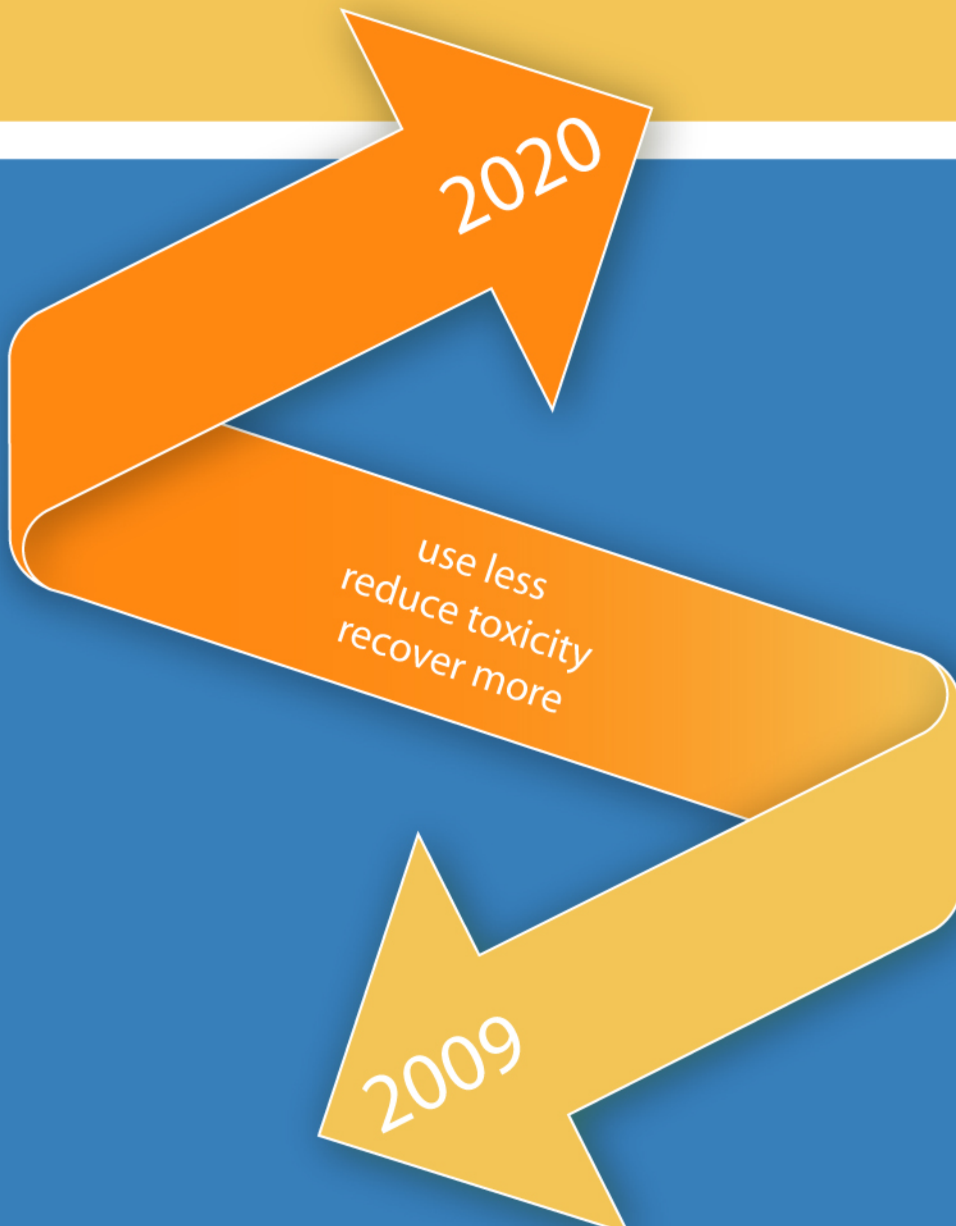
Sustainable Materials Management:

THE ROAD AHEAD



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Acknowledgements

THE 2020 VISION WORKGROUP

Derry Allen, US EPA National Center for Environmental Innovation

Shannon Davis, US EPA Region 9

Priscilla Halloran, US EPA Office of Resource Conservation and Recovery

Peggy Harris, California Department of Toxic Substances Control

Kathy Hart, US EPA Office of Pollution Prevention and Toxics

Jennifer Kaduck, Georgia Department of Natural Resources

Angela Leith, US EPA Office of Resource Conservation and Recovery

Clare Lindsay, US EPA Office of Resource Conservation and Recovery

Mark McDermid, Wisconsin Department of Natural Resources

Wayne Naylor, US EPA Region 3

Sam Sasnett, US EPA Office of Pollution Prevention and Toxics

Scott Palmer, US EPA Office of Resource Conservation and Recovery

Karen Sismour, Virginia Department of Environmental Quality

Pam Swingle, US EPA Region 4

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Executive Summary

We live in a material world. How our society uses materials is fundamental to many aspects of our economic and environmental future. If we want the U.S. to be competitive in the world economy, the sustainable use of materials must be our goal.

Our key message is simple.

- *Our use of materials is very large and increasing with population and economic growth. Energy and water use accompany materials use.*
- *Our use of materials now challenges the capacity of the Earth – air, water and land – to withstand the many resulting environmental problems. This situation fundamentally affects many other aspects of our future, such as the economy, energy and climate. We need to fulfill our human needs and prosper while using less material, reducing toxics and recovering more. Business as usual cannot continue.*
- *The public and private sectors have many of the tools that we need to manage materials much more carefully than we typically do today. However, these tools are seldom used to address the full life cycle of materials. This report describes specific measures that EPA and state environmental agencies can take to: (1) promote efforts to manage materials and products on a life-cycle basis, using present authorities, (2) build our capacity to manage materials in the future, and (3) accelerate the public dialogue necessary to start a generation-long shift in how we manage materials and create a green, resilient and competitive economy. We should begin aggressively.*

Our Material World

The foundation that underlies the world economy, prosperity and a healthy environment rests largely on how people extract and use the full range of materials that come from and return to the Earth such as wood, minerals, fuels, chemicals, agricultural plants and animals, soil, and rock.

The world at large and the United States in particular use vast amounts of materials and those amounts are rapidly increasing.

- In the past 50 years, humans have consumed more resources than in all previous history.
- The U.S. consumed 57% more materials in the year 2000 than in 1975; the global increase was even higher.
- With less than 5% of the world's population, the U.S. was responsible for about one-third of the world's total material consumption in 1970-1995.
- In 1900, 41% of the materials used in the U.S. were renewable (e.g., agricultural, fishery, and forestry products); by 1995, only 6% of materials consumed were renewable. The majority of materials now consumed in the U.S. are nonrenewable, including metals, minerals, and fossil-fuel derived products.
- Our reliance on minerals as fundamental ingredients in the manufactured products used in the U.S.—including cell phones, flat-screen monitors, paint, and toothpaste—requires the extraction of more than 25,000 pounds of new nonfuel minerals *per capita* each year.
- This rapid rise in material use has led to serious environmental effects such as habitat destruction, biodiversity loss, overly stressed fisheries, and desertification.

Projections are that between **2000 and 2050, world population will grow 50%, global economic activity will grow 500%, and global energy and materials use will grow 300%**. Commenting on the effects of material resource use on the environment, the heads of major research institutes in the United States, Germany, Japan, Austria, and the Netherlands have noted that "**unless economic growth can be dramatically decoupled from resource use and waste generation, environmental pressures will increase rapidly**.[1]"

The strategic importance of materials is causing many people to look very carefully at all aspects of the material life cycle that comprise our industrial practices and consumer habits. The material lifecycle begins with the extraction or harvesting of raw materials. Materials are then transported and processed to create the products and services that drive our society. They are distributed, consumed, reused or recycled, and ultimately disposed.

Each stage of this cycle requires energy and water as inputs and creates impacts on the environment. Because the stages are interrelated, it is important that sound approaches to materials use consider the entire life cycle. The price system, regulatory framework, technical information and human mindsets must all work together to enable and encourage **life-cycle materials management – an approach to serving human needs by using/reusing resources most productively and sustainably throughout their life cycles, generally minimizing the amount of materials involved and all the associated environmental impacts.**

By considering system-wide impacts, life-cycle materials management casts a far broader net than traditional waste and chemicals management approaches and represents a change in how we think about environmental protection. There are many means by which life-cycle materials management can be accomplished. For instance, careful industrial and product design that reduces virgin material use and reuses materials can reduce impacts throughout the system.

While there are a number of existing EPA and state programs that are helping to move the U.S. toward a more material-efficient society, there is no comprehensive materials management strategy at the Federal level. Regulations and economic instruments seek to prevent or mitigate certain impacts, but rarely take meaningful account of upstream or downstream effects.

To accomplish the shift to life-cycle materials management, governments at all levels need to make systematic efforts to enable, encourage, and collaborate with all parts of society, including business and consumers, to ensure that materials are used more efficiently and effectively. There is much work to be done, but there also is reason for modest optimism. An increasing number of industries and individual companies are taking a life-cycle view of their materials and processes and becoming more sustainable and competitive.

Origin of This Report

In 2002, EPA published “Beyond RCRA: Waste and Materials Management in the Year 2020”—commonly referred to as the 2020 Vision. The 2020 Vision was the product of a state/EPA workgroup and was endorsed by EPA and state environmental and waste program officials. One of the key findings was the need for society to shift focus away from waste management toward materials management. Even before the Vision’s release, states and EPA had been moving in this direction and in the years that followed they have continued to make progress.

In January 2007 the directors of EPA’s waste and chemical programs convened the present 2020 Vision Workgroup to develop a roadmap to accelerate the move toward sustainable materials management.

Building an Analytic Framework

The U.S. economy is a highly complex and intertwined system that transforms a few hundred raw materials into thousands of products. It would be unrealistic to focus on and transform all the materials and products consumed in an entire economy simultaneously. Instead, the Workgroup recommends a strategy that includes a few well-chosen demonstration projects to provide insights into applying integrated materials management approaches (including the need for better coordination of resources, product and waste programs). To help identify candidates for these demonstration projects, the Workgroup developed a framework to relatively rank the materials, products and services consumed in the U.S. from a life-cycle perspective, accounting for the environmental impacts, resource use (material, energy, water), and waste. This framework reflects the Workgroup's belief that these are the types of information that must be accounted for from a lifecycle perspective when applying materials management. Thirty-eight (38) materials, products and services were identified as possible candidates for demonstration projects. These can be roughly grouped into construction and development, food products and services, forestry, metals, nonrenewable organics, textiles, and other products and services.

Recommendations

The Workgroup makes three major recommendations to EPA and state environmental agencies. Some of these recommendations reflect points in international agreements under the Organization for Economic Cooperation and Development (OECD) and the Group of 8 (G8) endorsed by the United States in 2008.

1. **Promote efforts to manage materials and products on a life-cycle basis**. EPA and state environmental agencies should initiate demonstration projects on a few well-chosen materials and products to show the value of integrated materials management strategies. Further, these agencies should incorporate materials management as an important strategic approach for addressing climate change and other environmental challenges. The focus of existing chemical and waste programs should be expanded to encompass life-cycle materials management more fully.

2. **Build capacity and integrate materials management approaches in existing government programs**. EPA and state environmental agencies must ensure the availability of data and decision tools needed to support life-cycle materials management, including necessary research. Materials management strategies should be integrated into regulatory development, permitting and partnership programs. EPA and states should recognize and support champions who make this happen.

3. **Accelerate the broad, ongoing public dialogue on life-cycle materials management**. Governments alone cannot bring about the shift to life-cycle materials management. EPA and state environmental agencies should convene multi-stakeholder national dialogues on materials management to create public awareness of the environmental consequences of material and product choices and accelerate the momentum toward change at all levels. It also will be critical for the Agency to participate in international efforts related to sustainable material management.

These recommendations represent parallel paths that should be taken at the same time. Specific actions described under each recommendation are a mix of near term and long term efforts to develop the data, information, programs, policies, and partnerships that will begin to change the ways we think about and use materials.

These changes will not be easy. This report is a roadmap to the year 2020 – eleven years away. While this is not enough time to complete the changes recommended, it is enough time to make substantial progress. Starting now is critical because many of the issues we are facing require long-term solutions that cannot be put into place quickly when a problem becomes obvious or acute. The recommendations can be an important element of our national strategy to address current economic, energy, environment and climate issues and set us on a course to be more prosperous, competitive and resilient for years to come.

