic loads and in construction of bridges, ramps, and buildings (6).

The amount of recycled aggregates (crushed cement concrete) is not included in figure 1. The sparse data available indicate that use of recycled aggregates has been increasing, especially in the 1990's. As the recycling of construction and demolition debris increases, aggregate producers are starting to recycle concrete and asphalt. Because much recycling of aggregates occurs in place at highway construction sites without going through a market transaction, precise data are not available.

An evident, major shift in the U.S. consumption is the increased use of nonrenewable resources (fig. 2). At the beginning of the 20th century, about 41 percent (by weight) of the materials consumed domestically were renewable; by 1995, only 8 percent were renewable.

In the early 20th century, the U.S. economy moved rapidly from an agricultural to an industrial base. In the 1950's and 1960's, it began a shift toward a service economy. This trend has caused a change in the mix of materials consumed and has provided more extensive processing, miniaturization, sophisticated technology, electrification, computerization, automation, and high-speed transport. At the same time, increased transportation and new technologies have led to increases in energy consumption (7).

Figure 3, which excludes construction materials, illustrates trends in the other categories. Industrial minerals account for a large component of materials consumption, almost equivalent, on a per-weight basis, to all of the remaining materials. Industrial minerals include cement for ready-mix concrete; potash and phosphate for fertilizer; gypsum for drywall and plaster; fluorspar for acid; soda ash for glass and chemicals; and sulfur, asbestos, abrasives, and various other minerals for use in chemicals and industry. The proportion of industrial minerals to total materials consumption used in the economy increased until about 1960 and has been roughly constant since.

Materials derived from agriculture (such as cotton, wool, and tobacco), fishery products (such as fish meal), and

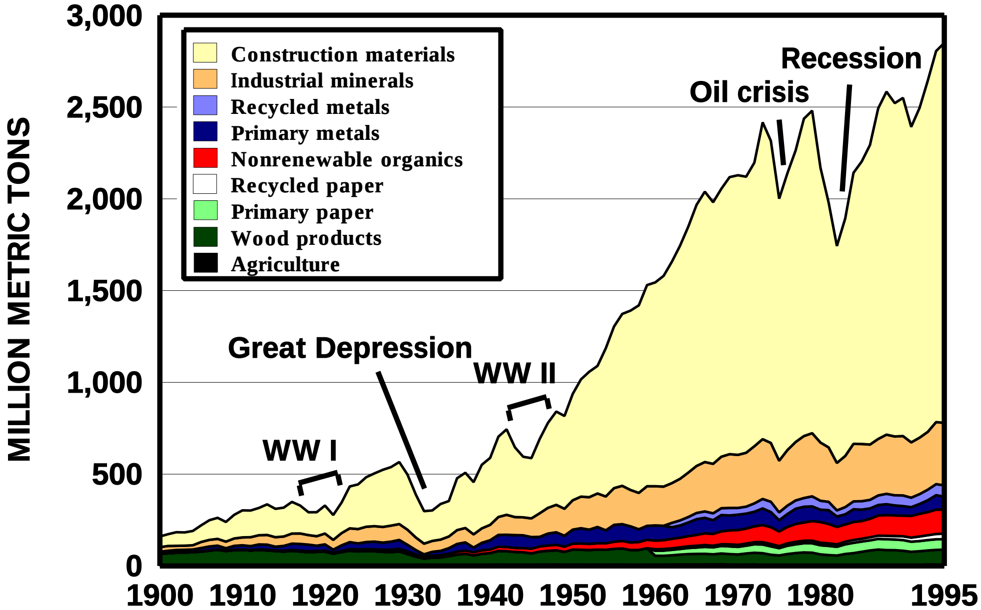


Figure 1. Measurement of the amount of raw materials consumed in the United States. WWI, World War I; WWII, World War II (5).