RECOMMENDATIONS

RECOMMENDATION 1: Promote efforts to manage materials and products on a life-cycle basis.

1.1 Select a few materials/products for an integrated life-cycle approach, and launch demonstration projects.
1.2 Expand the focus of existing environmental programs to encompass life-cycle materials management more fully.
1.3 Promote specific materials management approaches that can help address climate change.
1.4 Promote greener products, product stewardship, and product-to-service transformations.
1.5 Strengthen market signals to reduce waste and other adverse environmental impacts throughout the life cycle of materials.

RECOMMENDATION 2: Build capacity and integrate materials management approaches in existing government programs.

2.1 Establish and improve databases to promote materials management.
2.2 Improve decision tools to support life-cycle materials management.
2.3 Expand research and innovations support programs to promote materials management.
2.4 Emphasize materials management in EPA and state processes and procedures.
2.5 Support and reward federal, state, tribal, and local champions for materials management and encourage collaboration.

RECOMMENDATION 3: Accelerate the broad, ongoing public dialogue on life-cycle materials management.

3.1 Stimulate a national conversation about materials management, engaging multiple networks.
3.2 Open a dialogue on economic instruments to encourage better materials management.
3.3 Create ways to share knowledge on materials management.

Introduction:

Our Material World

Wood, minerals, fuels, chemicals, agricultural plants and animals, soil, rock and other materials form the foundation that underlies both the economy and the environment.

Climate change, energy policy, and the economy all create headlines, but the stories that follow often miss the point that all these issues are, in part, symptoms of how we use materials. It is becoming increasingly clear that how we use materials is a large factor in energy use, climate change and the economy, and an important issue in its own right. Therefore, if we want to address the issues behind the headlines, and if we want the U.S. to be competitive in the world economy, sustainable use of materials must be our goal.

The United States uses vast amounts of materials and these amounts are rapidly increasing—we consumed 57% more materials (by weight) in the year 2000 than we did in 1975 (see Figure 1). As described in Chapter 1, the global increase in materials use was higher. Materials returning to the environment increased 26% from 1975 to 2000 and the amounts remaining in use (mainly as durable products, buildings and roads, or "net additions to stock") rose 83%.[2] Historically, population and economic growth and new technologies have translated almost automatically into increased use of materials, energy and water.

No matter how one does the calculations, the implications of current patterns of material use for the environment (including climate), the economy and our survival are profound and unsustainable. We must change the historical relationship of materials, energy, growth and the environment. When used carefully, materials hold the keys to enormous opportunity, both as our nation competes in the global economy and as we move into the 21st century. Used carelessly, materials hold another set of keys, which open equally large threats to our health, our economy and our environment.

The opportunities presented by sound life-cycle approaches to using materials are being demonstrated in many places today. During the past several years, many companies and organizations have discovered ways to do what was previously thought improbable or even impossible. By changing the ways they use materials, they have found ways to lighten their environmental impacts significantly while increasing profit. They are making the U.S. more competitive with products that are recognized as more sustainable.

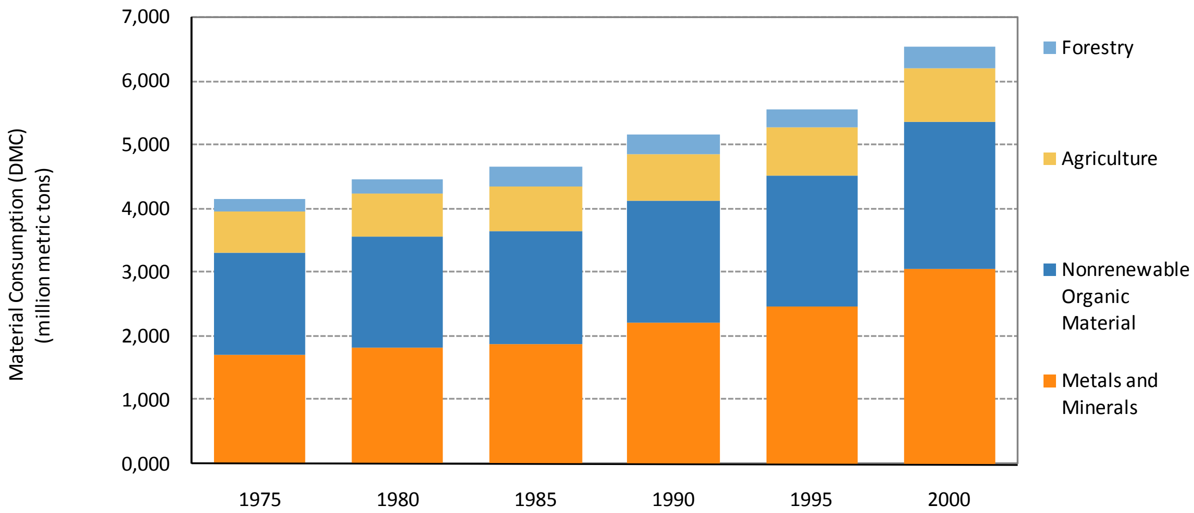


Figure 1: Materials Consumption in the United States by Sector of Origin, 1975–2000
Source: WRI Material Flows Database 2005

Threats to our environment caused by the ways we use materials are all around us and are not new. In 1992, world leaders participating in the Earth Summit declared that **"a principal cause of the continued deterioration of the global environment is the steady increase in materials production, consumption and disposal."**[3] In response, governments around the world, including the U.S., have acknowledged the goal of sustainable material use, but have struggled with how to achieve it.

This struggle about how best to manage materials demands a new level of awareness and cooperation within and between nations. The world shares a finite set of materials and other natural resources. We must know and respect the limits in order to live together and thrive within our means.

The current economic situation makes the opportunities and threats related to materials even more significant than they were only a short time ago. We are at a moment when many people are receptive to new approaches for the economy and the environment. We also observe many people and companies moving to use and spend less that they did previously.

It is not clear what choices individuals and companies will make. Therefore, **it is important that both the federal and state governments make more systematic efforts to enable, encourage, and collaborate with all parts of society to see that materials are used more effectively and efficiently with less overall environmental toll.**

These changes will not be easy. This report is a roadmap to the year 2020—eleven years away. Eleven years is not enough time to complete the changes this report describes, but it is enough time to make substantial progress.

There are actions we can take now that would build on our present programs and enhance our capacity for the future. We also need to accelerate the broad public dialogue about materials management to develop a common understanding, an ethic, a vision and a plan to move ahead. The recommendations in this report can be an important element of our national strategy to address the recent economic, energy, environment and climate headlines and set us on a course to be more prosperous, competitive and resilient for years to come.

This report builds on an effort begun in 1999, when EPA and state environmental agencies began a national dialogue through the Future of Waste Roundtable to suggest new ways of addressing waste generation and the use of our natural resources. In 2002, EPA published "Beyond RCRA: Waste and Materials Management in the Year 2020"—commonly referred to as the 2020 Vision.[4] (See Box 1.)

One of the key findings of the 2020 Vision was the need to shift from waste management to *materials management*.

This report is organized as follows:

Box 1

THE 2020 VISION

1. **Use resources in sustainable ways.**
2. **Take a life-cycle approach to managing risks.**
3. **Practice safe management for any waste that remains.**

The Vision was described in the 2002 report. It was endorsed by EPA, the Environmental Council of the States and the Association of State and Territorial Solid Waste Management Officials.

- **Chapter 1**, "A Resource Hungry World," describes trends in resource consumption, environmental impacts and why better materials management is essential.
- **Chapter 2,** "Building an Analytic Framework" describes the Workgroup's analytic approach to identifying materials and products that should be the initial focus of materials management demonstration projects.
- **Chapter 3**, "Workgroup Recommendations for Achieving Sustainable Materials Management" contains the recommendations.

Chapter 1:

A Resource Hungry World

Understanding the Flow of Materials

To understand the full effect that material use has on the environment, it is critical to understand the material life cycle, or how materials flow through the environment and the economy. The flow begins with the Earth itself, which provides a wealth of resources, including renewable and nonrenewable resource stocks, and energy sources. After materials are extracted and harvested from the Earth, most enter the product and service supply chains or are used for energy production. Through product design and manufacturing, materials are processed to create the products and services that meet the needs of society (see Figure 2).

Some raw materials and all products and services are then used or consumed by businesses or individual consumers. At the end of their lives, most products are collected and either reused, processed for return to use, or thrown away as waste.

Every step in this material flow requires energy and water as inputs and every step results in environmental impacts to air, water, and land. Throughout the material flow, materials and products require transport. As a result, this material flow contributes to a wide range of global, national, and local environmental impacts.

Trends in Global Material Consumption and Environmental Impact

In the past 50 years, humans have consumed more resources than they have in all previous history.[5] Between 1970 and 1995 alone, worldwide consumption of raw materials (not including food and fuel) doubled.[6] We can see the effects of material consumption on localized areas, and global environmental systems. For example:

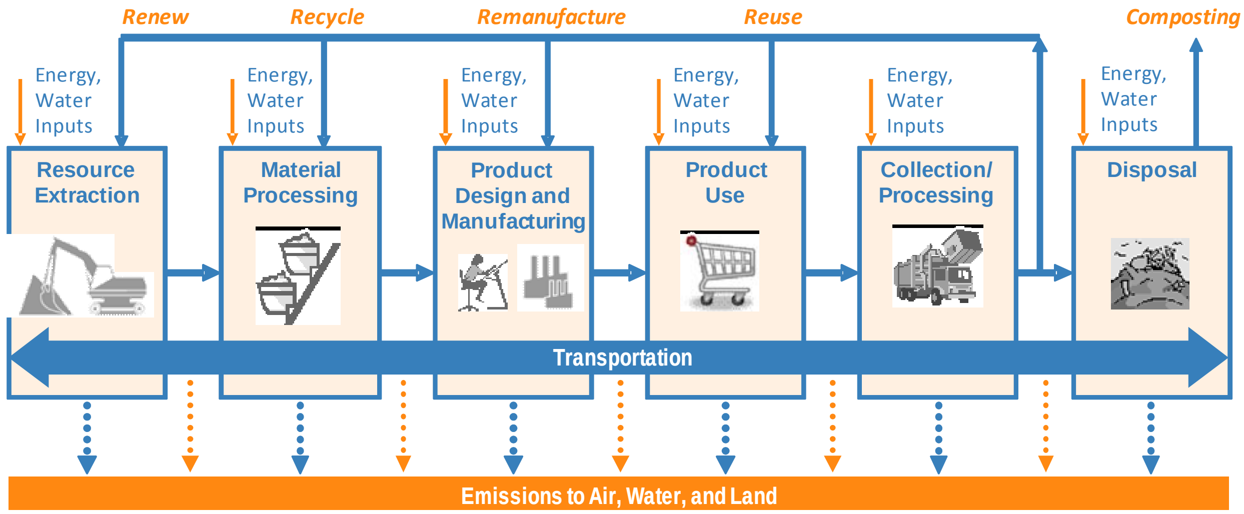


Figure 2: The Flow of Materials
Source: State/EPA 2020 Vision Workgroup

- The rate of deforestation in the tropics is approximately one acre per second.
- Half the world's tropical and temperate forests are now gone.
- 75% of marine fisheries are now overfished or fished to capacity.
- Freshwater withdrawals have doubled between 1960 and 2000; rivers including the Colorado, Yellow, Ganges, and Nile do not reach the ocean in dry seasons.
- Habitat destruction has contributed to species disappearance at rates about a thousand times faster than normal.
- Over half the agricultural land in drier regions suffers from some degree of deterioration and desertification.
- As available ore grades for some minerals decrease, the amounts of materials that have to be mined and processed to produce equivalent product increases, along with the environmental impacts.
- Persistent, bioaccumulative and toxic chemicals can now be found throughout the food chain.[7]
- Between 1970 and 2004, worldwide greenhouse gas emissions increased by 70%.[8] Most of the observed increase in global average temperatures since the mid-twentieth century is likely due to the increase in greenhouse gas concentrations associated with anthropogenic sources, including the extraction, processing, use and disposal of materials.[9]

The World Wildlife Federation routinely calculates humanity's ecological footprint—the area of productive land and water needed to provide resources and services such as food, fiber, and land on which to build, and land to absorb carbon dioxide released into the environment. This analysis is used to portray human demand, based on the **biological capacity** required to support resource consumption and waste absorption.