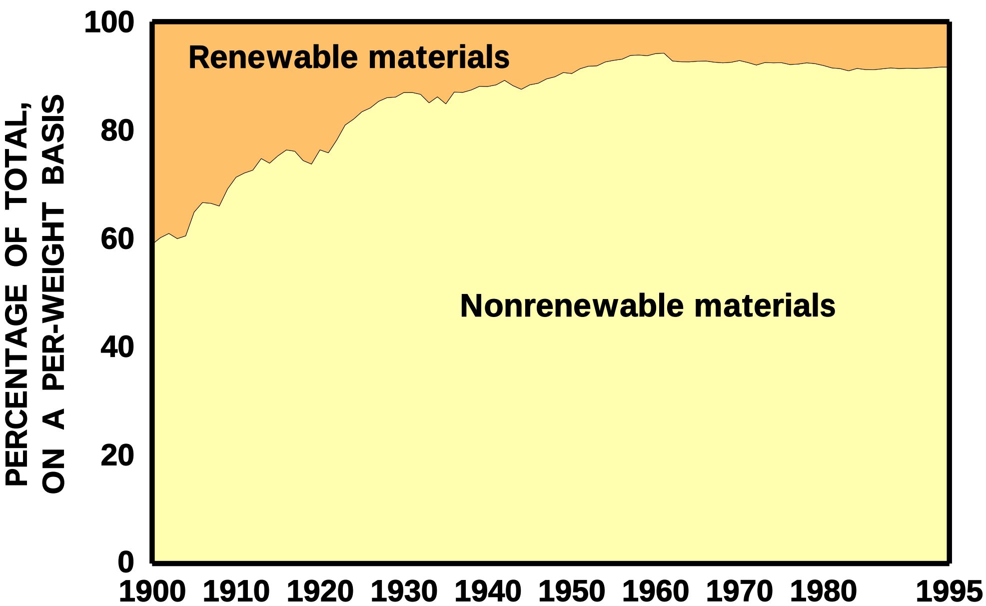


Figure 2. Measurement of the amount of renewable and nonrenewable materials consumed in the United States.

wildlife (primarily fur) are so light in weight that they represent only a small part of the total materials consumed by weight (4). In 1900, the United States used 3 million t of agricultural material; by 1995, it used more than 6 million t.

Consumption of paper (as a primary product) showed a slight increase from 1960 through 1995. Prior to 1960, the consumption of paper was included in the wood products category. Consumption of wood products (lumber, plywood, and veneer) remained essentially unchanged throughout the same period, thus representing about 6 percent of the total materials used.

Nonrenewable organic material is today a major component of materials consumption. The category emerged gradually in the early part of the century, accounting for approximately 2 million t in 1900. It has subsequently undergone rapid growth, to 131 million t in 1995. The use of nonrenewable organic material has increased as a result of the development of new products and markets and material replacements in established markets. In some applications, synthetic fibers have replaced natural fibers, plastics have replaced wood, and synthetic oils have replaced natural oils. These replacements were the result of more desirable properties or cost advantages. Nonrenewable organic material used in the production of asphalt, plastics, feedstock, synthetic rubber, fibers, and petrochemicals exceeded 130 million t in 1995. This quantity is approximately equal (on a per-weight basis) to all primary and recycled (secondary) metals consumed.

Use of metals declined slightly relative to other materials during the last few decades. Reasons for this

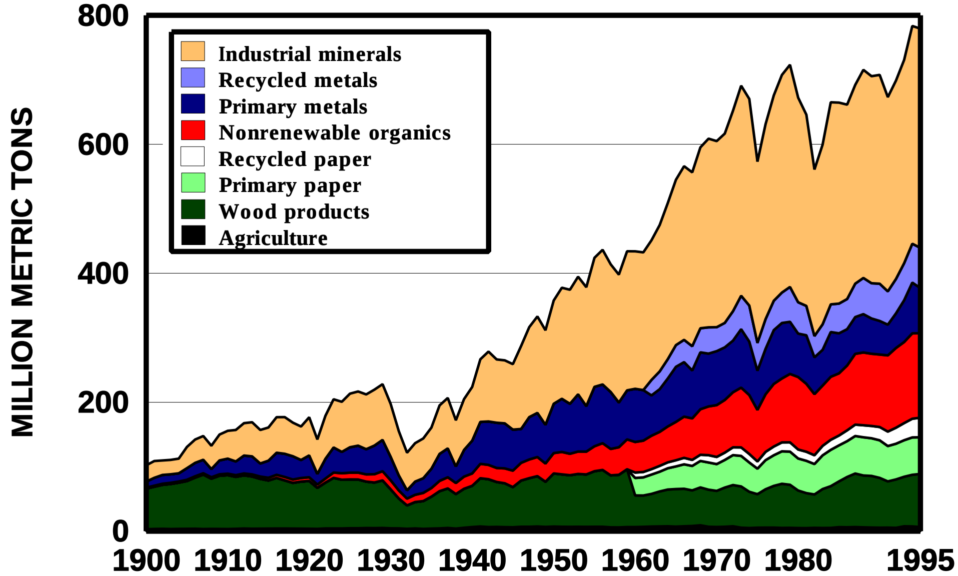


Figure 3. Measurement of the amount of raw materials (excluding crushed stone and construction sand and gravel) consumed in the United States.

include the need for lighter weight materials (such as aluminum), the introduction of high-strength steel alloys in vehicles, and the availability of lower cost substitute materials (such as plastics).

Improvements in recycling technologies, costs, and increased consumer preferences for environmentally sound products have resulted in the growth of recycled material use, both in metal and paper (fig. 3). The sudden emergence of recycled materials in the 1960's is more reflective of data desegregation, because prior to that time, recycled material was accounted for in total materials values. The data (3) show that in 1995, recycled metals accounted for 47 percent of metals consumption, up from 31 percent in 1970. This resulted in a decline in the percentage of primary metals used during the last few decades, even as total metal consumption has increased (4). According to 1996 estimates, 63.5 percent of all aluminum beverage cans, 58.2 percent of all steel cans, 37.9 percent of all glass containers, and 38.6 percent of all polyethylene terephthalate soft-drink bottles were recovered for recycling (8). As reported by the U.S. Geological Survey in 1995, recycling is a significant factor in the supply of many of the key metals used in our society; it provides environmental benefits in terms of energy savings, reductions in the volume of waste, and reductions in emissions associated with the energy savings (3). For example, recycling aluminum saves about 95 percent of the energy needed to make primary metal from ore (9).

Paper recycling has increased to 30 million t in 1995 from approximately 8 million t in 1960, almost a fourfold increase. This increase is a result of improvements in paper technologies, increased supplies of paper collected and recovered for recycling, and changes in government policies concerning the use of paper with recycled content.

Consumption Trends in the World, 1970–1995

As a basis for comparison, a consumption data set was constructed for the world by using the same commodity groupings as was used for the United States. The completeness and standards of data reporting vary from country to country, but world data are important as a point of reference.

As shown in figure 4, U.S. consumption rose from 2 to 2.8 billion t from 1970 to 1995. Over the same period, world materials consumption rose from 5.7 billion t to 9.5 billion t. Thus, world consumption grew at a rate nearly double that of the United States (1.8 percent vs. 1 percent). Nonetheless, the United States still consumed about one-third by weight of the reported world total materials consumed, even though it accounts for approximately 5 percent of the global population.

The increased U.S. and world consumption levels raise issues related to resource adequacy and the impact on the ecosystem. Further work is needed in this area to provide a holistic approach to global issues in material consumption.

For many countries, the existing data are not as comprehensive as those from the United States. To provide a comparative analysis on a per-capita basis, further work to account for data not reported by some countries and informal activities not accounted statistically is essential.