Since the late 1980s, our human footprint has exceeded the Earth's biocapacity. In 2005, global biocapacity was measured as 2.1 hectares *per capita,* while the average demand or footprint per person was 2.7 hectares. "This ecological 'overshoot' means that it now takes about one year and three months for the Earth to regenerate what we use in a single year."[10] The Earth's regenerative ability can no longer keep pace with human demand—people are turning resources into waste faster than nature can turn waste back into resources. In economic terms, we are no longer living off nature's interest, but drawing down its capital.[11] Globally, we can no longer presume that materials and resources we count on as abundant will remain so indefinitely.

In addition to exceeding the Earth's biocapacity by extracting too many materials, we return most of what we extract to the Earth as waste very quickly. According to the World Resources Institute, "one half to three quarters of annual resource inputs to industrial economies is returned to the environment as wastes within just one year." [12]

Prices for many materials are heavily influenced by global markets. During the past several years, increased demand caused worldwide prices for many raw and used materials to rise substantially. The recent economic situation, however, has reduced demand, causing prices for many materials to drop. The immediate effect of this has been to weaken recycling markets. If prices stay low, demand may increase over time. However, neither of these trends is helpful for long-term materials management or the environment.[13]

In general, it is widely understood that the price system leads to economically efficient allocation of material resources, but that does not mean that it necessarily encourages sustainable materials management. For instance, over the past 200 years, real prices for many industrial raw materials have fallen, often because of improved technology and low energy prices.[14] This has helped stimulate unparalleled economic growth, but, as mentioned above, it also has encouraged enormous increases in the amounts of materials used around the world.

There are several other features of markets and prices for many materials that do not encourage sustainable materials management:

- Prices for materials often do not adequately reflect "externalities" such as environmental damages incurred along the life cycle, leading to more consumption and greater environmental damages than would have otherwise occurred.
- Markets often deal poorly with intergenerational equity, and thus do not encourage sustainability.
- As historical patterns and the recent rise and fall of prices for oil and many materials illustrate, prices are frequently not a good indicator of long-term supplies and scarcities.

- Efficient use of material resources generally has little or nothing to do with toxicity, and in fact can encourage the use of toxic alternatives.

In theory, environmental and other regulations might be able to address many of these problems. In practice, however, our regulatory programs have not been designed to deal adequately with the multitude of decisions that are made along the life cycle of materials, and unsustainable materials use is often the result. Achieving materials management will require the full set of public policy tools including economic policies, regulations, information and partnerships. **With the right signals the market should be able to do a better job of addressing the range of problems that relate to sustainability.**

Trends in U.S. Material Consumption and Environmental Impact

The global trends are echoed by U.S. trends. Material resources used and consumed in the U.S. have grown from 161 million metric tons in 1900 to 2.8 billion metric tons in 1995—the equivalent of over 10 tons per person.[15] Of all the materials the U.S. consumed in the past 100 years, more than half were consumed in the last 25 years.[16]

Not only is the U.S. consuming more materials, but the types of materials consumed have changed significantly over time. In 1900, 41% of the materials used in the U.S. were renewable (e.g., agricultural, fishery, and forestry products); by 1995, only 6% of materials consumed were from renewable sources. The majority of materials consumed in the U.S. now are nonrenewable, including metals, minerals, and fossil-fuel derived products.[17] Our reliance on minerals as fundamental ingredients in the manufactured products used in the U.S.—including cell phones, flat-screen monitors, paint, and toothpaste—requires more than 25,000 pounds of new nonfuel minerals *per capita* each year.[18]

Correspondingly, the ecological footprint of a U.S. resident is estimated at 9.4 hectares, more than four times the global biocapacity *per capita*.[19] This large ecological footprint is primarily associated with energy production, which in turn is tied to greenhouse gas emissions.[20] A draft report being developed by EPA estimates that roughly 42% of U.S. greenhouse gas (GHG) emissions may be associated with material extraction and harvesting, and the production, transportation, and disposal of goods in the U.S., in part due to the energy needs for these processes.[21] (See Box 2.)

Not only are we drawing upon nonrenewable resources and impacting the environment at an increasing rate, we are also creating more waste. As U.S. consumers have grown to favor disposable products and convenience goods, waste has increased at all stages of the material life cycle.

The most visible waste in the U.S. is municipal solid waste, of which we generate over 250 million tons per year. U.S. *per capita* generation of municipal solid waste increased by 42% between 1970 and 2007, and has now leveled off at approximately 4.6 pounds per person per day.[22] But municipal solid waste represents only a small fraction of the total amount of waste generated within our society. One estimate of the total waste generated in the U.S. in 1996 is over 23 billion metric tons per year. Most of this waste is "hidden" from the economy.[23]

Box 2

MATERIALS AND CLIMATE

Reallocating the U.S. GHG Inventory to a materials management perspective reveals that roughly 42% of U.S. emissions are associated with the provision of materials and goods, including emissions from:

- Industrial sectors (direct emissions)
- Electricity used by industrial sectors
- Freight transportation
- Waste and waste management
- Agricultural sources
- Consumption of fuels and electricity in food processing
- Leaks from refrigeration
- Transportation of food-related products
- Industrial wastewater treatment by food processing facilities. [(a)]

Far more materials are being moved or transformed to meet society's needs than most people realize. In particular, "hidden" material flows (i.e., waste) include mining overburden, earth moving, and erosion, and account for as much as 75% of the total materials that industrial economies use. [24] However, because these hidden flows do not enter the economy as commodities bought or sold, they are not considered part of the traditional waste stream, and are not accounted for in the gross domestic product. They do, however, result in environmental degradation such as landscape alteration, loss of soil structure and fertility, stream flow changes, ecosystem disruption, and toxic impacts to land, air, and water from direct releases and leaching.

Global and U.S. Trends: Looking Ahead

Commenting on the effects of material resource use on the environment, the heads of major research institutes in the United States, Germany, Japan, Austria, and the Netherlands have noted that they expect that **between 2000 and 2050, world population will grow 50%, global economic activity will grow 500%, and global energy and materials use will grow 300%**. The world has been and is likely to continue experiencing unprecedented growth in global economic output, human population, and demands on air, land, water, and other resources. Reflecting on these trends, these same research leaders have stated that "**unless economic growth can be dramatically decoupled from resource use and waste generation, environmental pressures will increase rapidly**."[25]

While developed countries place more pressure on the environment than developing nations on a *per capita* and total basis today, this pattern is rapidly changing. (See Box 3.) The World Wildlife Federation has observed that "China is now on parity with the U.S. in terms of its pressure on the world's resources" as measured by ecological footprint.[26] As developing nations continue to industrialize and increase their material consumption, resource demands will only increase.

Through globalization, all countries are becoming increasingly reliant on imports. This shift has several important environmental consequences:

- It creates a disconnect between the environmental impacts of extraction, and production; these impacts are easy for the users of products and services to ignore when they take place far away.
- The environmental impacts of extraction and production can be higher than they might otherwise be if the exporting country has lower environmental safeguards than the importing country.
- Shipping goods long distances increases the impacts on the environment, including greenhouse gas emissions.

Box 3

US MATERIALS CONSUMPTION

Between 1970 and 1995, the U.S. represented about one- third of the world's total material consumption.[b]

With less than 5% of the world's population, the U.S. consumes:[c]

- 33% of paper
- 25% of oil
- 15% of coal
- 17% of aluminum
- 15% of copper

The world has not recently faced significant disruptive crises in the supply of materials, largely because new discoveries, substitutes, and technologies have averted or delayed predictions of shortages. Still, the international competition for some of the most abundant supplies is intense. The prospect for supply crises with certain key materials increases each year. It is not hard to imagine that if current and projected material consumption trends continue, we will face scarcity and depletion crises and leave far less resources than we have now for future generations.[27] However, the most pressing materials issue we face is the capacity of the Earth—the air, the water, and the land—to withstand the many types of environmental problems caused by our current patterns and rates of resource use.

These trends make the shift to sustainable materials management critical. The U.S. can lead the way in this effort. There is the potential not just to recover our own economy and environment, but also to assist developing nations in bypassing the less efficient practices of our history and achieving sustainable materials management. Without this leadership, we face increasing environmental deterioration and economic disruption. (See Box 4.)

Box 4

INTERNATIONAL AGREEMENTS

The international community is moving quickly towards life-cycle materials management. Many of the ideas and recommendations in this report reflect major points in two international agreements endorsed by the United States in 2008.

In the Organization for Economic Cooperation and Development (OECD) Council Recommendation on Resource Productivity (28 March 2008), OECD members agreed to:

- Strengthen their national capacity to measure and analyze material flows in ways that are internationally compatible;
- Develop and use indicators that assess the efficiency of material resource use;
- Take appropriate actions to improve resource productivity and reduce negative environmental impacts of materials and product use by promoting integrated life-cycle approaches, setting targets where appropriate, promoting new technologies, and sharing best practices;
- Work with relevant departments of government and organizations outside of government to this end; and
- Assist non-member countries to this end. [d]

The "Kobe 3R [Reduce, Reuse, Recycle] Action Plan" stresses that Group of Eight (G8) countries should:

- Give high priority to 3Rs policies, including the option of setting appropriate targets,
- Work together to encourage 3Rs on a global scale, through sharing of information and reducing regulatory and trade barriers that impede this goal, and collaborate to promote 3Rs capacity in developing countries.

The plan highlights were included in the G8 Summit Leaders Declaration in July 2008.[e][f]

Leading the U.S. to a More Sustainable Future: Materials Management

Materials management is a conceptual framework for systematically addressing the movement of materials through the economy and the environment from extraction to end of life. Figure 3 shows the complex interaction between the ecological, industrial, and societal systems supporting material use. Ecological systems provide the raw material inputs that drive industrial systems, or may be consumed directly by societal systems. Industrial and societal systems generate waste that can be recovered for beneficial use or disposed. As shown in Figure 3, there are many connections between components of the material life cycle, and therefore, many potential points for policy intervention.

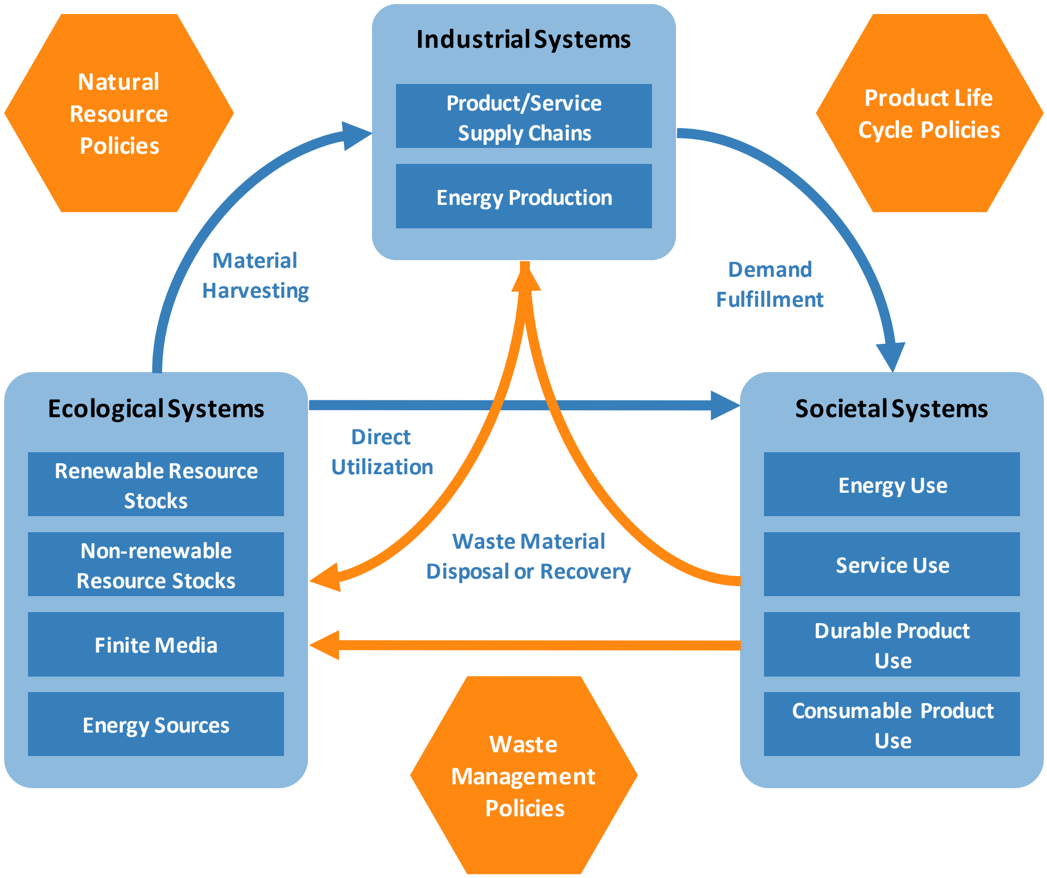


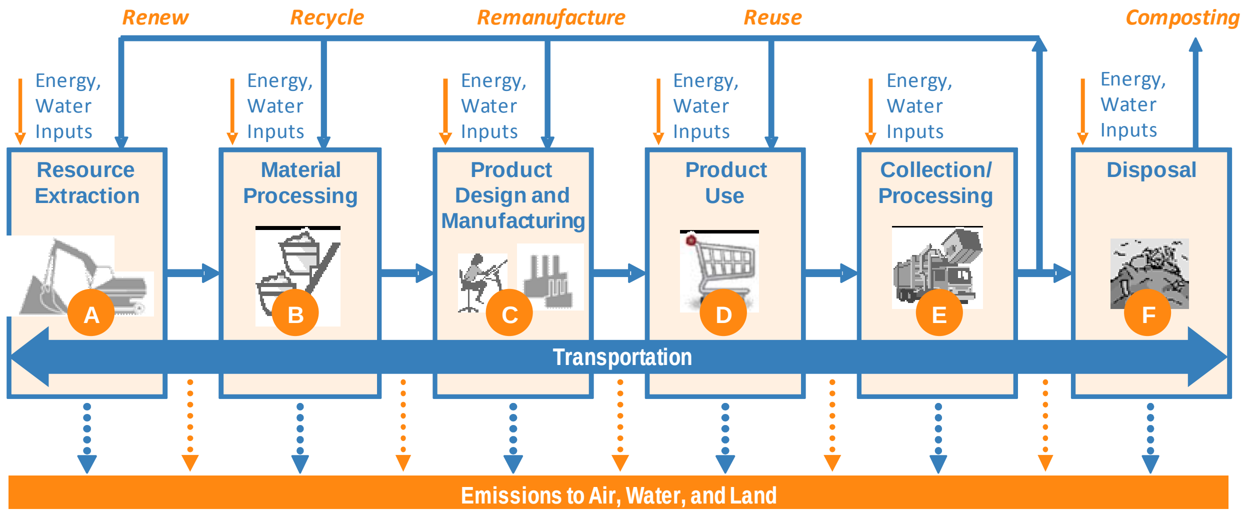
Figure 3: Framework for Examining Materials Management
Source: Fiksel, Joseph. "A Framework for Sustainable Materials Management," Journal of Materials, August 2006

The concept of **materials management** is fundamental to reducing our environmental footprint and assuring that we have adequate resources to meet today's needs and those of the future. The Workgroup developed the following definition of materials management, drawing from definitions used by other groups in the U.S. and abroad:

Materials management is an approach to serving human needs by using / reusing resources most productively and sustainably throughout their life cycles, generally minimizing the amount of materials involved and all the associated environmental impacts.

In this context, the Workgroup has followed the lead of many international organizations and defines materials to include everything that is extracted or derived from natural resources, which may be either inorganic or organic, at all points throughout their life cycles. We consider water and air as resources, but do not include them in our definition of materials, except as they become incorporated into a product. However, materials use does have direct impacts on air and water quality and scarcity.

By considering the impacts throughout the entire life cycle, materials management works to reduce environmental impacts, both (1) directly at each stage and (2) indirectly at multiple stages by reducing the amounts of materials used, and thus reducing system-wide environmental impacts. Some of the means by which this can happen are shown in Figure 4. For instance, industrial and product design can reduce impacts throughout the system.



Key: Approaches to Reduce Environmental Impacts in Individual Stages

A-C Material substitution, replacing toxic or hazardous materials with benign ones (detoxification)
A-C Cleaner technologies, reducing the toxic or hazardous properties of waste streams
A-C Redesign industrial processes to reduce toxic pollution and waste
A-F Reduction of GHG emissions associated with fossil fuel combustion and disposal
A-D Material regulation, restricting the use specified materials
D-E Recovery and beneficial recycling of post-industrial or post-consumer waste (Product Stewardship)
F Waste modification through chemical or biological treatment
F Waste containment or isolation to prevent human and ecological exposure
F In-situ waste treatment

Key: Approaches to Reduce Systemwide Material Use

A Extract less raw materials; extract only what is needed
A Prioritize the use of renewable materials and those that can be used in closed loop systems
A-F Increase in the material efficiency in the supply chain (zero-waste, dematerialization, industrial ecology)
A-F Industrial and product redesign to reduce mass, material use, packaging, life-cycle energy requirement, and toxicity
A-F Reduction of transport in the supply chain, thus reducing fuel and vehicle use
D-F Consume products that are less material-intensive, made with recyclable components, and more durable
C-D Substitution of electronic services for material intensive services
C-D Substitution of services for products
F Only biodegradable materials are disposed and returned to the Earth
A-F Consider the function of the product and whether it can be provided in a different manner

Note, Each of these approaches can be encouraged by a variety of "tools," such as regulations, economic incentives, information, collaboration, and so forth.

Figure 4: Materials Management Approaches
Source: State/EPA 2020 Vision Workgroup

Materials management encourages reduction in the amount of material extracted, and selection of renewable materials over non-renewable resources, where appropriate. Materials management also encourages changes in product design to use less material, reduce toxicity, and make products more reusable and/or recyclable. From the consumer perspective, materials management encourages consumption of products and services with the least environmental impact.

In a system that recognizes the true value of materials, and accounts for all the environmental impacts associated with materials use, the concept of waste is significantly changed. Products and materials presently viewed as acceptable to throw away will increasingly be recognized as valuable. Materials that used to "go to waste" will be reused or become feedstocks for new products and processes. Biodegradable materials that are not reused will be returned to the Earth to renew natural systems. Over time, as products and processes and ways of using things change, materials will begin to move in abundant sustainable cycles that nourish rather than deplete the Earth.

Different materials will require different management strategies. For example, the most important focus for non-renewable materials such as metals often will be to get the most use and reuse from each finite unit of the resource, while the focus for renewables such as wood and forest products has to include protection for the natural ecosystems that produce the resource.[28]

Attention to materials use efficiency and recovery will accelerate as concerns over climate results in new mandates to reduce greenhouse gas emissions. It is likely that new laws to address climate change will raise the cost of carbon-based energy, driving more efficient use of materials and favoring less energy-intensive materials. Incentives to conserve water in industrial settings are also likely to encourage more material conservation.

Some organizations and businesses already are making great strides in improving their economic bottom line and materials management processes. (See Box 5.)

How Does Materials Management Differ From Current Approaches?

Our current environmental regulatory system focuses largely on controlling "end-of-pipe" emissions—direct releases to air (e.g., from smokestacks or car tailpipes), water (e.g., effluent from factories or water treatment), and the land (e.g., landfill disposal). This system has and will continue to prevent or alleviate some important environmental impacts. However, because we do not systematically address materials movement through our economy and the environment (looking at the whole life cycle), we end up missing some impacts and/or inadvertently shifting environmental impacts from one medium to another.

These missed opportunities and undesired shifts leave us ill-equipped to address the pressures that will come with increases in population, economic activity and materials use.

Box 5

MOVING TO MATERIALS MANAGEMENT

An increasing number of industries and individual companies are taking a life-cycle view of their materials and processes, with the goal of reducing their environmental footprint, identifying greater efficiencies, stimulating technical advances, and making themselves more sustainable and competitive. Three examples are as follows:

- The metals industry, under the leadership of the International Council on Mining and Metals, has developed a Materials Stewardship Strategy, which aims to supply metals responsibly and to supervise materials flows so as to maximize societal value and minimize impact on human health and the environment. As part of this effort, the metals industry is starting to develop a better understanding of the full life-cycle of minerals and metal products. It is building and strengthening relationships with actors along the value chain (including commodity associations, fabricators, product manufacturers, scrap sellers, and recyclers). In addition, this project is making efforts to optimize the production and application of metals.[g]
- Ten cement companies are participating in a World Business Council for Sustainable Development-sponsored sustainability initiative for cement and concrete. One recommendation of this effort is that all old concrete should be used to make new concrete, or as aggregate for road construction, working toward a goal of recycling all demolition concrete. Work is also underway to reduce the carbon footprint of cement by using clinker substitutes, alternative fuels and raw materials, and improving energy efficiency.[h]
- The Keystone Center is facilitating discussions by a collaborative stakeholder group (consisting of producers, agribusinesses, food and retail companies, and conservation organizations) to develop a supply-chain system for encouraging sustainable agriculture. One of the first tasks of this group has been to develop metrics to measure the environmental, health, and socio-economic outcomes of agriculture in the U.S. These metrics will be used to create a Sustainability Index to help quantify and identify key impacts and trends over time, encourage industry-wide dialogue and goal-setting, and assist in continued progress on the path to sustainability over time.[i]

Even if our current regulatory framework operated perfectly, it was not designed with sustainability in mind and would not bring us to this point. This is a major challenge for EPA, state, tribal, and local governments, along with the governments of other nations. We need to identify new approaches and better integrate currently separate programs, to address how we extract materials and design, manufacture, use and deal with products at end-of-life. We need to do this not only for our environmental well-being, but also to maintain our competitiveness in the global market place. Increasingly, other nations are demanding more sustainable uses of materials and chemicals. U.S. industry needs to be equipped to meet these demands or it will fall behind competitively.

Materials management is different from current waste management approaches in several important ways:

- Materials management seeks the most productive use of resources, while waste management seeks to minimize and/or manage wastes or pollutants.
- Materials management focuses broadly on impacts and policies relating to all the life-cycle stages of a material or product—including such upstream considerations as using less material, using less environmentally intensive materials, or making products more durable, as well as downstream solutions such as reuse and recycling. Waste management usually focuses only on what to do with wastes once they are generated.
- Materials management is concerned with inputs and outputs from/to the environment, including use of materials, energy and water, plus multiple environmental impacts; it is not geographically constrained. Waste management is concerned mainly with outputs to the environment (air, water, land) and usually only those from waste and only where the waste is managed.
- The goal of materials management is overall long-term system sustainability, while the goal of waste management is often focused on managing a single set of environmental impacts.
- Materials management counts as responsible parties all those who are involved in the life cycle of a material or product, including industry and consumers. In contrast, waste management usually counts as responsible parties only those who generate waste.

Materials management therefore casts a far broader net than waste and chemicals management has traditionally done. It seeks to address and reduce the life-cycle environmental impacts from the making and consumption of materials and products and applies a systems-wide perspective in doing so. While there are a number of existing EPA and state programs that are helping to move the U.S. toward a more material-efficient society, there is no single strategy at the Federal level in the U.S. that collectively looks at all environmental impacts of materials and products throughout their life cycles. Regulations and economic instruments seek to prevent or mitigate certain impacts, but they rarely take sufficient account of upstream or downstream effects.

Seen this way, materials management is a very broad concept. It overlaps and supplements many other concepts that are being adopted by governments, businesses and others. (See Box 6.)

Solid waste programs at EPA and in most states tend to address waste in two ways: (1) by regulations governing waste identification, management, disposal and cleanup; and (2) by collaborations to encourage waste minimization, greater recycling, use of more recycled content, and identification of beneficial uses for materials that would otherwise be thrown away. In recent years, waste programs also have begun to address toxic chemicals reduction. For instance, the National Program for Environmental Priorities (NPEP) focuses on toxic chemical content in processes, products and intermediaries. However, the majority of waste programs' efforts have not focused on reducing the use of materials or the toxicity of products or manufacturing processes, or working with manufacturers to make sure that materials and products are more easily reused or recycled at end of life. Only by further shifting our focus away from end-of-life management towards solutions that address the root cause of waste can we begin to conserve resources and ensure that materials have high-value end markets when the products containing them reach the end of their useful lives.