Although the United States consumes a lot of material, future shortages are not necessarily inevitable, for several reasons. Advances in technology and management increase efficient materials use, reducing the need for resources. There is also greater efficiency in materials extraction. Recycling and materials substitution are also occurring. Not every nation will necessarily repeat the American pattern of development. The lessons learned about efficient materials use in industrialized nations like the United States, if taught

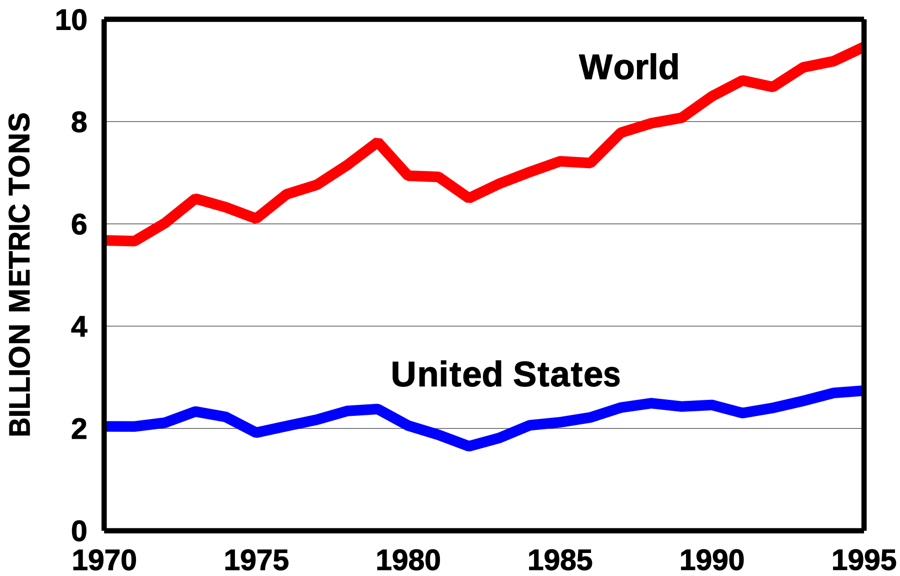


Figure 4. Measurement of the amount of materials consumed in the United States and the world (10).

and applied in developing countries, could usher in more efficient global consumption of materials. The sooner industrialized nations develop better technologies to use materials more efficiently and diffuse this knowledge, the less we risk future global materials scarcity.

Consumption Measurements

Different measurements—such as weight, volume, or value—provide different perspectives on consumption. Depending on the purpose of the analysis, one form of measurement may be preferable, although a comprehensive analysis that encompasses all perspectives may be the more appropriate.

Historically, mineral feedstocks have been valued by weight; agricultural and fishery products by weight and volume; forest products by volume; and organic fuels by weight, volume, and energy content. The data presented in this paper have been standardized in terms of weight and volume. An accounting of consumption trends in monetary terms would be valuable, but data for the commodity groupings were not available.

Weight and Volume Comparisons

A group of commodity categories were selected for analyses over the period 1960 through 1995. As shown in figures 5 and 6, the commodity groupings are wood products (lumber, plywood, veneer, and other forestry products), primary paper, recycled paper, primary metals, recycled metals, and plastics.

Primary metals have the highest apparent consumption in terms of weight (fig. 5), but this picture changes when viewed in terms of volume (fig. 6), where lower density materials are given more emphasis.

In absolute values, both by weight and volume, recycled metals and paper have gained market share during this period. Although metals have faced strong competition from other materials, demand has been strong, reflecting the U.S. economy.

Plastics have shown an interesting growth pattern during the same period. Since 1976, the population of the United States consumed more plastics than recycled paper on a per-weight basis and more than metals on a per-volume basis.

Intensity of Materials Use

Long-term trends in materials consumption can also be analyzed by examining the consumption per capita or per unit of gross domestic product (GDP) because consumption levels are heavily tied to the growth of population and the economy. Intensity of materials use is defined as the amount of materials used per year with respect to population or economic output, often measured as total GDP. Intensity of use measures may help gauge developmental status, economic growth, and environmental quality, which is determined by an efficient use of natural resources that minimizes depletion and reduces pollution (11).