EPA's work with the Sustainable Packaging Coalition (SPC), an NGO, provides an example of how lifecycle materials management approaches are being applied today. EPA has supported the SPC's efforts in creating a comprehensive set of resources for design of more sustainable packaging – the Design Guidelines for Sustainable Packaging and the COMPASS design tool. As the design of packaging influences the entire packaging supply chain, designers who understand the flow of materials are in an ideal position of optimizing a package for its entire life cycle. (See Figure 5.)

Box 6

MATERIALS MANAGEMENT AND RELATED CONCEPTS

Materials management is a very broad concept. It overlaps and supplements many other concepts being adopted by government, business and others including, but not limited to:

- Sustainable Materials Management (OECD)
- Sustainable Production and Consumption (UNEP)
- Sustainable Resource Management (UNEP)
- 3Rs: Reduce, Reuse, Recycle (G8)
- Sound Materials Society (Japan)
- Design for the Environment (EPA and others)
- Green Chemistry
- Lean Manufacturing
- Sustainable Supply-Chain Management
- Eco-labeling
- Green Procurement
- Zero Waste

EPA's **chemical programs** have made progress in recent years towards adopting life-cycle materials management. Efforts that address choices made early in the life cycle, such as the Green Chemistry, Green Engineering, Pollution Prevention and Design for the Environment Programs, form a good foundation on which to build. However, the more "traditional" parts of the programs remain largely focused on reducing or eliminating the use of individual chemicals, or classes of chemicals in certain products or processes that may pose potential risks—often by using informed substitution to move toward safer chemical substitutes. To move more aggressively toward the broader goal of sustainability, more effort needs to be made to identify and address the full range of environmental impacts associated with materials and products throughout their life cycles. Some states are moving in this direction. (See Box 7.)

Box 7

STATES' PROGRESS TOWARDS MATERIALS MANAGEMENT

A number of states have ambitious programs to move towards materials management. One example is California's green chemistry program which requires that the State identify chemicals of concern, evaluate alternatives, and specify regulatory responses where chemicals of concern are found in products. Washington and Maine have similar programs.

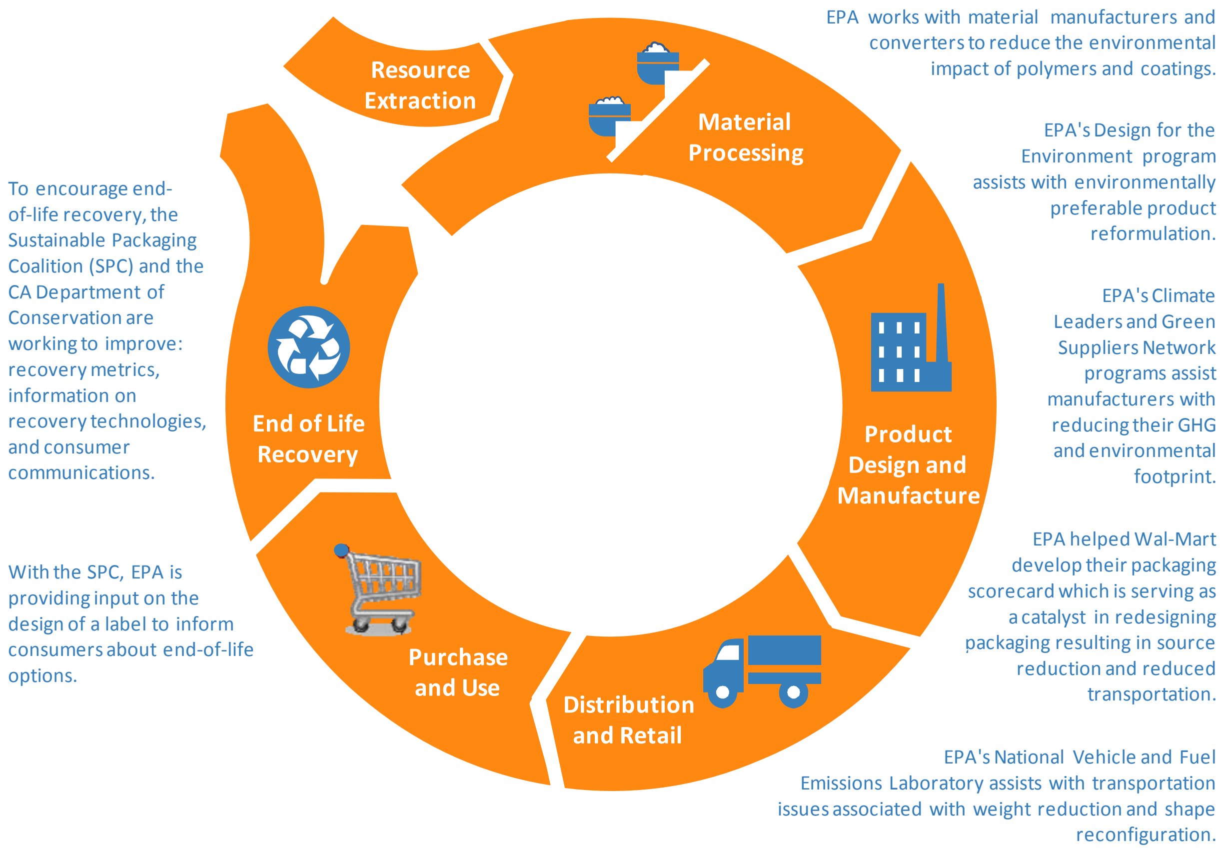


Figure 5: Example of a Life-cycle Materials Management Approach for Packaging
Adapted from "Design Guidelines for Sustainable Packaging," Sustainable Packaging Coalition, GreenBlue, 2006

Independent efforts to address the issues of climate change, energy conservation, and water conservation miss opportunities for achieving maximum environmental impact, because they do not also consider broader approaches to managing materials more sustainably. Because materials have such a large impact on a wide variety of environmental issues, integrated materials management approaches will yield significant benefits while achieving more efficient resource use and cost savings.

A comprehensive materials management approach serves to direct environmental, product, and resource policy to those areas where it will provide the greatest environmental benefit. It will enable us to focus on those material flows which potentially cause the greatest harm and where in the life cycle they occur. It also will allow us to determine which material flows are overly wasteful, where they originate, and where they ultimately end up. It will also help identify which activities or products are primarily responsible for these harmful flows, and devise strategies that have the greatest likelihood of being environmentally and economically effective.

Chapter 2:

Building an Analytic Framework

While considering the idea of a comprehensive materials management approach, the Vision Workgroup recognized the importance of identifying priorities and conducting a few well-chosen demonstration projects to show the value of this approach and gain greater insights on integrating policies and programs around materials management. The Workgroup also recognized that any comprehensive materials management strategy should build on an analytical framework that accounts for the fact that a few hundred raw materials are extracted or harvested from the environment and subsequently transformed into thousands of final products by a highly complex and intertwined system. As noted earlier, numerous environmental impacts arise as a consequence of how this system of materials and products currently operates.

Developing the Framework

To formulate a materials management analytical framework, the Workgroup built on the experiences of other organizations and initiatives. The Workgroup reviewed the efforts of the European Commission, the Organization for Economic Cooperation and Development, and other nations, seeking to prioritize materials, products or wastes. This body of knowledge suggested the need to understand the life-cycle impacts of materials in order to construct more interlocking and effective materials management policies. For example, the European Commission (EC) conducted its Environmental Impacts of Products (EIPRO) study to identify products which potentially cause the greatest life-cycle environmental impacts across eight environmental impact categories such as global warming potential and human toxicity. The EC is identifying ways to reduce life-cycle impacts and develop appropriate policy measures to achieve reductions.[29]

Evaluating the life-cycle environmental impacts of material use is important and can identify which materials have the greatest overall potential impacts to humans and the environment. However, the Workgroup felt it was important to go beyond environmental impacts and to include resource use (materials, water, and energy) and material waste. Examining all these aspects from a life-cycle perspective enables strategic targeting of policies to promote more efficient use of materials and reduce environmental impacts across all stages of the material system.

Another important consideration when developing materials management strategies is viewing the environmental aspects from more than one perspective across the material system. As a point of comparison, the EIPRO study assessed the life-cycle impacts of products consumed by households (often termed final consumption.) This meant all of the impacts from all stages, from extraction of the raw materials through end-of-life, are “passed on” and embedded in the final product sold to a household. This perspective reveals final products that are familiar to consumers and that have the greatest life-cycle impacts.

However, using a final consumption perspective may hide significant impacts of upstream material stages, especially when the outputs of those stages become widely dispersed across a large number of different final products. Each of those final products will have separate material composition profiles and life cycles. For example, copper mining potentially contributes significantly to environmental and human health impacts, uses a fair amount of energy, water, and material, and produces quite a bit of waste. Using a product or final consumption perspective, these potential impacts would be dispersed among the thousands of products in which copper is used, such as currency, batteries, circuits, industrial components, telecommunications equipment, roofing, household items, piping, and a wide variety of electronic products. The life-cycle impacts associated with creating those products would be captured, including the impacts of copper mining, but because copper comprises such a small portion of the individual products, the impacts of copper mining as a whole would be hidden.

Thus, it is important to include perspectives that can reveal environmentally problematic upstream stages such as extraction (e.g., copper ore) or initial material processing (e.g., smelting) and middle stages such as manufacturing, as well as the final product. Evaluating a material system through more than one perspective can yield dramatically different results and better inform a materials management strategy.

In summary, the Workgroup identified the following components as integral in establishing an analytical framework for materials management strategies:

- **Establishing the universe**: Use the most complete dataset of materials, products, and services whose relationships in an economy are well mapped.
- **Understanding all impacts, inputs, and outputs**: Include the full range of environmental aspects including environmental impacts, resource use (material, energy, and water) and material waste. For environmental impacts, cover as many environmental and human health impacts as possible.
- **Using perspectives to understand where the impacts are occurring**: View the material system from different perspectives to ensure impacts are fully revealed.

Applying the Framework to the U.S. Economy

In applying this framework to identify potential candidates for demonstration projects, the Workgroup created an approach using existing tools and data to produce a relative ranking of the materials, products and services consumed in the US economy. The methodology developed is based on the components identified above and is described in detail in the Appendix (a separate document).

The **universe established** for this analysis was the 480 materials, products and services included in the U.S. Bureau of Economic Analysis (BEA) 1998 input/output (I/O) tables (most recent year available when analysis done). These 480 materials, products and services span all stages of the material system from extraction such as copper ore to final consumption of products or provision of services such as jewelry or hospitals. The I/O tables map the relationships of these materials, products and services to one another in the U.S. economy. Also, the primary data source used in the analysis was the Comprehensive Environmental Data Archive (CEDA 3.0) which uses the BEA I/O tables as its baseline list of materials, products and services. The CEDA 3.0 tool was used in the EIPRO study and enhanced to incorporate end-of-life.

For the **environmental impacts and inputs and outputs,** the Workgroup considered thirteen environmental impacts included in CEDA: abiotic depletion, land use, global warming, ozone layer depletion, human toxicity, freshwater aquatic toxicity, marine aquatic toxicity, terrestrial ecotoxicity, freshwater sedimental ecotoxicity, marine sedimental ecotoxicity, photochemical oxidation, acidification, and eutrophication. Further, material, energy and water use and material waste were included. These became the 17 criteria on which the 480 materials, products and services were relatively ranked. Although it may appear that there are some redundancies among the 17 criteria, they each address an important consideration in priority setting.

While CEDA was equipped to assess environmental impacts and energy use, it did not have the ability to assess material and water use, or material waste disposed. Data for these came from the World Resources Institute's Material Flows Analysis database (material use and waste) and the U.S. Geological Survey (water use). However, these data were compiled using different classification schemes which meant that extensive cross-walking to the BEA classification scheme was required. The Workgroup used innovative techniques for allocating those data into the BEA's list of 480 materials, products, and services. For example, a WRI material may have had a direct relationship with a material in BEA's lists (e.g., WRI coal to BEA coal). In other cases, a WRI material was related to a number of different products (e.g., WRI grain to a number of BEA commodities such as bread, meat animals, etc).

Finally, the Workgroup examined the 480 materials, products and services from **three different perspectives** referred to as "direct impact/resource use/waste," "intermediate consumption," and "final consumption." (See Figure 6.)