Per Capita

Figures 7 and 8 show the apparent consumption per capita in the United States of selected materials in terms of weight and volume, respectively. On a per-weight basis, primary metals show a declining trend in apparent consumption

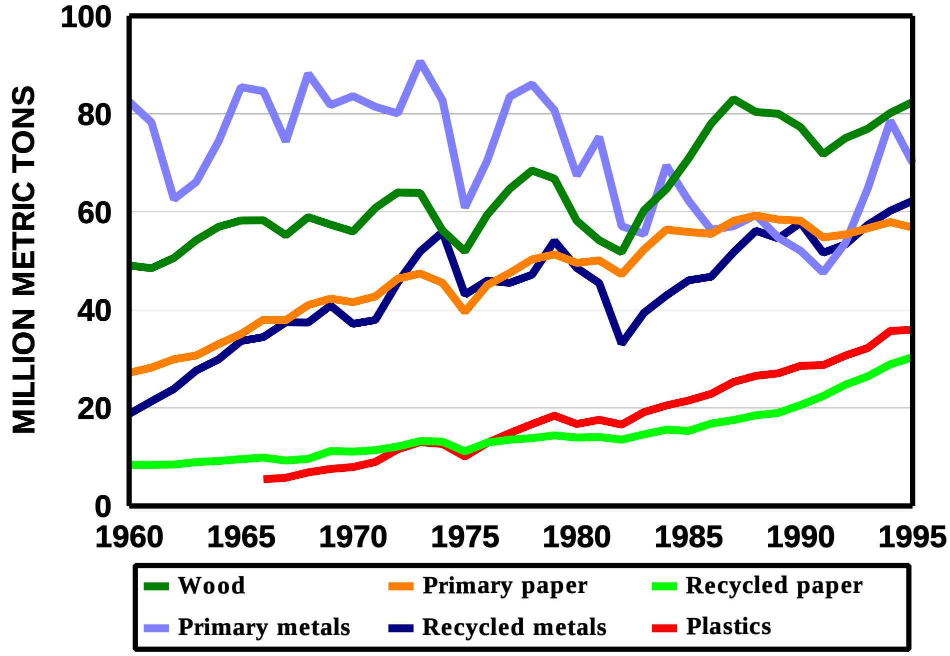


Figure 5. Measurement (by weight) of the amount of selected materials consumed in the United States.

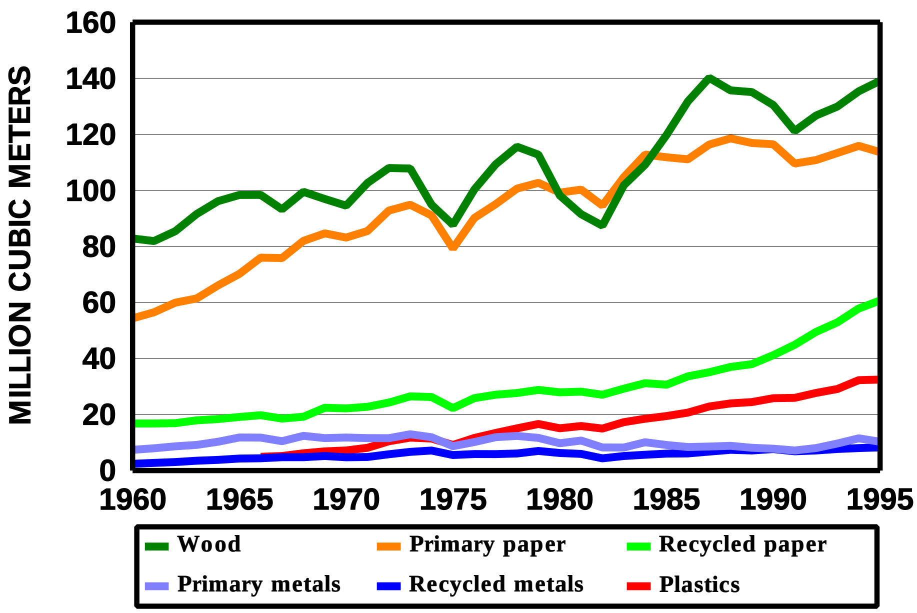


Figure 6. Measurement (by volume) of the amount of selected materials consumed in the United States.

per capita from 1970 through 1991. Recycled metals, however, present a consistent upward trend. On a per-volume basis, trends remained steady during the same period and indicate a consumer preference for lighter materials, such as plastics.

The use of primary and recycled paper products per capita increased. In the last decade, recycled paper use has steadily risen, as a result of improvements in paper recycling technologies and in increased supplies of paper collected and recovered. Some increases in the volume consumed per capita reflect increases in the velocity of consumption of goods (the frequency with which materials are used and discarded or expended in a year). This velocity increases when consumers replace durable goods such as automobiles or appliances more frequently or when they consume disposable products instead of longer lived substitutes.

Plastics consumption per capita shows an upward trend, mainly owing to the development of new products and markets and material substitution in established markets. In fact, in many cases, plastics have become the material of choice, displacing metals, paper, leather, glass, and wood in a range of common products (12).

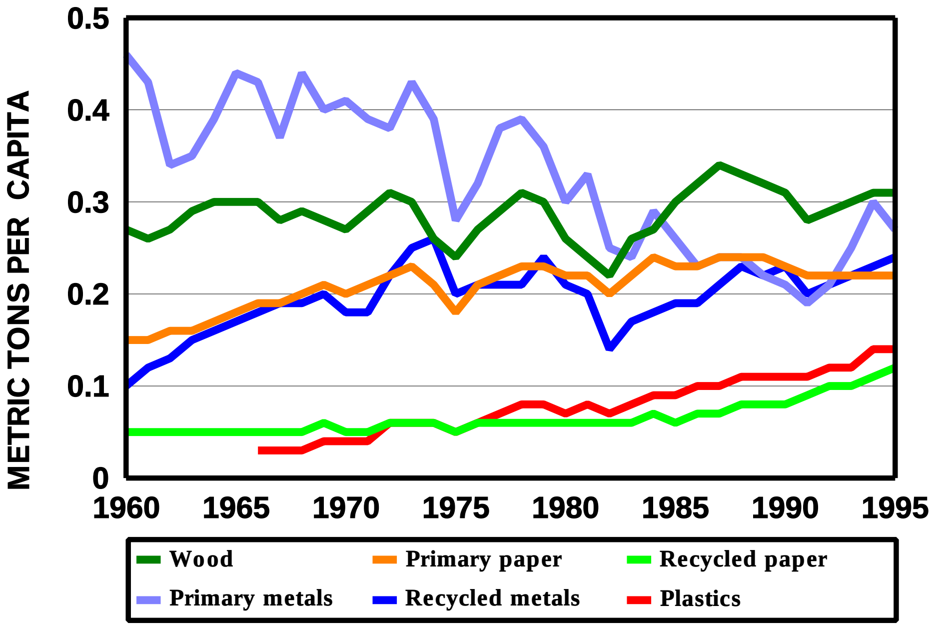


Figure 7. Measurement (by weight per capita) of the amount of selected materials consumed in the United States.