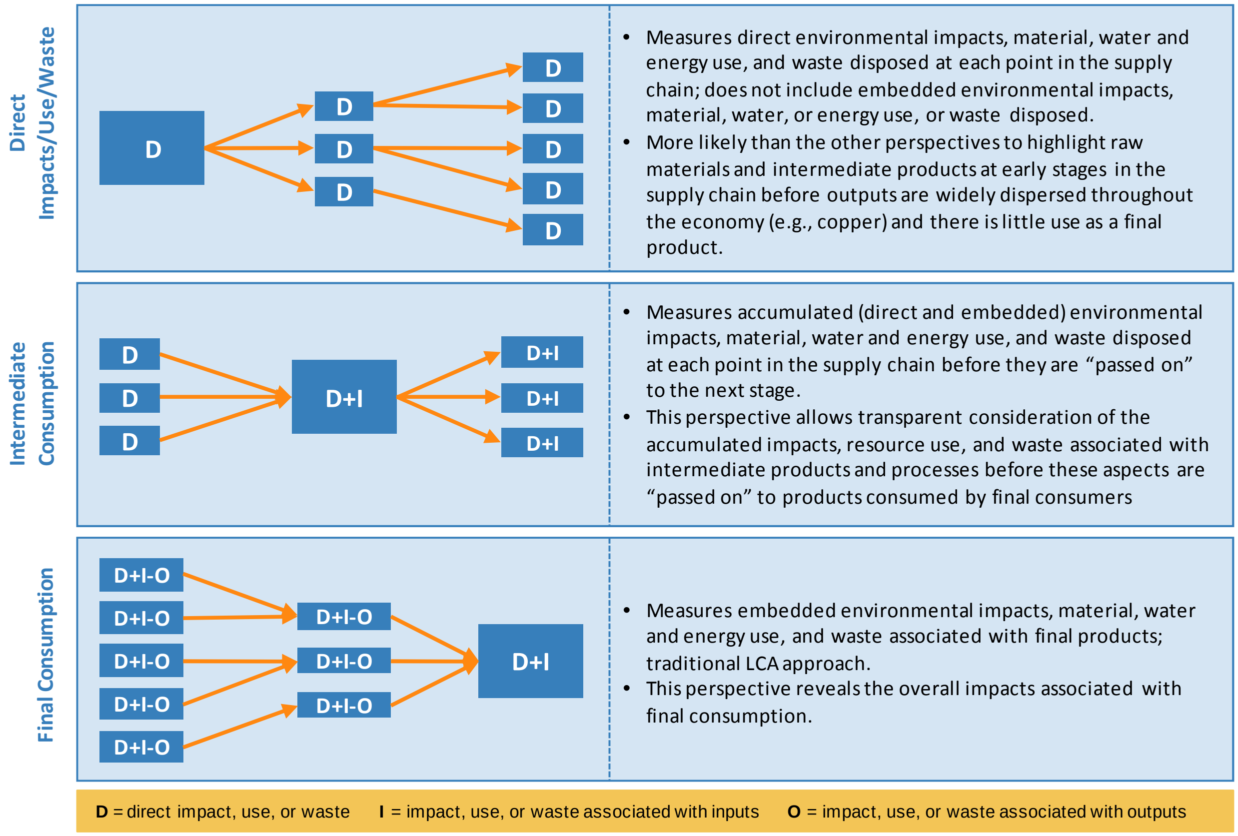


Figure 6: U.S. Supply Chain Perspectives

The direct impact/resource use/waste disposed perspective examines what environmental impacts, resource use and waste are occurring at each life-cycle stage of a material system; nothing is embedded from other stages. This perspective potentially reveals where in a material or product life cycle the greatest direct impacts occur (and those over which a facility has direct control). Upstream stages such as extraction and harvesting are likely to be revealed.

The intermediate consumption perspective examines all the accumulated life-cycle impacts at each life-cycle stage before they are embedded and passed on to the next stage. This perspective reveals where in a material system the greatest accumulated impacts, resource use and waste occur, and is likely to reveal upstream activities (e.g., material processing and manufacturing) and intermediate products.

The final consumption perspective "passes on" and embeds all impacts from across the material system in the final products consumed. For this analysis, final consumers were defined as both households and government. This perspective reveals which materials, products and services consumed by households and government have the greatest life-cycle impacts, resource use and waste.

Once all the results were obtained, an applied vector analysis approach was used to produce a relative ranking of the 480 materials, products and services in each of the three supply chain perspectives.

It is important to recognize that the results produced by this analysis are not direct measures of impacts or risk, but rather provide a relative ranking of materials, products, and services potentially contributing significantly to environmental issues. Also, the 480 materials, products and services represent commodity groupings and thus the results cannot be interpreted to single out any individual company or specific product as particularly resource-intensive, wasteful or environmentally damaging.

Recognizing the complexities of the analysis, the Workgroup had it peer reviewed by independent experts. The peer reviewers found the overall approach and results produced a reasonable starting point for identifying materials, products, and services on which to focus. They also provided several recommendations for improving the analysis. The Workgroup followed-up on some of these recommendations.

What We Found

Table 1 presents the results of the Workgroup's analysis of the U.S. consumptive economy. The table is a compilation of the top 20 highest ranked materials, products and services from each system perspective when ranked across all criteria. This process identified 37 materials, products and services. Just under half of the 37 ranked within the top 20 in only one or two system perspectives. Because the analysis was conducted using 1998 data, we conducted an analysis of significant market trends between 1998 and the present to determine whether any adjustments should be made to the overall results. As a result, "Computer and Data Processing Services" was added due to its profound growth. Therefore, Table 1 contains a total of 38 materials, products and services.

The table presents the individual materials, products and services grouped into seven broad categories: construction and development, food products and services, forestry, metals, nonrenewable organics, textiles, and other products and services. They are grouped in a manner to depict crude direct relationships (e.g., feed grains, meat animals, meat packing plants, eating and drinking places). For each material, product and service, the table shows the final rank for each perspective, as well as the environmental aspects contributing significantly to its high ranking.

All of the 17 criteria proved important to the ranking outcomes, although certain criteria tended to contribute more significantly to high rankings than others.

To demonstrate the merits of including all the criteria, a comparative examination of rankings was performed to observe changes as more criteria groups were added. This was done using the final consumption perspective. For example, results for a single criterion, global warming, were compared to the results when all environmental impact criteria were used, and then to the results when all seventeen criteria were used. For global warming, air transportation and meat packing plants ranked high and were close in terms of their potential life-cycle global warming impacts. Addressing either from a life-cycle perspective would achieve important GHG reductions. However, when the remaining environmental impact criteria are included, the rank of meat packing plants rose significantly while air transportation fell. When the resource use and material waste criteria are added, meat packing plants maintained their high ranking position and air transportation rose, but remained significantly lower than meat packing plants. Thus, if meat packing plants are addressed from a life-cycle perspective, significant benefits potentially could be realized related to land use, freshwater aquatic ecotoxicity, photochemical oxidation, terrestrial ecotoxicity and eutrophication, in addition to global warming. Addressing air transportation, on the other hand, potentially offers only energy use and global warming benefits.

The table also demonstrates the importance of using several perspectives. Different materials, products and services rank high depending on which perspective is used and these materials, product and services generally fall within different life-cycle stages. Extraction and harvesting tend to rank high under the direct impact/resource use/waste perspective, while finished goods and services rank high under the final consumption perspective. The intermediate consumption perspective tends to rank high in the material processing and manufacturing stages, and less likely to rank high in services. Each perspective highlights potentially significant problematic materials, products, or services that the other perspectives missed.

The Workgroup was also interested in looking at the results related specifically to greenhouse gas (GHG) emissions from all 3 perspectives. The results showed that when looking at direct GHG emissions, the upstream stages were highly ranked – for example, feed grains, and blast furnaces/steel mills. However, when looking at embedded GHG emissions, the downstream stages are highly ranked such as hospitals, meat packing plants, and automotive repair shops and services.

Conclusion

The Workgroup believes that this examination of the 480 materials, products, and services across seventeen environmental criteria and from three different material system perspectives provides a reasonable narrowing of the economy to identify a pool of potential candidate materials, products and services which are important enough to be considered for projects to demonstrate the value of using life-cycle materials management. However, the Workgroup recognizes that an analysis such as this gives rise to many limitations and uncertainties such as correlations between criteria, the difference in level of commodity aggregation that exists for 480 materials, products and services examined, and the varying quality levels of the data used. Nevertheless, the 38 materials, products and services identified in Table 1 are likely to represent significant contributors to environmental issues in the U.S.

This life-cycle analysis of the U.S. economy provides a rough sense of what impacts are occurring, where they are occurring, and what demands are behind them through its rather complete set of criteria and perspectives, limitations and uncertainties notwithstanding.

This analysis also enables us to select demonstration projects that focus on particular types of materials management challenges. These challenges can include trying to address materials that become highly dispersed in the economy (e.g., aluminum); products or services that are a convergence of highly dispersed upstream materials (e.g., electronics, hospitals); or materials from each type of raw material category (e.g., agriculture, metals and minerals, nonrenewable organics). Each of these cases would have very different cycling pathways through the economy, from almost circular such as metals to essentially linear such as food. In addition, the process for selecting the demonstration projects can take advantage of the crude “supply chain” relationships that can be observed in Table 1 (e.g., feed grains, meat animals, meat packing plants, and meat consumers).

Regardless of how projects are selected, they should be designed to address the entire materials system. The analysis can serve as an initial guide on which impacts need to be addressed, where they are in the supply chain, and which parties should participate in crafting a materials management strategy.

Beyond identifying demonstration projects, this analysis may offer interesting insights on the value of present program activities, as well as any priority-setting endeavors around a particular environmental impact such as GHG emissions. The analysis performed for this report can serve well as a model for environmental analysis in the future.

Table 1: Summary of Top-Ranked Materials, Products, and Services

	Material, Product, or Service	Final Rank			Environmental Aspects Significantly[1] Contributing to Final Rank		
		DI	IC	FC	Direct Impact/Resource Use/Waste Perspective	Intermediate Consumption Perspective	Final Consumption Perspective
Food Products & Services	Dairy farm products	19	–	–	LUC		
	Poultry and eggs	20	–	–	LUC		
	Meat animals	6	6	–	LUC	LUC, FAETP, TETP, EP	
	Food grains	13	–	–	LUC, EP		
	Feed grains	9	15	–	LUC, FAETP, TETP, EP, MU	ADP, LUC, FAETP, TETP, EP	
	Miscellaneous crops	16	–	–	FAETP, TETP, EP		
	Meat packing plants	–	11	7		LUC, FAETP, TETP, EP	LUC, FAETP, TETP
	Poultry slaughtering and processing	–	–	17			LUC,
	Eating and drinking places	–	16	5		LUC, GWP, FAETP, TETP, POCP, EP	LUC, GWP, ODP, HTP, FAETP, MAETP, TETP, FSETP, MSETP, POCP, AP, EP, MU, MW, EU
	Food preparations, n.e.c.	–	–	19			FAETP,TETP,EP
	Fluid milk	–	–	20			LUC
Textiles	Cotton	2	2	–	FAETP, TETP, EP	FAETP, TETP, EP	
	Apparel made from purchased materials	–	13	2		FAETP, TETP, EP	ODP, HTP, FAETP, TETP, MSETP, EP
	Broadwoven fabric mills and fabric finishing plants	–	10	–		FAETP, TETP, EP	
Nonrenewable Organics	Coal	5	9	–	ADP, MU, MW	ADP, MU, MW	
	Crude petroleum and natural gas	4	4	–	ADP, GWP, POCP	ADP, GWP, POCP, AP, EP	
	Industrial inorganic and organic chemicals	3	3	–	ODP, HTP, MSETP, MW	ODP, HTP, MSETP, POCP, EP, MW	
	Petroleum refining	8	5	3	MU, MW	ADP, GWP, POCP, AP, EP, MU, MW	ADP, GWP, ODP, POCP, AP, EP, MU, MW
	Electric services (utilities)	1	1	1	GWP, HTP, MAETP, FSETP, POCP, AP, EP, WU, EU	ADP, GWP, HTP, MAETP, FSETP, POCP, AP, EP, MU, MW, WU, EU	ADP, GWP, HTP, MAETP, FSETP, POCP, AP, EP, MU, MW, WU, EU
	Natural gas distribution	15	14	12	MU, MW	ADP, MU, MW	ADP, MW
Metals	Blast furnaces and steel mills	–	17	–		GWP, HTP, POCP, MW, EU	
	Primary aluminum	18	20	–	ODP, HTP, MAETP, FSEPT, MSEPT	ODP, HTP, MAETP, FSETP, MSETP	
	Motor vehicles and passenger car bodies	–	12	4		GWP, ODP, HTP, MAETP, FSETP, MSETP, POCP, EP, EU	ADP, GWP, ODP, HTP, FAETP, MAETP, TETP, FSETP, MSETP, POCP, AP, EP, MW, EU