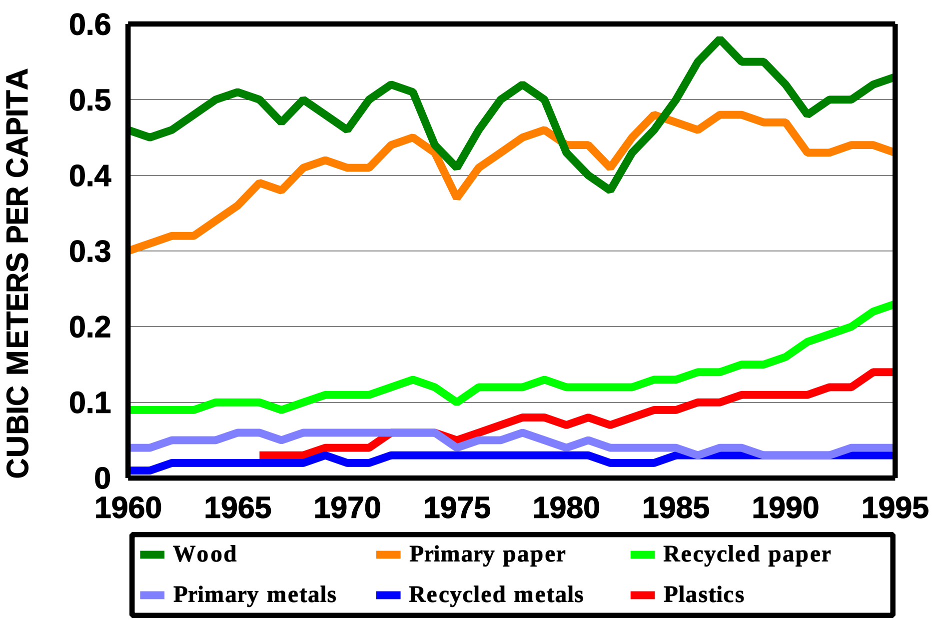


Figure 8. Measurement (by volume per capita) of the amount of selected materials consumed in the United States.

Per Unit of Gross Domestic Product

When the trends of the apparent consumption of materials per unit of GDP are analyzed on a per-weight and per-volume bases, a slightly different trend emerges (figs. 9 and 10). On the basis of a per-ton unit of GDP, slightly more recycled (metals and paper) products were consumed in the economy per unit of GDP in 1995 than in 1960. Consequently, primary metals and paper declined. The recycled products contribute to the overall supply of metals and paper, thereby reducing the demands on virgin metals and wood products.

Plastics show an upward trend in terms of weight and volume per unit of GDP. This reflects the increasing role that plastics play in the economy.

The data from the analysis of materials consumption neither confirm nor deny the notion that the economy is in the process of dematerialization or is less material intensive. They do, however, indicate that increases in consumption and changes in the composition of materials have been significant, especially for low-density materials. Furthermore, taking into account that quantities of post-consumer waste will increase as population and GDP increase, new technologies will be required, and consumer preferences may have to change.

Figure 9. Measurement [by weight per unit of gross domestic products (GDP)] of the amount of selected materials consumed in the United States.

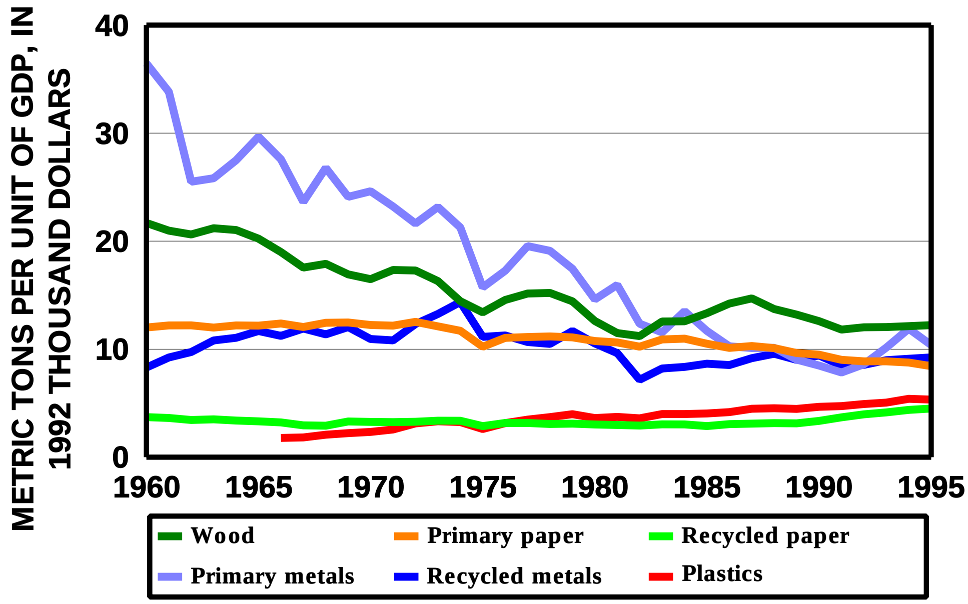
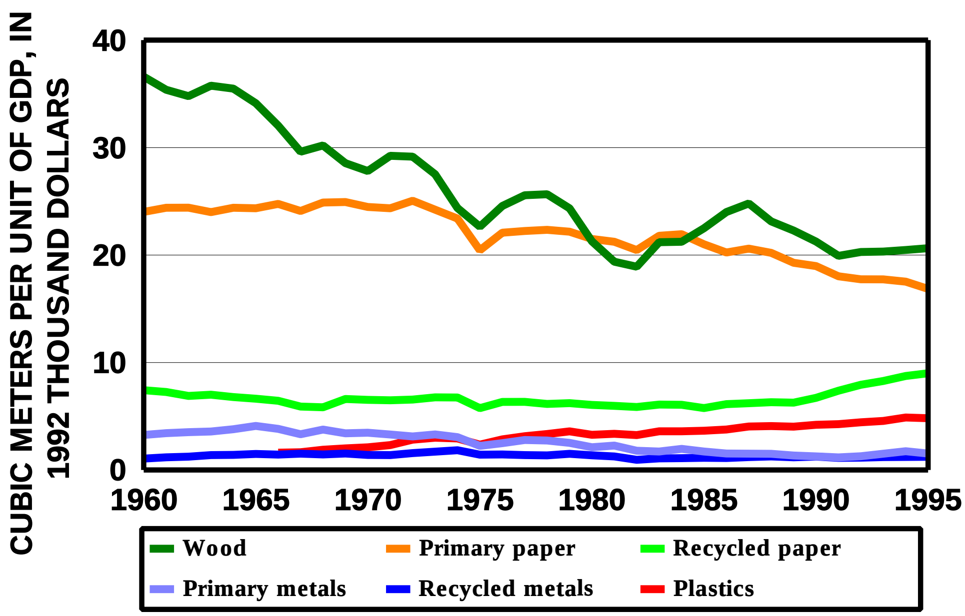