	Material, Product, or Service	Final Rank			Environmental Aspects Significantly[1] Contributing to Final Rank		
		DI	IC	FC	Direct Impact/Resource Use/Waste Perspective	Intermediate Consumption Perspective	Final Consumption Perspective
Construction & Development	Dimension, crushed and broken stone	14	–	–	MU		
Construction & Development	Sand and gravel	17	–	–	MU		
Construction & Development	New residential 1 unit structures, nonfarm	10	8	8	MU	BWP, ODP, HTP, FSETP, MSETP, POCP, MU	GWP, ODP, HTP, MSETP, POCP, EP, MU, MW
Construction & Development	Other new construction	–	–	13			GWP, ODP, HTP, MSETP, POCP, MU
Construction & Development	Owner-occupied dwellings	–	–	11			GWP,OCP, HTP, MSETP, POCP, EP, MU
Construction & Development	New highways, bridges, and other horizontal construction	–	–	10			HTP, POCP, MU
Construction & Development	New office, industrial and commercial buildings construction	–	–	16			ODP, MTP, MSETP, POCP, MU
Forestry	Pulp mills	11	–	–	HTP, MSETP		
Forestry	Paper and paperboard mills	7	7	–	HTP, MSETP	HTP, MSETP	
Other Prods & Services	Computer and data processing services: including own-account software[2]	–	–	–			
Other Prods & Services	Photographic equipment and supplies[3]	12	–	14	HTP, MSETP		HTP, MSETP
Other Prods & Services	Wholesale trade	–	19	15		GWP, ODP, HTP, MSETP, POCP, EU	ODP, HTP, MSETP, POCP
Other Prods & Services	Retail trade, except eating and drinking	–	–	6			ADP, GWP, ODP, HTP, MAETP, FSETP, MSETP, POCP, AP, EP, MU, MW, WU, EU
Other Prods & Services	Hospitals	–	–	9			GWP, ODP, HTP, TETP, FESTP, MSETP, POCP, EP, MW, EU
Other Prods & Services	Real estate agents, managers, operators, and lessors	–	18	18		GWP, HTP, POCP, MU	ODP, HTP, POCP, MU

NOTES: (1) Significantly means value greater than two standard deviations from the mean.

(2) The supplemental markets trends analysis suggests that if relative output were adjusted from 1998 to 2007 levels, the "computer and data processing services" category would rank as high as second from the final consumption perspective. For 1998 levels, it ranks 26th in the final consumption perspective with marine sedimental ecotoxicity being the significantly contributing environmental aspect.

(3) The supplemental market trends analysis suggests that if relative output were adjusted from 1998 to 2007 levels, the "photographic equipment and supplies" category would be ranked below the top 20 from the final consumption perspective.

KEY:

DI = Direct impact/resource use/waste
IC = Intermediate consumption
FC = Final consumption

- *Shading shows the top 10 highest ranks for each perspective.*
- *– = ranked below top 20.*

Environmental Impacts
ADP = abiotic depletion potential
AP = acidification potential
EP = eutrophication potential
FAETP = freshwater aquatic ecotox. potential
FSETP = freshwater sediment ecotox. potential
GWP = global warming potential
HTP = human toxicity potential
TETP = terrestrial ecotox potential
LUC = land use
MAETP = marine aquatic ecotox. potential
MSETP = marine sediment ecotox potential
ODP = ozone depletion potential
POCP = photochemical oxidation potential

Resource Use and Waste
EU = Energy Used
MU = Materials Used
MW = Material Waste
WU = Water Used

Chapter 3:

Workgroup Recommendations for Achieving Sustainable Materials Management

The recommendations are an integrated plan that provides a "roadmap" of tasks to promote materials management within EPA, state and tribal environmental programs. They call for immediate actions along three parallel paths.

- First, we recommend steps that EPA and state environmental agencies can take to promote integrated materials management, building on current programs including core regulatory programs.
- Second, we recommend that EPA and state environmental agencies move quickly to enhance their capacity for future life-cycle materials management.
- Third, we recommend accelerating an active, multifaceted conversation on life-cycle materials management with other parts of the federal government, state government, industry, academia, non-governmental organizations, and the public.

Along these three paths, several cross-cutting themes underlie a national movement towards sustainable materials management.

- Government itself does not manage most materials, but its collective actions can have a strong impact on how materials are managed throughout the economy.
- EPA, state, tribal, and local environmental programs need to align and integrate their approaches, where possible, to move beyond existing program and product "silos."
- Government agencies at all levels need to work together to use a variety of regulatory, economic, information and collaboration tools to accomplish the shift to materials management.

Government environmental agencies need to engage across administrative, geographical, governmental and stakeholder boundaries to develop effective materials management strategies. These engagements are particularly needed to achieve changes early in the life-cycle of materials.

The recommendations focus on materials management in the year 2020—eleven years from now. This time frame is intended to emphasize that the changes described in this report will take longer than a few years to achieve. But it is possible—and necessary—to begin now.

RECOMMENDATION 1:

Promote efforts to manage materials and products on a life-cycle basis.

1.1 Select a few materials/products for an integrated life-cycle approach, and launch demonstration projects.

Working with the Environmental Council of the States (ECOS), the Association of State and Territorial Solid Waste Management Officials (ASTSWMO), and other groups as appropriate, EPA should select a few materials and/or products where an integrated life-cycle materials management approach could possibly achieve significant benefits for the environment and reduce resource use. The selection should be based on the analysis described in Chapter 2/Table 1 of the top ranked materials/products and on expressions of interest and likely collaboration by potentially affected stakeholders and key decision makers.

Once demonstration projects are selected, EPA should convene and empower EPA/state workgroups to develop frameworks to reduce environmental impacts of the materials/products throughout the life cycle. These groups should start by examining ongoing efforts (in government and/or private sector) and consider questions such as those in Box 8 to develop initial frameworks that:

1. strategically address life-cycle impacts with ambitious targets;
2. integrate existing and new efforts across environmental media and programs (e.g., air, water, toxics, waste);

Box 8

QUESTIONS FOR MATERIAL/PRODUCT WORKGROUPS TO ADDRESS

1. What are the significant environmental impacts associated with this material or product (e.g., where in the life cycle do the impacts occur, what processes drive these impacts, and what type of opportunities exist to reduce these impacts)? Also, are there potential risks of short or difficult-to-obtain supplies?
2. What is currently being done to address the impacts associated with this material/product?
3. If all impacts are not being addressed, what more can we do (e.g., fill information gaps, do more with less, find substitutes for toxic inputs, close the loop)?
4. What targets/strategies for improvement are advised? How should progress be measured?

3. use a variety of regulatory and non-regulatory tools; and
4. account for the full cost of products and waste.

EPA and the states should seek stakeholder input on the frameworks and work with interested stakeholders to develop shared action plans. Action plans should consider creating multi-stakeholder teams capable of sustained and adaptive management for the pilot material or product (e.g., building on the model of the Quicksilver Caucus for mercury). They also should share information and insights with groups that are already working on those materials/products.

1.2 Expand the focus of existing environmental programs to encompass life-cycle materials management more fully.

EPA should work with states to expand the focus of the "mainline" environmental programs, especially the solid and hazardous waste and chemicals programs, to encompass the complete life cycle of materials more fully. At a minimum, EPA and states should identify specific opportunities to realign, refocus, or expand their efforts to promote life-cycle materials management. (See Box 9.) This should include:

- Examine regulations to find ways to reduce barriers to life-cycle material management and promote resource efficiency.
- Encourage greater recovery and reuse of critical materials.

Box 9

OPPORTUNITIES FOR WASTE AND CHEMICALS PROGRAMS

1. Set realistic targets to transition towards increased use of secondary materials, reduced material and toxic intensity, as well as reduced waste, toxic and physical insults to the environment.
2. Find ways to prevent key materials/product streams from becoming waste in the first place (e.g., consider use of RFID tags to improve the recycling, reuse and refurbishment of materials in consumer products).
3. Work with the Department of Commerce—Manufacturing Extension Partnership to expand lean manufacturing support to small and medium enterprises to include reduction in material throughput and other aspects of life-cycle materials management.
4. Encourage the trend that we see among leading waste management companies to transform themselves into full-service life-cycle materials management advisors and service providers.
5. Initiate energy recovery once reuse, recycling, and composting have been performed or are shown to be not viable.
6. Incorporate life-cycle materials management principles in all EPA P2 strategy and program guidance documents that are generated. Explicitly expand the agency's concept of pollution prevention to embrace system-level life-cycle materials management, not just source reduction at the facility level.

- ➔ Harness strategic planning, national guidance, budget, and performance metric systems to facilitate materials management. (See 2.4 below.)

In addition, EPA and the states need to take the Resource Conservation Challenge (RCC) to the next stage by creating more emphasis on interventions earlier in the material life cycle. (See Box 10.)

1.3 Promote specific materials management approaches that can help address climate change.

EPA, state, tribal and local environmental agencies should work to integrate climate change and life-cycle materials management policies by emphasizing to decision-makers the connection between GHG emissions and materials. EPA and states also should pursue strategies that reduce GHG emissions through materials management approaches that balance GHG with other environmental impacts.

1.4 Promote greener products, product stewardship, and product-to-service transformations.

EPA should more actively promote the availability of environmentally preferable products by working to improve product design, reduce impacts associated with product supply chains, and increase product recovery. EPA and state waste and chemical programs should significantly expand their efforts to identify and encourage the use of products that are greener throughout their life cycle. This should include a number of specific efforts, such as:

- ➔ Encourage disclosure of all materials included in products.
- ➔ Work with states, manufacturers, retailers, and institutional buyers to develop EPA-endorsed life cycle-based, multi-attribute green product labeling standards for multiple product categories, with emphasis on priority materials/products.
- ➔ Use Design for the Environment (DfE), Green Chemistry, Green Engineering, and green product standards/labeling initiatives within EPA waste, chemicals and innovations programs as drivers for new product design and production technologies, and product designs that use materials more efficiently.
- ➔ Work with states, manufacturers, retailers, NGO's, and others to identify efficient ways to take back and recover products at end-of-life.
- ➔ Facilitate "business to business" approaches that promote material reuse, such as material and waste exchanges, "by-product synergy" and "eco-industrial" relationships.

- Promote business models that transform the sale of products to the sale of services and help ensure that such business models maximize materials use efficiency and other environmental improvements.

Box 10

THE RESOURCE CONSERVATION CHALLENGE AND MATERIALS MANAGEMENT

In 2002, EPA launched the Resource Conservation Challenge (RCC). The RCC was an early effort to respond to the RCRA Vision by placing renewed emphasis on RCRA mandates to prevent pollution, and conserve natural resources and energy through more efficient materials management.

The RCC currently emphasizes four major resource areas: 1) municipal solid waste reuse and recycling; 2) green initiatives, such as reducing the life-cycle environmental impacts of electronics, and promoting green building construction and retrofitting of existing buildings; 3) industrial materials reuse and recycling; and 4) reduction of toxic chemicals in products and waste.

Most RCC initiatives focus on the beneficial use of post-consumer and post-industrial materials, either by recycling, composting, or waste-to-energy. Putting to good use materials that would otherwise be disposed is an important element of a materials management strategy. Indeed, building an understanding of the value of material wastes and the needed infrastructure for their return to our economy is a necessary first step towards a materials management transformation.

The RCC also includes some initiatives that point more upstream in the materials and product cycles by encouraging materials substitution and eco-design of products. For example, the National Partnership for Environmental Priorities (NPEP)—a partnership between EPA's waste and chemicals programs—calls on partners to reduce the use of priority chemicals. The Electronic Products Environmental Assessment Tool (EPEAT), another waste and chemicals program partnership, challenges electronics manufacturers to remove toxics, use recycled content, and to make these products more energy efficient and easier to recycle or refurbish. The Sustainable Packaging Coalition aims to encourage a sustainable flow of materials through design guidance and tools to guide the selection of more sustainable materials. The Lifecycle Building Challenge calls for buildings to be designed for adaptation (so that buildings can be repurposed rather than torn down and rebuilt) and deconstruction (so building materials can be reused).

A fully-realized materials management strategy will not only address recovery and beneficial use of wastes in industrial and biological cycles, but will also emphasize powerful upstream efforts to reduce and change materials use, such as: 1) full recognition of the life-cycle impacts of the use of certain materials; 2) using less materials in the first place; 3) substituting safer and renewable materials in place of toxic or non-renewable materials; and 4) substituting services for products (to provide maximum utility with minimal material inputs and environmental impacts).

This kind of thinking requires us to ask very different questions. For example, we often ask "What should we do with scrap tires, or electronics, or fluorescent lights when they need to be disposed?" But the question for the future may need to be: Is there a way to eliminate this waste completely, to provide these same services with fewer resources and no adverse environmental impacts? Can we do this by substituting something else that does not wear out so fast, can be reused, that can be fully or almost fully recovered and repurposed so that it never becomes waste? These kinds of questions, some of which are already being asked, can really "change the game." They can generate untold innovation, improve lives, meet society's needs without overexploiting resources (renewable or non-renewable), and keep our economic activity within the absorptive capacity of the environment.

- Work with producers, retailers, the waste collection/recycling industry, recyclers, and local governments to develop the materials collection and processing infrastructure needed to support life-cycle materials management.
- Improve the amount and type of consumer information available to support green purchasing.
  - Encourage consolidation of green product claims under fewer, more comprehensive and trusted product labels to reduce consumer confusion and "greenwashing."
  - Review and update government procurement practices at all levels to support life cycle-based product standards. Consider allowing companies who supply superior "green" products to advertise that they supply these products to the U.S. Government.

1.5 Strengthen market signals to reduce waste and other adverse environmental impacts throughout the life cycle of materials.

Governments at all levels should work with industry and other stakeholders to use market signals to promote better materials management throughout the life cycle. Possibilities include:

- Charge more for disposal and less for recycling; charge for disposal by amount disposed ("pay as you throw").
- Charge emissions and permit fees.
- Reward citizens/communities that recycle with rebates or coupons (e.g., Recycle Bank).
- Limit landfilling and incineration of recyclable/compostable materials.

RECOMMENDATION 2:

Build capacity and integrate materials management approaches in existing government programs.

2.1 Establish and improve databases to promote materials management.

EPA should establish a panel that includes stakeholders and outside experts to advise on materials management information priorities, including types of information needed, key indicators to track, how to make U.S. information compatible with information being generated in other countries, and how to get started in developing the necessary data sets. This process should be open and should invite public input. (See Box 11.) EPA should then establish an EPA/state workgroup to follow up on the panel's advice and create a plan for a broadly useful set of indicators for life-cycle material management.

EPA also should create new partnerships with other government agencies, the research community, and the private sectors to collect, improve, harmonize, and disseminate quality data that is critical for life-cycle materials management. This should include establishing a better mechanism than now exists for sharing data between EPA and states.

2.2 Improve decision tools to support life-cycle materials management.

EPA should work with states to create two decision support tools to support life-cycle materials management:

- Create a business decision support tool that connects economic and environmental performance associated with materials management (including carbon footprint reduction, as well as increased innovation and competitiveness).
- Create a consumer decision support tool that calculates the human health and environmental benefits associated with buying less material-intensive products or services. The tool should have the ability to display information on product-specific material use and provide performance comparisons.

These tools should focus on depicting the energy/economic value of materials to help guide fees and other economic incentives that encourage sound materials management and discourage sending materials to disposal.

Box 11

CRITICAL DATA SETS FOR EFFECTIVE AND SUCCESSFUL LIFE-CYCLE MATERIALS MANAGEMENT

- Material Flow Accounts to track the movement of materials from extraction to manufacturing, product use, reuse/recycling, and eventual disposal, showing emissions to the environment. Recommended by the National Academy of Sciences, as well as OECD. A growing number of nations have regularly-updated official Material Flow Accounts, but the U.S. has only prototypes.
- Life-cycle inventories and life-cycle assessment models to enable industry, consumers, and government to analyze and understand the life-cycle impacts of products, both easily and in a standard, comparable manner.
- Data that more fully characterize chemical content of materials/products, toxicity, chemical emissions, and waste generation.
- Data on critical minerals to enable industry and government planning for using key minerals whose supply may be uncertain. Recommended by the U.S. National Academy of Sciences.
- Data on water use associated with the life cycles of materials and products, to enable business and government planning in the water-constrained situations we find now and expect to encounter more frequently in the future.
- Data that connect the movement of materials, goods, and services in our economy to the environment; such data should be available for use at several levels, from national to state. The Comprehensive Environmental Data Archive (CEDA) which was used by the 2020 Vision Workgroup is a leading candidate for such a database.

All these initiatives will require the support and cooperation (political, technical, and resource) of other public and private organizations. EPA can not undertake them alone.

2.3 Expand research and innovations support programs to promote materials management.

Research and innovation will be critical to giving government agencies and businesses the information they need to implement materials management approaches. More work is needed in a number of areas including the following.

➔ Expand the materials-related research described in EPA's Sustainability Research Agenda.

- Expand research on life-cycle impacts of new materials and technologies (e.g., nanotechnology, biomimicry, enzymes).
- Work with other federal agencies to expand science and policy research to enable better global management of critical materials, following the NAS recommendations in their report, "Minerals, Critical Minerals, and the U.S. Economy" (2007).

2.4 Emphasize materials management in EPA and state processes and procedures.

EPA has a number of opportunities to immediately begin to emphasize materials management in Agency processes and procedures. These include:

- Augment EPA regulatory development guidance to encourage consideration of full life cycles and all types of impacts and externalities in the analysis for each regulation. This should include exploring ways to integrate life-cycle materials management considerations into economic and cost-benefit analysis. At present, such analyses generally focus on the most direct impacts of an action, and not life-cycle impacts.
- Consider ways for EPA and states to use the permitting process to encourage life-cycle materials management. (See Box 12.)
- Incorporate consideration of life-cycle materials management in EPA program evaluations, wherever appropriate.
- Encourage all current and future EPA and state partnership programs to address the full life cycle of materials, not just one stage.
- Revise EPA's Government Performance and Results Act (GPRA) mission statement, goals, and strategic plan to emphasize that the Agency will be a leader in promoting sustainability and materials management. Make sustainability central to EPA's mission, and emphasize materials management targets and actions.

Box 12

INTEGRATED PERMITTING IN THE EUROPEAN UNION

Member countries of the European Union (E.U.) are implementing a new Integrated Pollution Prevention and Control (IPPC) permitting system. Under this system, environmental permits for large and complex industrial facilities must address the entire footprint of a facility's operations. This includes not only the parameters traditionally regulated in the U.S. (emissions and discharges to air, water and land), but also the selection and use of all materials that serve as inputs into each industrial process.

On an ongoing basis operators are expected to evaluate the use of materials and where possible minimize their environmental impacts. The "footprint" focus of E.U. integrated permits also means that environmental standards—best available techniques— apply to the use of natural resources such as water and energy. [j]

2.5 Support and reward federal, state, tribal, and local champions for materials management and encourage collaboration.

EPA should bring attention to successful materials management efforts, encourage staff and managers in EPA and state, tribal and local government agencies to further materials management concepts, and promote and reward collaboration. There are a number of specific opportunities to move towards these goals including the following.

- Promote collaboration and partnership on life-cycle materials management between the Agency and states, especially through ECOS and ASTSWMO. Life-cycle materials management should be part of joint EPA/state environmental strategies.
- Motivate staff throughout the federal and state governments to address the challenges of materials management by providing consistent resources, attention, support, and recognition.
- Focus EPA's life-cycle materials management efforts and engage broader participation using multiple groups across the Agency, especially EPA's Innovation Action Council (IAC) and the Multi-Media Pollution Prevention (M2P2) Forum around specific, cross-cutting materials management issues such as labeling for products.
- Consult with the Tribal Operations Committee and Local Government Advisory Committee to plan the best ways to work with tribes and local governments on materials management.
- Work with federal and state agencies to create proactive hiring and training strategies to build the social marketing and social science skills, and engineering expertise, needed to support materials management.
- Adjust EPA and state recognition programs to reward superior life-cycle materials management efforts, including superior product design, or create new programs to recognize these efforts.

RECOMMENDATION 3:

Accelerate the broad, ongoing public dialogue on life-cycle materials management.

3.1 Stimulate a national conversation about materials management, engaging multiple networks.

EPA should use its convening power to bring multiple parties together to advance a national conversation about materials management. There are a number of specific opportunities for this, including the following.

- Develop an EPA-wide materials management communications plan and encourage state agencies to develop similar plans.
- Work with states, tribes, local environmental agencies, businesses, non-governmental organizations (NGOs), consumer groups, and the academic community to engage the general public in a dialogue on the environmental impacts of consumption and the need for more sustainable materials management.
  - Develop a clear articulation of the urgent environmental and economic issues we face with respect to materials and products, and why life-cycle materials management approaches are needed.
  - Share this statement with the public and invite public input by a variety of means, including an electronic dialogue.
- Consider establishing a national advisory group (a "Materials Innovation Council") to advise on life-cycle materials management strategies. Include states, tribes, local environmental agencies, business and industry, environmental and public interest groups, and the academic community. The Council could be part of the National Advisory Council on Environmental Policy and Technology (NACEPT), or free standing. Their initial assignment might be to assess and comment on the materials management strategies currently underway in EPA program offices.
- Consider what additional statutory authorities (if any) are needed for EPA and the states to implement robust life-cycle materials management programs using both regulatory and non-regulatory approaches.
- Use the Environmental Executive Order 13423 and OMB's Environmental Stewardship Scorecard to initiate a broader dialogue with federal agencies on actions they can take to support life-cycle materials management.

3.2 Open a dialogue on economic instruments to encourage better materials management.

Linking materials management choices to their economic implications and using economic policy to better promote materials management will be important to integrating materials management into the mainstream. There are a number of specific opportunities including the following.

- Work with other federal agencies to examine the full environmental impact of taxes and subsidies, and their impacts on competitiveness and ensure that taxes and subsidies put recycled materials on the same or better footing as virgin materials.
- Work with other federal agencies to consider creating and promoting an alternative measure of Gross Domestic Product (GDP) that reflects the value of protecting the environment and conserving resources.

3.3 Create ways to share knowledge on materials management.

One of the most powerful things EPA can do to further materials management is to make clear and accurate information about the benefits of materials management approaches available. This includes both information on best practices, case studies and lessons learned, and the basic data and decision tools needed to implement materials management concepts. EPA has a number of opportunities to share knowledge and information on materials management including the following:

- Create an internet-accessible network of information resources (e.g., data, decision support tools, best practices) on materials management. The network should have nodes for federal government, state government, businesses, NGOs, academia, and communities, which allow easy movement of information and facilitation of action between and among nodes. EPA should expand its work with the Department of Commerce and its Manufacturing Extension Partnership to help on this effort.
- Encourage institutions of higher education to incorporate systems and materials management training across disciplines (from chemistry to engineering to business).
- Share knowledge, best practices, and technology related to materials management, product policy, and waste prevention efforts with other countries and learn from their efforts. In particular:
    - Expand U.S support for the Organization for Economic Cooperation and Development's work on resource efficiency/productivity and sustainable materials management and for the G-8's work on 3Rs (Reduce, Reuse, Recycle).

- Support efforts of international organizations and research institutes to characterize international flows of materials.
- Actively pursue the U.S.–Canada partnership on Sustainable Consumption and Production (SCP) under the United Nations Environment Program (UNEP). Contribute to the UNEP Marrakech Process to support SCP efforts and produce a global 10-Year Framework of Programs on SCP.
- Advocate that the U.S. join the UNEP International Panel for Sustainable Resource Management.
- Increase support for U.S. Government efforts to promote free trade in goods destined for or created by reuse, remanufacturing, and/or recycling.
- Involve state governments in international efforts where appropriate and feasible.

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