Figure 10. Measurement [by volume per unit of gross domestic products (GDP)] of the amount of selected materials consumed in the United States.



Environmental impacts can be mitigated to the extent that flows of materials are reduced by more efficient product design, which will result in source reduction to the waste stream or to where waste materials are recovered and recycled. Reducing the amount of materials used per unit of population or GDP can contribute to the alleviation of environmental stress and to greater economic and industrial productivity.

Conclusions

As shown by the data presented in this paper, consumption of raw materials in the United States has increased dramatically throughout the 20th century and has changed its composition substantially. The data underscore the need to understand better our natural resources so that adequate supplies of materials will be available to meet future demands, improve efficiency of materials use, and limit negative impacts from the ultimate disposition of materials. There is also a need to analyze materials use from all perspectives.

Further efforts are needed to develop consistent standardized information for accounting of resources and the impact of resource use on the environment, the economy, and, ultimately, the human population. The U.S. government has a long history of tracking the flow of materials through the economy. The basic data-collection and data-analysis functions provided by Federal agencies are key elements to the understanding of materials use and shifts in materials production and demand. It is crucial for future studies that academia, policy makers, and business people have ready access to a consistent set of statistics on material extraction, use, disposal, and recycling/reuse.

In addition, understanding the flows of materials and monitoring materials consumption trends provide the information to assist the United States in determining how it can satisfy its material needs at acceptable economic and environmental costs. This is an important function because materials, as well as food and energy, support the U.S. economy. The shifts in materials use during the last 95 years have created a number of questions about the long-range impacts of these trends in the domestic economy, the international marketplace, and the environment.

As we approach the 21st century, we have challenges to face. Using a materials flow approach to materials usage can lead to improvements in product design, to technological innovation that increases the efficiency of resource use, to better waste-management practices, and to more-effective policies. Furthermore, the awareness of materials choices and consumption behavior can help us avoid activities that degrade the environment and encourage activities that conserve ecosystems for the future.

Two basic issues need to be addressed: potential scarcity (the continued availability of material resources both regionally and globally) and the environmental impacts of the extraction, processing, use, and disposal of this material. This will require (a) monitoring changes in domestic consumption levels and the reciprocal changes needed to support these levels by the ecosystem and the economy, (b) analyzing the factors that are causing changes in current and future demand for materials, and (c) supporting effective policy alternatives, such as government procurement policies and labeling about environmental effects.

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